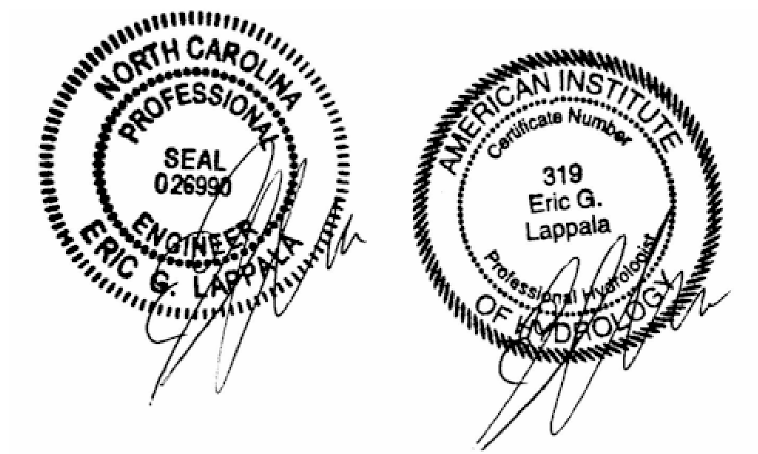
Cooperative Hydrology Study (COHYST)
Independent Peer Review Findings
Final Report

October 15, 2005



Kenneth L. Wahl, P.E.

Eric G. Lappala, P.E., P.H.

Eagle Resources
Advocacy → Sound Science → Innovation → Solutions
4005 Lake Springs Court
Raleigh, NC 27613

Contents

List of Figures

List of Tables

List of Attachments

Executive Summary

This report documents the results of the Peer Review of the Independent Peer Review of the Cooperative Hydrology Study of the Platte River Basin in Nebraska (COHYST). This review was performed by Eric Lappala of Eagle Resources, P.A. and Ken Wahl as a subcontractor to Eagle Resources, P.A..

COHYST is a cooperative effort among State and local agencies in Nebraska to develop a Decision Support System (DSS) comprising groundwater flow models and supporting data that is intended to provide:

- A better understanding of the groundwater flow system, including interrelationships between groundwater and surface water, than was previously available; and
- The ability to calculate with confidence how stresses on the groundwater system impact flows in the Platte River.

The COHYST DSS will be used by managers and policy makers to:

- Assist Nebraska in meeting her obligations under the Cooperative Agreement among Colorado, Nebraska, Wyoming, and the U.S. Department of the Interior;
- Assist the Natural Resources Districts within the Platte River Basin in providing appropriate management and regulation of groundwater;
- Provide the citizens of Nebraska with a basis to develop policies and procedures related to groundwater and surface water; and
- Help the citizens of Nebraska analyze the proposed activities developed under the Three-State Cooperative Agreement and understand the hydrologic consequences of these activities.

The purpose of the Independent Peer Review was to evaluate the credibility of the model reports, the underlying model datasets, and supporting data and information by providing answers to the following questions:

1) Were the development, calibration, sensitivity analyses, and documentation performed within industry standards for regional groundwater flow models?

2) Do the models adequately represent the regional properties and processes for the physical settings that were modeled and for the intended uses?

3) Can the regional groundwater flow models provide the ability to determine reliable estimates of the quantity, timing, and location of impacts on Platte River & tributary stream flow and on groundwater supplies from: existing or new wells pumping in a given area or in the vicinity of the Platte River Basin; recharge projects used for flow augmentation; and surface water supply projects and activities used to increase their water use efficiency?

4) Do the models provide the ability to develop sub-models for specific projects or specific sub-areas of the regional models to determine the quantity, timing, and location of impacts on Platte River and tributary streamflow?

5) Were data collection methods, use of data, and selection and use of various tools and algorithms described in the reports for Streamflow Data Analysis and Development of Model Input Coverages on Hydrogeology, Land Use, Recharge, Evapotranspiration, and Pumpage: performed within the standards of the industry for the topic; and appropriate for subsequent use in regional groundwater flow models of the modeled area of Nebraska?

We have attempted to group all of our findings so that they address these principal review questions.

The COHYST team is to be credited for development of conceptual and numerical models of the hydrologic system, including the interaction of groundwater and surface water, that appears to be the most consistent and comprehensive effort to date that covers the entire project area. The methods used to develop hydrostratigraphic units across the study area provide a common basis for understanding the hydrogeologic framework component of the conceptual models. The assembly and analysis of water level information has provided a common basis for assessing water level changes in response to changed stresses on the system, groundwater flow directions, and the interaction of groundwater with streams, lakes, and river systems in the study area. The assembly and analysis of all historical low flow in streams and rivers provides a common basis across the study area of the interchange between groundwater and surface water. The assembly and analysis of historical surface water diversion and distribution networks provides a common basis for evaluating the losses from such systems to groundwater.

The models that have been developed provide the best tools to use in improving the understanding of hydrologic conditions throughout the study area. Unfortunately the model reports do not take advantage of information that is contained in the model datasets to document this understanding with regard to the relative importance of physical processes that are important to assessing the effects of changes in water management policies on the flow of the Platte River and adjacent riparian areas.

The general finding of this peer review is that additional work should be done with the models and additional documentation provided before they are used as part of the DSS to support management and policy decisions to meet project objectives. Many of the issues raised by this review may be adequately addressed by additions to the model documentation sections discussions using existing information. The following summarize our general review findings:

1. The development and documentation of the models, and methods used to generate model input and supporting information are generally consistent with standards in the groundwater industry and community.

2. The models and supporting datasets provide a more defensible set of tools to document and demonstrate understanding of the operation of the groundwater – surface water system in the project area than has been documented in the reports.

3. Water levels simulated with the models fit observed head values both during the Pre-Development and Development periods better than documented in the model reports. Simulated stream and river reach gains and losses to the Platte River fit changes in November low flows better than documented in the model reports.

4. The methods used to estimate groundwater discharge to streams for use in model calibration provide values that are reasonable compared to those determined with other methods that do not require the use of arbitrary statistics to represent baseflow. However the methods used do not include rigorous analyses to document temporal changes in such discharge that are apparent from inspection of the data and which are correlated with known changes in the hydrologic regime of the study area.

5. The Development period fit between simulated and observed water level changes exhibits considerable scatter and uncertainty. Further, these fits show a bias that implies that the balance between net recharge and net pumpage to the modeled system is too high (too much water being added to the system). The model documents do not address either the degree of scatter or the bias.

6. The validity of using CropSim for computing pumpage for future land use change scenarios has not been adequately demonstrated because pumpage used for development period calibration was determined with CropSim using the same methodology, equations, parameters, and variables used to compute recharge which was deemed by the authors of the model unit reports to be ‘infeasible’ or otherwise unacceptable.

7. Further analysis and support for the additional recharge to cultivated land in excess of rangeland rates that was added to calibrate the models is needed. Plots of simulated water balance components over time show a net increase of water in the groundwater system. The increased recharge has the effect of reducing the water level declines caused by pumpage, and increasing the water level rises caused by canal and surface irrigation losses. The additional analyses should assess whether the pumpage values generated with CropSim were too high, resulting in the need to add recharge. Until this analysis is completed and documented, analyses that assess scenarios involving changes in water use efficiency that use CropSim to generate changes pumpage may not be defensible. The analysis should also include citation of available studies on the High Plains and elsewhere that have documented such increases in recharge under cultivated land by measuring soil moisture tension and geochemical profiles (See references 22 and 23). There also may be groundwater quality studies in the COHYST study area that have documented increases in chemical constituents leached from cultivated land as a result of such increased recharge that can be used to support this concept.

8. Additional analyses are needed to document the impacts of differences in specific yield values determined during Development Period Calibration and those held constant during Pre-Development calibration.

9. Reliability of the models in predicting impacts on the Platte River and tributaries and on groundwater supplies has not been documented because the reviewed reports and datasets do not include the level and completeness of sensitivity analyses necessary to account for uncertainty in model parameters, boundary conditions, pumpage, and recharge. The sensitivity analyses do not include an analysis of which of the four types of errors are

present in the model, including Type IV error, in which changes to input parameters significantly affect model outputs to be used for decision making, but the parameter changes do not significantly affect the measures used to determine model calibration.

10. Reliability and confidence in the ability of the models to assess impacts on the Platte River and tributaries and on groundwater supplies should be further established by developing specific, quantitative water management scenarios and metrics of these impacts that managers and policy makers find useful. For example, such scenarios would include changes in river stage during flow augmentation events.

11. Additional analyses are needed to demonstrate the ability of the models to reliably assess scenarios and conditions for which ET from groundwater is or may be a significant component of the water balance.

12. Confidence would be further demonstrated by performing and documenting verification analyses using calibration to the period with the most observed data (1973-85) and using the results to simulate the other three Development periods.

13. The Eastern Model Unit model requires additional analyses that allow water levels to fall below the base of model layers if necessary. These analyses should include checks on model calibration and sensitivity analyses.

14. The utility and reliability of the models to be used to assess the impacts of management scenarios is constrained by the existence of three overlapping models. Confidence in the results of analyses of scenarios for areas that include model overlap areas would be significantly increased if the calibrated models were used as the basis to construct for a simpler single model that includes fewer layers. Review of the model datasets shows that such a model may be justified because differing hydraulic conductivities of the layers as used in the models do not result in significant vertical gradients and flow. Construction and checking of such a model using GMS need not be a significant undertaking.

15. The COHYST Decision Support System will require consensus on the methods and protocols to be used to simulate conditions from 1998 on that preserves the existing transients in the simulated system.

16. GMS should be retained and used as part of the Decision Support System as the modeling shell for the regional models and as a guide to constructing sub-models, and to formulate and test management scenarios. Standard GMS conceptual model feature datasets need to be generated that represent the calibrated regional models and which cover the entire COHYST study area.

Table E-1 summarizes out findings in terms of our professional judgment as to how well the report, models, and supporting data conform to the five review questions posed by COHYST.

Table E-1.—Summary Score of Reviewed COHYST Reports, Models, and Work Products.

COHYST Review Question		Grade	Principal Reasons for Not Scoring "A"
Are Regional Flow Models Conformant with Industry Standards for Intended Use?	Development	A-	EMU watertable problem; River Boundary Condtion will not allow rivers to go dry - limits scenarios
	Calibration	B-	Non-uniquness; No flow change targets; W/L change scatter and bias; No verification, Documentation not complete
	Sensitivity Analyses	C-	All calibration parameters not used; No analyses of Platte; No error analysis
	Documentation	B	No example predictions of interest
Conformance with Industry Standards for Data Collection, Selection & Use of Data, Tools, & Algorithms for Intended Use	Baseflow analysis	B-	Arbitrary selection of 7Q5 and 14Q2, no time trend analyses
	Hydrostratigraphic Units	A	Most comprenhensive and consistent approaach to date
	Land Use	A	Uses best available technology
	Recharge	C	CROPSIM documentation poor
	Evapotranspiration	B-	Method actually used unclear
	Net Pumpage	B	CROPSIM algorithm not documented
Adequate Representation of Physical Settings, Processes & Properties for Intended Purpose	Aquifer System	B	Continuous thin layers vs fewer vert. integrated layers or HUF approach
	Initial Condition	B	No test of quasi-steady state 1900-98
	Boundary Conditions	B-	Flow boundaries of overlapping models not consistent, GHB not evaluated
	Interaction with Surface Water	C	No sensitivity analyses to Platte changes, ET from GW needs work
	ET discharge of Groundwater	C-	ET during non-growing season; EMU ET surface
	Recharge from Precipitaion	C	Unresolved conflict between CROPSIM and calibration values
	Recharge from canals and sw irrigation	A	Used best, most complete records and estimates
	Net pumpage	C	See Recharge from Precipitation
	Hydraulic Conductivity	A-	Streambed conductance also used for calibration, but Kh changes from initial estimates small and reasonable
	Storage	B-	Non-uniqueness with net Q; Unresolved additional recharge on cultivated land
	River and Streambed Leakance	C	No sensitivity analysis; Values for Platte in CMU is 2/3 EMU
	ET from GW Variables	C	No sensitivity analyses, Inconsistent with CROPSIM Etr

Table E-1(concluded).—Summary Score of Reviewed COHYST Reports, Models, and Work Products.

COHYST Review Question		Grade	Principal Reasons for Not Scoring "A"
Reliable Estimates of Timing, Quantity, and Timing of Impacts to Platte River and Tributaries	Existing or New Wells Pumping	B-	Reliable only for differences betw een scenarios only; Unresolved cultivated land recharge justification and effect on pumpage computed w ith CROPSIM
	Recharge Projects for Flow Augmentation	C	ET from Groundw ater needs additional analyses, including focus on riparian areas; no sensitivity analyses to streambed conductance, models not calibrated to historical flow changes to Platte reaches
	Increased Surface Water Use Efficiency	B-	Reliable only for differences betw een scenarios only; Unresolved cultivated land recharge justification and effect on pumpage computed w ith CROPSIM
Reliable Estimates of Timing, Quantity, and Timing of Impacts to Groundw ater Supplies	Existing or New Wells Pumping	C	Reliable only for differences betw een scenarios only; Unresolved cultivated land recharge justification; calibration scatter and bias
	Recharge Projects for Flow Augmentation	C	Model not calibrated to historical changes to Platte reaches
	Increased Surface Water Use Efficiency	C	Reliable only for differences betw een scenarios only; Unresolved cultivated land recharge justification; calibration scatter and bias
Sub-models to Determine Quantity, Timing, & Location of Impacts on Platte River and Tributaries	Construction	B-	Sub-models that cover areas in more than one model; Fixed Flow s at boundaries not made consistent; General Head Boundary not used
	Verification	C	Lack of calibration to historical flow changes; lack of sensitivity analyses for Platte reach gains and losses;lack of sensitivity analyses to riverbed conductance
	Use	C	Need to run same scenario on multiple models, explain and justify differences; All problems assiociated w ith unresolved additional recharge above CROPSIM values

This final version of the Peer Review Report includes clarification of certain review issues that were provided by the authors of the Western, Central, and Eastern Model Unit Reports subsequent to their review of the draft report and the presentation Eagle Resources made to COHYST on September 20, 2005, in Kearney, NE. For completeness, we have included as Attachment O to this final report their comments and our responses.

1 Introduction

This report documents the results of the Independent Peer Review of the Cooperative Hydrology Study of the Platte River Basin in Nebraska (COHYST). This review was performed by Eric Lappala of Eagle Resources, P.A. and Ken Wahl as a subcontractor to Eagle Resources, P.A. This work was authorized by execution of Eagle Resources Standard Services Agreement by Mr. Don Kraus on December 6, 2004. Subsequently, the schedule for the completion of the review was modified at the request of COHYST from May 31, 2005 to September 30, 2005 owing to delays in the completion of the Central Modeling Unit report.

Both reviewers contributed to multiple sections of this report. Mr. Wahl was principally responsible for the review and assessment of alternative approaches to estimating baseflow for use as calibration targets. Sections from his stand-alone report have been incorporated in to the main body of this report. His report is included in its entirety as Attachment H.

1.1 COHYST Purpose

COHYST is a cooperative effort among State and local agencies in Nebraska to develop a Decision Support System (DSS) to *"…improve the understanding of the geologic and hydrologic conditions of the Platte River Basin in Nebraska upstream from Columbus"*. This DSS is to comprise scientifically defensible databases, analyses, and models that can be used to:

- Assist Nebraska in meeting her obligations under the Cooperative Agreement among Colorado, Nebraska, Wyoming, and the U.S. Department of the Interior;
- Assist the Natural Resources Districts within the Platte River Basin in providing appropriate management and regulation of groundwater;
- Provide the citizens of Nebraska with a basis to develop policies and procedures related to groundwater and surface water; and
- Help the citizens of Nebraska analyze the proposed activities developed under the Three-State Cooperative Agreement and understand the hydrologic consequences of these activities.

Figure 1 shows the 29,300 square mile study area that extends from Frenchman Creek and the Republican River on the south to the South Loup River, Loup River, and a mapped groundwater divide on the north (Figure 1). The three overlapping Model Unit areas used to construct groundwater models of the COHYST study area are also shown in Figure 1.

Note that the southeastern boundary of the Eastern Model Unit is the Kansas State Line and not the Republican River.

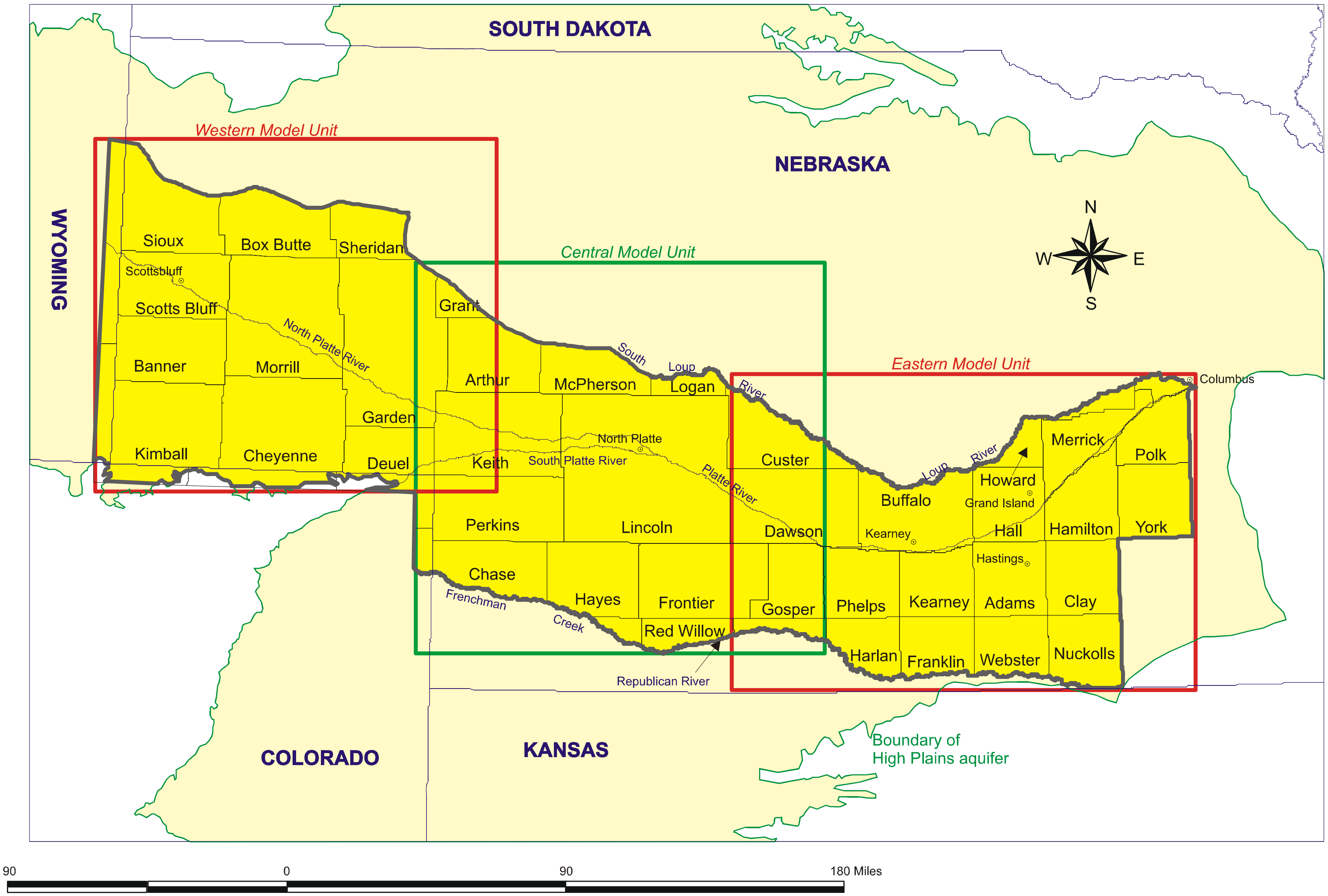


Figure 1. -- COHYST Study Area and the Three Model Units for Which Reports were Reviewed.

1.2 COHYST Objectives

As stated in the COHYST Overview document (COHYST 2004a), the DSS was to be constructed by meeting the following objectives:

1. *Collect existing data and models.*
2. *Place data into an appropriate database.*
3. *Review existing data and models to identify data gaps.*
4. *Collect supplemental data as necessary to be added to the database.*
5. *Develop linked, regional models to cover the Platte basin in Nebraska above Columbus.*
6. *Establish credibility of the data, database and models.*
7. *Design and develop a geographical user interface and GIS-based Internet link to the data and models.*
8. *Put models to use in accomplishing purposes described above.*

1.3 Peer Review Purpose and Objectives

The purpose of the Independent Peer Review was to meet COHYST Objective 6: "…establish credibility of the data, database and models". This credibility was assessed by providing answers to the following questions that were included in the COHYST Request for Proposals for this peer review:

1) Were the development, calibration, sensitivity analyses, and documentation performed within industry standards for regional groundwater flow models?

2) Do the models adequately represent the regional properties and processes for the physical settings that were modeled and for the intended uses?

3) Can the regional groundwater flow models provide ability to determine reliable estimates of the quantity, timing, and location of impacts on Platte River & tributary stream flow and on groundwater supplies from: existing or new wells pumping in a given area or in the vicinity of the Platte River Basin; recharge projects used for flow augmentation; and surface water supply projects and activities used to increase their water use efficiency?

4) Do models provide ability to develop sub-models for specific projects or specific sub-areas of the regional models to determine the quantity, timing, and location of impacts on Platte River and tributary stream flow?

5) Were data collection methods, use of data, and selection and use of various tools and algorithms described in the reports for Streamflow Data Analysis and Development of Model Input Coverages on Hydrogeology, Land Use, Recharge, Evapotranspiration, and Pumpage performed within the standards of the industry for the topic; and appropriate for subsequent use in regional groundwater flow models of the modeled area of Nebraska?

The following review questions were formulated as an aid to assess the extent that the model reports, the underlying model datasets, and supporting data and information have addressed these questions:

- Were the purposes and intended uses of the models clearly defined?

- Were acceptable conceptual models developed that were consistent with the intended uses of the models?

- Were acceptable simulation models constructed that properly captured the conceptual models?

- Were models calibrated to observations of targets that include all intended uses of models?

- Were the calibrated models verified by simulating conditions not used for calibration?

- Were variability and uncertainty accounted for with regard to effects on intended uses of models and were all the processes and parameters used in the models clearly documented in reports?

- Were all the processes and parameters documented in the reports used in the models?

The COHYST models are intended to be used by resource and other managers to support management and policy decisions to meet overall COHYST objectives. Consequently, this peer review also included a general assessment as to the ease with which the constructed models can be used by persons other than the model authors for this purpose. The following questions were formulated and used to summarize this review assessment.

- Are all the model datasets and information available in a form that can be used?

- Can the model datasets be loaded into GMS and run with no errors?

- Can the model datasets be run by model shells other than GMS?

- Can the different models be applied with confidence to address scenarios in areas of overlap?

- Can the models be simplified while retaining or improving the degree of confidence in model predictive simulations?

- How will continuity in time be maintained between 1998 and the present and any future simulation periods?

2 Documents and Project Work Products Reviewed

This peer review reviewed over 25 reports which were either provided directly by COHYST, were downloaded from the COHYST and other related websites, or were obtained in response to requests by the peer review team. Table 1 shows the reports that were reviewed. Final versions of the model documentation reports for the Western and Eastern Model Units and a draft version of the Central Model Unit report were provided for review. The preliminary report describing the development of Hydrostratigraphic Units was provided for review. A final version of the CropSim Update and Scenario Report was provided. Upon request from Eagle Resources the draft CropSim methodology report by Dr. Martin and several draft documents prepared by Rich Kern of Nebraska DNR which document the process used to prepare recharge and pumpage datasets for the models were provided. The remainder of the documents reviewed listed in Table 1 were downloaded from the COHYST and other websites. Additional documents reviewed or used in this review are provided in the list of references at the end of this report.

Clarification of the content or origin of several model datasets and supporting information was provided by the model authors in response to requests from the peer review team via email prior to the preparation and presentation of the draft report.

Table 1.-- Documents and Work Products Reviewed

Reviewed Document	How Obtained
1. COHYST, 1998. Cooperative Hydrology Study Work Plan: Technical Coordination Committee 7/10/98	COHYST Web Site
2. COHYST, 2000. Flow Modeling Strategy for COHYST, Version 1.0 March, 2000	COHYST Web Site
3. Cooperative Hydrology Modeling & Assessment of Activities Impacting Threatened & Endangered Species Target Flows (COHYST II) Work Plan 10/24/2001	COHYST Web Site
4. COHYST, 2004a. Overview of the Objectives, Processes and Products of the COHYST Project: September 21, 2004	COHYST Web Site
5. Luckey, R. R, and J.C, Cannia, 2005. Groundwater Flow Model of the Western Model Unit of the Cooperative Hydrology Study (COHYST), January.	COHYST upload to Eagle FTP Site
6. Carney, C.P. 2005, Groundwater Flow Model of the Central Model Unit of the Cooperative Hydrology Study (COHYST), DRAFT, June.	COHYST upload to Eagle FTP Site
7. Peterson, S. M. 2005. Groundwater Flow Model of the Eastern Model Unit of the Cooperative Hydrology Study (COHYST), February..	COHYST upload to Eagle FTP Site
8. COHYST, 2004b. The 40-Year, 28-Percent Stream Depletion Lines for the COHYST Area West of Elm Creek, Nebraska (August 2004 version) COHYST Technical Committee	COHYST Web Site
9. Cannia, J.C, D. Woodward, and L.D. Cast, 2004. Hydrostratigraphic Units and Aquifer Characterization Report December 30, 2004 Preliminary Report	COHYST Web Site
10. Peterson, S.M, and C.P. Carney, 2002, Estimated Groundwater Discharge to Streams from the High Plains Aquifer in the Eastern Model Unit of the COHYST Study Area for the Period Prior to Major Groundwater Irrigation, March.	COHYST Web Site
11. C.P. Carney and Peterson, S.M, 2001. Estimated Groundwater Discharge to Streams from the High Plains Aquifer in the Central Model Unit of the COHYST Study Area for the Period Prior to Major Groundwater Irrigation, November.	COHYST Web Site
12. Luckey, R. R, Carney, C. P., and Peterson, S.M, 2001. Estimated Groundwater Discharge to Streams from the High Plains Aquifer in the Western Model Unit of the COHYST Study Area for the Period Prior to Major Groundwater Irrigation, September.	COHYST Web Site
13. The Flatwater Group, 2004. Final CROPSIM Update and Scenario Report, October.	COHYST Web Site / hardcopy from COHYST
14. Martin, D, undated. CROPSIM, A Crop Simulation Program incomplete draft.	Hardcopy from COHYST following request
15. Kern, R, undated, Simulated Historical Land Use Distribution , unpublished draft(file last modified February 3, 2004)	COHYST upload to Eagle FTP Site
16. Kern, R, undated, Development of Pumpage/Recharge Estimates, unpublished draft(last modified date unknown)	COHYST upload to Eagle FTP Site
17. Kern, R, undated, Distributed Historical Pumpage/Recharge Estimates , unpublished draft(last modified date unknown)	COHYST upload to Eagle FTP Site
18. Kern, R, undated, Pumpage/Recharge Preparation, unpublished draft(file last modified November 10 2004)	COHYST upload to Eagle FTP Site
19. Kern, R, undated, Weighting System for Distribution of Simulated Historical Land Use, unpublished draft(file last modified November 10 2004)	COHYST upload to Eagle FTP Site
20. Kern, R, undated, Model Input Preparation, unpublished draft(file last modified November 10 2004)	COHYST upload to Eagle FTP Site
21. Sanders, Glen, 2001Groundwater and River Flow Analysis: Technical Report of the Platte River EIS Team U.S. Department of the Interior, Bureau of Reclamation, and Fish and Wildlife Service.	COHYST Web Site
22. Lewis, G.L. Groundwater Modeling in Nebraska: Powerpoint™ presentation at GMDA Summer Session, June 7, 2004	COHYST Web Site

Eight calibrated model datasets, 14 sensitivity run model datasets, and numerous other files of supporting data were provided for review for each of the three model units by either uploading to the Eagle Resources project FTP site or on CDs. These included calibrated datasets for the Pre-Development period and development period and several example sensitivity analysis datasets for each model. The quasi-steady state 1895 model dataset for the Central Model Unit was provided. The data and analyses used to prepare baseflow estimates for each of the three model units was provided on CDs   Upon requests from the peer review team, limited content GMS project datasets were provided for the Eastern and Western Model Units. Attachment A lists the model datasets and related work products that were reviewed and provides the level of review performed.

3 Approach

The following 7 tasks were used to meet the peer review objectives:

- Task 1. Review project objectives for conformance with conceptual model(s);
- Task 2. Review model documentation and supporting reports for completeness against industry standards;
- Task 3. Review the content of the modeling reports and supporting reports for adequacy;
- Task 4. Identify critical assumptions, datasets, modeling processes and methods;
- Task 5. Review consistency and adequacy of supporting data for models;
- Task 6. Identify and evaluate alternative approaches and methodologies to those used;
- Task 7. Assess the adequacy, appropriateness, and methods recommended to apply the models for future uses; and
- Task 8. Prepare and present combined review findings report.

The following sections describe the details of the approach used for these tasks.

3.1 Task 1. Review Project Objectives for Conformance with Conceptual Model(s)

This task consisted of reviews of the following COHYST reports

- *Overview of the Objectives, Processes and Products of the COHYST Project: September 21, 2004;*
- *Flow Modeling Strategy for COHYST, Version 1.0 March, 2000;*

- Conceptual Model Section of the *Groundwater Flow Model of the Eastern Model Unit of the Nebraska Cooperative Hydrology Study (COHYST) Area (file dated February 11, 2005);*

- Conceptual Model Section of the *Draft Groundwater Flow Model of the Central Model Unit of the Nebraska Cooperative Hydrology Study (COHYST) Area (file dated July 1, 2005);* and

- Conceptual Model Section of the *Groundwater Flow Model of the Western Model Unit of the Nebraska Cooperative Hydrology Study (COHYST) Area January, 2005.*

The review used both the professional experience of Mr. Lappala and Mr. Wahl, as well as using the following as a guide:

1. *ASTM Standard E 1689. Standard Guide for Developing Conceptual Site Models for Contaminated Sites; and*

2. *Computer Models for Subsurface Water. In Handbook of Hydrology (M.P. Anderson, D.S. Ward, Eric G. Lappala, and T.A. Pricket). Ed. David R. Maidment. McGraw-Hill, Inc. 1992.*

3.2 Task 2. Review Model Documentation and Supporting Reports for Completeness Against Industry Standards

ASTM Standard D5718. Documenting a Ground-Water Flow Model Application was used for the completeness review because it was developed and is currently used by representatives of the groundwater modeling and engineering industry as well as government agencies responsible for developing hydrologic and hydrogeologic investigation and modeling techniques and applying them to real world problems (e.g. the U.S. Geological Survey, U.S. Environmental Protection Agency, and the U.S. Nuclear Regulatory Commission).

3.3 Task 3. Review the Content of the Modeling Reports and Supporting Reports for Adequacy

This review used our professional experience and expertise as well as the following ASTM Standards as review guides:

- *ASTM D5979. Conceptualization and Characterization of Ground-Water Systems;*

- *ASTM D5880. Standard Guide for Subsurface Flow and Transport Modeling;*

- *ASTM D5490.Comparing Ground-Water Flow Model Simulations to Site-Specific Information;*

- *ASTM D5610. Standard Guide for Defining Initial Conditions in Ground-Water Flow Modeling;*

- *ASTM D5609. Standard Guide for Defining Boundary Conditions in Ground-Water Flow Modeling.*

- *ASTM D5981. Calibrating a Ground-Water Flow Model Application; and*

- *ASTM D5611. Conducting a Sensitivity Analysis for a Ground-Water Flow Model Application.*

3.4 Task 4. Identify Critical Assumptions, Datasets, Modeling Processes and Methods

Approach: The data collection methods, computer processing algorithms, model choices, modeling processes, calibration methods, sensitivity analyses and written reports used to support all of these were evaluated to ascertain if they support answers to question 5 listed under Task 3. Assumptions, datasets, modeling processes and/or methods used were identified that, in our opinion and judgment have the potential for significantly affecting the suitability, accuracy, and applicability of models to meet project objectives and future model uses.

Critical assumptions were reviewed by using the COHYST Model Strategy (COHYST, 2000) and both Work Plan Documents, (COHYST 1998, 2001), as well as the project overview document (COHYST, 2004a), the CropSim Scenario and Update report (Flatwater Group, 2004), and an unpublished draft of the CropSim model documentation (Martin, undated). The model datasets listed in Attachment A were reviewed for additional assumptions not documented in these reports.

The model datasets were reviewed by reviewing the model input and output files using the Department of Defense Groundwater Modeling System (GMS), version 5.1. This version of GMS uses MODFLOW 2000 and the COHYST team used GMS version 3 which used MODFLOW 96. This review comprised the following steps:

- Loading the GMS/MODFLOW 'superfiles' provided by COHYST into GMS and using the capabilities and functions of GMS to evaluate the degree to which the model inputs and outputs conformed with those reported in the model documentation reports;

- Using the GMS functions and capabilities to assess information contained in the model datasets that was not included in the model reports, such as the temporal history of computed mass balance components for the model as a whole and other sub-areas such as reaches of the Platte River and tributaries;

- Running MODFLOW from within GMS using the input files provided to assure that the output provided by COHYST could be replicated. This step was only performed on the calibrated model datasets and one of the provided sensitivity analysis datasets for each Model Unit;

- Running MODFLOW from within GMS for the calibrated Pre-Development period using only 1895 recharge to assess the degree to which the steady state initial condition was maintained for the 1900 to 1998 period in the absence of stress changes occurring after 1900;

- Running MODFLOW from within GMS for the calibrated Eastern Model Unit for the Pre-Development and Development periods with the option turned on that allowed the water table to fall below the top of layers;

- Importing the Pre-Development MODFLOW dataset for the calibrated Pre-Development Western Model Unit into a modeling shell different from GMS, as described further in the alternative approach section of this review report; and

- Running MODFLOW using no modeling shell and comparing output contained in the principal output file (xxx.OUT file) with that produced by GMS for the calibrated Pre-Development Western Model Unit, as described further in the alternative approach section of this review report.

Additionally, the time history of simulated mass balance components were extracted from the MODFLOW xxx.OUT files for analysis and examination using a Visual Basic™ program written specifically for this peer review.

3.5 Task 5. Review Consistency and Adequacy of Supporting Data for Models

Approach: Databases and GIS Coverages were acquired from the COHYST web site or directly from COHYST by upload to the Eagle Resources FTP site. Supporting GIS coverages and datasets were reviewed using ArcGIS™ version 9.0, which was also used to prepare the maps and illustrations included in this peer review report. Data bases and spreadsheets were reviewed using Microsoft Access™ and Excel™ for conformance with the conceptual model, reports that described their development and use, and the underlying data and information used to develop them.

This task included an assessment of quality control and data validation methods included in the project databases and GIS Coverages.

This task reviewed the following from ASTM D5718 to assess the adequacy of maintaining the Model Archives for future use:

- Existence, Location and Accessibility of Model Archives
- Simulation Logs
- Computer Code
- Model Documentation
- Input and Output
- Archival Media

3.6 Task 6. Identify and Evaluate Alternative Approaches and Methodologies

Multiple methods and approaches may be appropriate to conceptualize, construct, test, calibrate, perform sensitivity analyses, and prepare documentation of models. This step provided a qualitative comparison of the methods used to possible alternatives, using ASTM standards and the experienced professional judgments of Mr. Lappala and Mr. Wahl. It will also included limited set of analyses and/or or model runs independently performed to assess the degree whether the answers to the questions posed in the RFP would be significantly affected if different methodologies had been used.

3.6.1 Task 6.1 Groundwater Modeling Alternative Approach Assessment

Approach: The COHYST project used the GMS modeling shell to prepare datasets, run MODFLOW, and evaluate output datasets. We imported the calibrated Pre-Development one-half mile model dataset for the Western Model Unit into a different modeling shell, Visual MODFLOW Pro 4.0™, which is published and maintained by Waterloo Hydrogeologic.

In addition, we ran one MODFLOW dataset for the Western Model Unit using no modeling shell and compared the outputs to those produced from GMS.

3.6.2 Task 6.2 Groundwater Discharge to Surface Water Alternative Approach Assessment

Approach: Central to all three low-flow reports is the assumption that fall season average 7-day and 14-day low flows are representative of groundwater discharge to the streams. The low-flow determinations were generally restricted to the months of October and November because those months are believed to be relatively free from diversions and return flows. The Data Analysis reports explain the process used, but do not establish the basis for the assumption. The validity of this assumption is crucial to the COHYST study because the groundwater flows to the streams are used to calibrate the regional groundwater models.

The base flow of streams during periods of minimal evapotranspiration is generally indicative of ground-water flow. Several computerized methods exist for using hydrograph-separation techniques to estimate base flow from daily mean discharges of streams. One such model (BFI) was used to estimate the base flows at the stream-gauging sites used in the study. Annual average base flows for the non-irrigation season (October-March) were defined for each site for the period of record used by COHYST, and the distribution of those base flows was defined. Flows were compiled both for the October-November period used by COHYST and for October-March. The relation between the base flows and average 7-day, 5-year and 14-day, 2-year low flows shown in the reports were examined in order to determine the validity of the above assumption.

Hydrograph separation is not usually done on regulated streams because a relatively constant release from a reservoir will be interpreted as base flow. However, the purpose of the COHYST study was to define gains from or losses to groundwater in the respective reaches. Therefore, BFI was run for the main-stem stations used in the reports under the assumption that irregularities caused by regulation will be reflected on stations at each end of the respective reaches. If that is the case, differences in base flows between the ends of a reach should be representative of flow to or from the groundwater system.

This assessment was accomplished using the following steps:

- Download daily flow data for the individual stations from the USGS NWIS website;
- Reformat the data for State of Nebraska stations as necessary. BFI accepts most USGS data formats;
- Run the BFI model for each station, and reformat daily base flow output to isolate the non-irrigation season data;
- Define distribution of daily base flows for the fall period at each station; and
- Determine the relation between 7-day, 5-year and 14-day, 2-year low flows (COHYST minimum and maximum groundwater discharges) and daily base flows.

3.6.3 Task 6.3 Assessment of Alternative Methods to Development of Recharge, Evapotranspiration, and Pumpage

Approach: This review initially proposed to assess the reasonableness of the methods used by COHYST to develop recharge and net pumpage datasets generated by CropSim by using a similar industry standard water balance model developed by the U.S. Department of Agriculture (USDA). That model, the Soil and Water Assessment Tool (SWAT) was developed to predict the impact of land management practices on water, sediment, and agricultural chemical yields in large, complex watersheds with varying soils, land use, and management conditions over long periods of time. However, during the review it was determined that because of the similarities in CropSim and SWAT that an adequate assessment could be made by comparing the methods, equations, parameters, and variables used by each program.

3.7 Task 7. Assess the Adequacy, Appropriateness, and Methods Recommended to Apply the Models for Future Uses

Approach: The future uses of the model listed in the project objectives, including the generation and application of sub-models of smaller areas were assessed against the findings of all of the foregoing tasks. This task identified limitations of the future uses of the models based upon this assessment.

4 Review Findings: Conformance of Conceptual Model(s) and Project Objectives

The utility of the models as part of the COHYST DSS is determined by how well they can provide answers to questions that have been or will be formulated to support management and policy decisions that affect the operation of the project hydrologic system. The assessment of this utility requires the definition of specific scenarios or questions and system response metrics to which the models will be expected to apply.

The conceptual model(s) must include the necessary physical processes, described and simulated at the appropriate spatial and temporal scales with sufficient accuracy for the intended use of the models. The conceptual models should also anticipate the required content and format of model output that can best be used to provide answers to these questions and scenarios.

4.1 COHYST Model Purpose

The COHYST Model Strategy document states:

> *"The overall purpose of the COHYST flow models is to aid in understanding the groundwater flow system and the interrelationships between the groundwater system and the surface-water system. Ultimately, the models will be used to calculate how stresses on the groundwater system impact flows in the Platte River. Stresses include all additions and subtractions of water from the groundwater system, including pumpage from wells, evapotranspiration by vegetation, aquifer storage and recovery, flow to artificial drains, groundwater recharge from precipitation, deep percolation from irrigation, enhanced recharge due to certain land uses, recharge from canal and lateral leakage, and recharge from surface-water impoundments.*
>
> *The COHYST flow models will be used in support of regulatory and management decisions and must be defensible in both scientific and legal arenas. Data collection is to be as detailed and encompassing as possible to allow for a modeling strategy that moves from simple to complex. The models will be built using the best scientific information and methods available and the information and methods used will be clearly documented."*

From this discussion, there are two general COHYST objectives that the models are to meet:

1. A better understanding of the groundwater flow system, including interrelationships between groundwater and surface water, than was previously available; and

2. The ability to calculate with confidence how stresses on the groundwater system impact flows in the Platte River and on groundwater supplies.

This is a reasonably clear statement of the project objective and the groundwater models reviewed provide an excellent tool to demonstrate the operation of the interconnected groundwater and surface water system. However, without definition of which conditions required an improved understanding and why, it is difficult to ascertain the degree of improvement that has been achieved. It appears from all the planning documents that the assumption was made that if more detailed and consistent databases of geologic and hydrologic conditions were developed and used to construct and calibrate new models then by definition an improved understanding would be achieved.

Over thirty previous models of parts or all of the COHYST study area have been constructed and used to support a variety of groundwater and surface water management systems. It would have been useful to summarize conditions or questions from these models that required an improved understanding.

4.2 Intended Uses of Models

A general statement of the intended uses of the DSS was developed and documented in the 1998 COHYST work plan and has been carried through out all subsequent documentation of project work plans and results These general intended uses are the following:

- Assist Nebraska in meeting her obligations under the Cooperative Agreement among Colorado, Nebraska, Wyoming, and the U.S. Department of the Interior;

- Assist the Natural Resources Districts within the Platte River Basin in providing appropriate management and regulation of groundwater;

- Provide the citizens of Nebraska with a basis to develop policies and procedures related to groundwater and surface water; and

- Help the citizens of Nebraska analyze the proposed activities developed under the Three-State Cooperative Agreement and understand the hydrologic consequences of these activities.

These stated uses provide a general framework for the construction of the DSS. However, specific scenarios and system response metrics to which the models will be expected to apply were apparently not developed at the outset of the project and used to guide the model construction, calibration, and sensitivity analyses. The tacit assumption from this lack appears to be that if complex, detailed models were developed, and properly calibrated, then they can be applied with confidence to any such scenarios. Without specific scenarios (such as limitations on net pumpage within certain distances from the Platte) and clearly defined metrics of expected system response (such as change in baseflow in a given reach of the Platte River), it is impossible to ascertain the degree of confidence with which the models can be used to support specific management and policy decisions.

An example of an intended use of the models was published by COHYST to compute stream depletion factors (SDF) for the entire modeled area using the one-mile grid models. That report concluded that "……Due to the methods used, the COHYST models could not differentiate which tributary or even which river basin would be depleted by a pumping well" (COHYST Technical Committee, September, 2004: The 40-Year, 28-Percent Stream Depletion Lines for the COHYST Area West of Elm Creek, Nebraska). This analysis was completed using the one-mile grid versions of the models which have not been published or provided for review.

If the computation of SDF maps is an intended use of the models, and if the one-half mile grid models were to be developed and used for this purpose, then it should have been so stated, and the construction and calibration of these models should have addressed problems and issues identified and published in the September 2004 report.

4.3 Model Simplicity vs. Complexity

The model strategy did not go far enough to assure the credibility and utility of the models and model documentation provided for review. The tacit assumption made in the modeling strategy was that more detailed, complex models are better then simpler models. This violates the fundamental principal of modeling natural systems that the simplest model that explains the important processes with the accuracy and precision necessary for the intended purposes is always the best model. No documentation has been provided that demonstrates how additional complexity built into the models improved either the understanding of the hydrogeologic system or the ability to reliably predict effects on flows of the Platte River and its tributaries.

The complex models reviewed have two significant features that will limit their utility and reliability in analyzing future water management scenarios that address areas or river reaches that are present in more than one model unit area or in the overlap areas of the models:

1. Multiple models will have to be set up and run to address the same scenario; and

2. Differences in predicted conditions caused by differences in calibrated model parameters, the degree of calibration, and sensitivity to uncertainty among the models and in the areas of overlap will require resolution and explanation.

These difficulties may be eliminated by construction of a simpler model covering the entire study area using the calibrated models constructed to date. Such a model comprising one to three layers would be smaller (fewer cells) than the Central or Eastern models alone and would facilitate its ease of use and increase the number of scenarios that could be analyzed. Such a model would eliminate the need for running the same management scenario on overlapping models and the consequent need for justifying or explaining differences in computed results such as changes in base flows of Platte River reaches that will occur with the separate models.

The calibrated values of aquifer parameters should be used to construct the simpler model using thickness-weighted values for hydraulic conductivity and values of specific yield for the units that correspond to the reasonably anticipated range in water level fluctuations based upon historical data. This model should be able to quickly resolve differences in simulated aquifer parameters in the overlap area of adjacent models.

Justification for using a simpler model with fewer layers includes the lack of significant vertical head gradients that are caused by differences in hydraulic conductivity between model layers. Analysis of vertical head gradients using the calibrated EMU (corrected to allow cell drying) and CMU models shows that the gradients are most probably caused by recharge and discharge, and not by using different hydraulic conductivities for the different model layers.

Most irrigation and municipal wells in the COHYST are completed across and interconnect multiple hydrostratigraphic units. Many of these are used for observation wells used for model calibration. The model assumed that wells were open only to one layer. This is not a restriction of MODFLOW, as there is an option to open wells to multiple layers. Therefore, the real world system operates as a single, interconnected layer and observations of that single interconnected system have been used for calibration. This fact was not discussed in the conceptual model section of any reports.

4.4 Conceptual Model

The conceptual models for each of the three regional models have been developed using a reasonable and generally complete approach, and the three regional reports provide a clearly written description of these models. The reports include clear and thorough discussions of conceptual boundaries, groundwater-surface water interaction, and the use of conceptual boundary conditions. Because the occurrence and general hydraulic properties of the hydrostratigraphic units are an important component of the conceptual models, the hydrostratigraphic units section should have been placed beneath the conceptual model heading.

The development and documentation of the conceptual models would have been improved and provided stronger support for use as the basis for the numerical models if they had included additional descriptions and analyses discussed in the following sections.

4.4.1 Boundary Conditions

4.4.1.1 Support for Fixed Flow Boundaries

The use of conceptual specified flow instead of Head-dependent (GHB) for arbitrary boundaries imposes the need to independently determine what boundary flows are. Neither the conceptual model nor the numerical model sections of the reports provide an explanation of the method(s) and data used to specify the flow rates at these boundaries.

Review of the model datasets show that the models used different methods to simulate the fixed flow boundaries. The Western Model used positive values of recharge at the fixed flow boundary cells to specify inflow and negative values of recharge to specify outflow. The Eastern Model and Central Models used extraction or injection wells at the boundaries to simulate fixed flow in and out.

There is no documentation in the reports to demonstrate that the fixed flow boundaries were determined by iterative analyses using adjacent, overlapping models.

4.4.1.2 Use of Head – Dependent or General Head Boundaries

An alternative to the iterative analyses to make specified head boundaries at the edges of overlapping boundaries consistent with each other would have been the use of general head boundaries instead. This option would use the simulated heads in each of the model layers from some distance outside the overlap areas for the boundary condition head and a conductance between that location and the physical model boundary computed using the distance and hydraulic conductivity of the intervening portion of each model layer.

4.4.2 Importance and Role of Evapotranspiration from Groundwater

Past studies have shown evapotranspiration (ET) from shallow groundwater to be an important process that controls the interaction of groundwater and surface water in riparian areas along the

Platte River. Because ET as presently simulated is approximately one third of the water budget, it is an important function in the present models.

Constraining ET to pre-defined areas does not allow ET to occur or increase where shallow water tables develop as a result of rises in response to excess recharge. Since large areas where this has occurred are known in the COHYST area, this is an unnecessary constraint. Because the models do not simulate ET from groundwater that is further below the ET surface than the extinction depth, there is no reason not to include ET everywhere and let the model decide when and where it occurs.

Further, the use of an ET surface for the Eastern Model Unit that is higher than the mean land surface in model cells for over one third of the area in which ET was simulated further underestimates ET for that model.

ET from groundwater was simulated in all the models throughout the year. As discussed subsequently, the simulated non-growing season was approximately the same as the growing season ET. This is unrealistic, as during the winter months in the project area, all ET from vegetation in shallow watertable areas is reduced to essentially zero. There was no attempt to make the maximum ET rates used in the model consistent with the Reference Crop ET (ETr) computed using the Penman-Monteith method used in CropSim. The maximum ET rate was not varied over the growing season.

5 Review Findings: Completeness of Model Documentation

The completeness review of the modeling reports for the Eastern, Central, and Western Modeling Units was performed to assess their conformance with industry standards for documenting regional groundwater flow modeling reports. The principal review guide for this assessment was the following report content recommended by ASTM D5718:

- **Introduction:** Modeling Objectives, Model Function, and General Setting
- **Conceptual Model:** Aquifer System, Hydrologic Boundaries, Hydraulic Properties, Sources and Sinks, and Water Budget
- **Computer Code Description:** Assumptions; Limitations, Solution Techniques, and Assumption Effects on Model
- **Model Construction:** Model Domain, Hydraulic Parameters, Sources and Sinks, Initial and Boundary Conditions, Selection of Calibration Targets and Goals, and Numerical Parameters
- **Calibration:** Qualitative/Quantitative Analysis, Sensitivity Analysis, Model Application Verification
- **Predictive Simulations**
- **Summary and Conclusions**
- **References**

While many of the supporting reports are not covered directly by ASTM D5718, the completeness of their contents that is necessary to support their use by the groundwater models was assessed using this standard as a guide.

5.1 Model Completeness Assessment

A spreadsheet checklist was prepared for each of the three model unit reports and was used to document whether they included the topics listed above. The checklists also were used as a guide to summarize the adequacy of the content of these topics which is discussed in more detail in the following section of this review report. These checklists are included as Attachments A, B, and C.

This assessment also included a review to compare information included in the model datasets that was not included in model reports, and conversely, information that was included in the reports that was inconsistent with that found in the model datasets.

The general content and organization of all three model reports is essentially identical, which facilitates comparison of the models and review of the documents. Common formats, for figures and tables are used, and many sections of the text are identical for all three reports. All reports contained information to address most of the topics that are generally included in industry standard reports. However, inclusion of additional sections and information as described below would improve the conformance with industry standards.

5.1.1 Model Verification

None of the reports contained sections on model verification, nor was a model verification task included in the COHYST Model Strategy document. Many groundwater modeling studies do not include model verification because data does not exist over long enough time periods or that documents hydrologic conditions different from those encountered during calibration, but which may be expected in the future. However, COHYST has compiled large datasets that document water levels and stream flows over at least the development period which comprises approximately 50 years. The use of this data for model verification would have improved the credibility of the models. For example, because most of the reliable information on water level change targets was available during the 1973-85 period, this period could have been the only one used for calibration, and the calibrated model could be then verified by simulating the 1950-61, 1961-73, 1985-98, and 1950-98 periods.

5.1.2 Predictive Analyses

The predictive simulation sections contained in industry standard reports usually are included to describe the results of analyses and simulations that address questions posed as part of stated project purposes and objectives. If example scenarios had been developed at the outset of the COHYST project, and the models used to predict their likely effects on water levels and streamflow, the confidence and credibility of the models would have been significantly improved.

The Central Mode Unit report contains sub-sections titled Simulation Results under the Model Calibration section and the other two model unit reports contain similar information with no section titles. The information in these sections of the reports is important to demonstrating how well the models reproduce known responses of the simulated systems. It would improve the credibility of the reports if this information had been collected and included in a section with a title similar to ‘Calibration Adequacy Analyses’.

5.1.3 Information in Model Datasets Different from Reports

Examination of the model datasets show that they either contain information not documented in the reports, or that is different from that documented in the reports.

5.1.3.1 Storage Coefficients

The model reports do not discuss the storage coefficient used in the models for layers that lie below the one that contains the watertable. For multiple layer models, two values of the storage parameters are required and are applied depending upon the position of the watertable at any time during the simulation. When the layer contains the water table, Specific Yield, S_Y is used. When the layer lies below the one containing the watertable, a confined Storage Coefficient, S_C is used that accounts for the release of water by the expansion of water and compression of the aquifer in response to changes in hydraulic head, and their sum applied to a unit layer thickness is the Specific Storage, S_S. The confined storage coefficient is the product of S_S and the layer thickness. The Eastern and Central Models are multi-layer, and all layers below layer 1 in these models were specified as being able to be either confined or unconfined, depending upon whether they contained the watertable. Examination of the model input datasets showed that values for both S_Y and S_C were included. S_C was computed as a constant value of S_S of 0.00001 multiplied by the layer thickness. This is a reasonable number based upon industry literature values for relatively incompressible materials such as sands and gravels, but is lower than the expected value for silts and clays.

5.1.3.2 ET Surface

All model units reportedly used an ET surface that used elevations of this surface that were midway between the mean land surface elevation in the cell and the lowest surface elevation in the cell in an attempt to represent areas within a cell that may have a smaller depth to the water table than that represented by the mean elevation. While this is a reasonable approach, checking of the model datasets shows that for the Eastern Model unit, the ET surface used is actually higher than the mean land surface elevation in approximately one third of the cells in which ET was simulated. This resulted in simulated ET from groundwater in these areas being lower than it would have been if the land surface had been used, and even lower than it would have been if the ET Surface described in the report had been used. Because ET from groundwater provides an important control on water levels in riparian and wetland areas, this inconsistency needs to be addressed.

5.1.3.3 Multiple Boundary Conditions for Lake McConaughy

Review of the Western Model Unit datasets showed that a River boundary condition was assigned to the North Platte River along the axis of Lake McConaughy and a General Head boundary condition was assigned to the footprint of the reservoir. Different driving heads and conductances of the bottom sediments were used for these two different boundary conditions.

5.2 Model Documentation Report Format

Because the model documentation reports were prepared by different authors over different time periods, some variability in report format is expected. However, the clarity with which the reports document the completeness of the models would be significantly improved and the included information easier to locate if more section headings were used in all the reports. We suggest the following format to achieve this improvement:

- Cover Page
- Contents
- List of Figures
- Executive Summary
- Introduction
    - Project Description
    - Project Objectives
    - Use of Model to Meet Project Objectives
    - Model Area Setting and Description
    - Model Time Frame
    - Modeling Responsibilities
- Conceptual Model
    - Areal Extent and General Description
    - Time Domain
        - Initial Hydrologic Condition
        - Pre-Development Period
        - Development Period
    - Aquifer System
        - Geologic Components
        - Hydrostratigraphic Components
        - Hydraulic Properties
        - Boundary Conditions
        - Project Area Boundaries
        - Vertical Boundaries
    - Sources and Sinks
        - Rivers and Streams
        - Canals and Reservoirs
        - Drains
        - Areally –Distributed Recharge
            - Rangeland
            - Cultivated Land
            - Irrigated Land
        - Wells and Net Pumpage
        - Evapotranspiration from Groundwater
    - Conceptual Water Budget
        - Components
        - Fluxes
        - Temporal Changes
    - Conceptual Calibration and Verification
        - Targets for Flow and Head
        - Time periods for Calibration
        - Time periods for Verification
- Numerical Model Construction
    - Code Selection
    - Computational Grid

- Lateral Resolution
- Layer Definition and Resolution

- Model Time Domain
- Hydraulic Properties
  - Hydraulic Conductivity
  - Specific Yield or Drainable Porosity
  - Storage Coefficient
- Sources and Sinks
- Initial Head Conditions
- Boundary Conditions
  - Specified Head
  - Specified Flux
  - Specified Gradient (General Head Boundary)
- Sources and Sinks
  - Rivers and Streams
    - Bed Conductance
    - Stage
    - Upstream inflow
  - Canals and Reservoirs
  - Drains
    - Drain Conductance
    - Drain Elevations
  - Areally –Distributed Recharge
    - Rangeland
    - Cultivated Land
    - Irrigated Land
  - Wells and Net Pumpage
    - Screened Intervals
    - Pumpage Rates
  - Evapotranspiration from Groundwater
    - ET surface
    - Maximum ET Rates
    - ET Extinction Depth
- Numerical Solution Method
  - Method used
  - Convergence criteria and challenges

Model Calibration

- Calibration Targets
  - Flow Targets
  - Head Targets
  - Mass Balance Targets
- Calibration Parameters
  - Selection Method
  - Constraints
- Goodness of fit metrics
- Calibration Method (Manual, Automated, or Combination)
  - History Matching Results
  - Residual Statistics

Hydrologic Reasonableness
Calibrated Parameters
Sensitivity Analysis
Goals
Procedures
Parameters and Ranges
Method Used (Automated or Manual)
Results
Model Error Type Analysis
Model Verification (not included in this study, although it could and should have been)
Verification Simulations
Calibration Adequacy Analysis
Changes Made to Calibrated Model
Predictive Simulations (not included in the reviewed reports)
Description
Results
Summary and Conclusions
Recommendations
References
Attachments

6 Review Findings: Adequacy of Models and Supporting Reports

Adequacy of the models, model documentation, and supporting reports were reviewed using ASTM standards, as well as the experienced professional judgments of Mr. Lappala and Mr. Wahl. This review also encompassed Task 4 in our approach. Our findings are summarized in the following sections with regard to their ability to answer the following questions posed in the COHYST Peer Review Request for Proposals:

1) Were the development, calibration, sensitivity analyses, and documentation performed within industry standards for regional groundwater flow models?

2) Do the models adequately represent the regional properties and processes for the physical settings that were modeled and for the intended uses?

3) Can the regional groundwater flow models provide ability to determine reliable estimates of the quantity, timing, and location of impacts on Platte River & tributary stream flow and on groundwater supplies from: existing or new wells pumping in a given area or in the vicinity of the Platte River Basin; recharge projects used for flow augmentation; and surface water supply projects and activities used to increase their water use efficiency?

4) Do models provide ability to develop sub-models for specific projects or specific sub-areas of the regional models to determine the quantity, timing, and location of impacts on Platte River and tributary stream flow?

5) Were data collection methods, use of data, and selection and use of various tools and algorithms described in the reports for Streamflow Data Analysis and Development of Model Input Coverages on Hydrogeology, Land Use, Recharge, Evapotranspiration, and Pumpage: performed within the standards of the industry for the topic; and appropriate for subsequent use in regional groundwater flow models of the modeled area of Nebraska?

The COHYST team has in general done a credible job in creating components of the DSS. The development and support used to create the conceptual models of the hydrologic system, including the interaction of groundwater and surface water appears to be the most consistent and comprehensive effort to date. The development of consistent hydrostratigraphic units across the study area provides a common basis for understanding the hydrogeologic framework component of the conceptual models. The assembly and analysis of water level information has provided a common basis for assessing groundwater flow directions and the interaction of groundwater with streams, lakes, and river systems in the study area. The assembly and analysis of all historical low flow in streams and rivers provides a common basis across the study area of the interchange between groundwater and surface water. The assembly and analysis of historical surface water diversion and distribution networks provides a common basis for evaluating the losses from such systems to groundwater. The methods and data developed to estimate recharge under rangeland, cultivated, and irrigated land uses potentially can be used in conjunction with the models constructed to date and/or modifications of these models as part of the DSS.

The general finding of this peer review is that additional work needs to be done with the models before they are used as part of the DSS to support management and policy decisions to meet project objectives. The reasons for this additional work are summarized in the following sections of this report.

6.1 Conformance with Industry Standards for Regional Groundwater Flow Models

This section provides an assessment to the following question provided by COHYST:

Were the development, calibration, sensitivity analyses, and documentation performed within industry standards for regional groundwater flow models?

The models reviewed have generally been developed and calibrated within industry standards for regional groundwater flow models. General project objectives were specified, conceptual models were developed, and supporting data for the conceptual models was assembled and used to construct numerical flow models. The models were calibrated to conditions that are represented by a large and reasonably well defined set of model targets comprising water levels in observation wells, changes in such water levels between four different time periods, and estimated groundwater discharge to streams. However, confidence in the models for their intended uses can be significantly improved by providing further documentation of information that is contained in the model datasets. The following paragraphs describe areas where the models could have been made more conformant with industry standards.

6.1.1 Model Development

The models were developed using a rational, systematic approach that is consistent with industry standards.

However, the demonstration of the reliability of the models to meet COHYST objectives would have been enhanced by the following:

- Development of specific model application scenarios and metrics;
- Documentation of the information used from previous model studies; and
- Documentation of the needed improvements in models and approaches from previous studies.

6.1.1.1 Constraints on Intended Uses of Models

The 1998 COHYST work plan stated that the purpose of COHYST was to "…improve understanding of the hydrological and geological conditions in the Platte Basin in Nebraska upstream of Columbus, Nebraska.". This improved understanding was to be quantified using a Decision Support System (DSS) comprised of computer models of the groundwater flow system that include the interaction of groundwater and surface water and the data developed by COHYST to construct these models.

This is a reasonably clear statement of the project objective and the groundwater models reviewed provide an excellent tool to demonstrate the operation of the interconnected groundwater and surface water system. However, without definition of which conditions required an improved understanding and why, it is difficult to ascertain the degree of improvement that has been achieved. It appears from all the planning documents that the assumption was made that if more detailed and consistent databases of geologic and hydrologic conditions were developed and used to construct and calibrate new models, then by definition, an improved understanding would be achieved.

Specific scenarios and system response metrics to which the models will be expected to apply were apparently not developed at the outset of the project and used to guide the model construction, calibration, and sensitivity analyses. The tacit assumption from this lack appears to be that if complex, detailed models were developed, and properly calibrated, then they can be applied with confidence to any such scenarios.

Without specific scenarios and clearly defined metrics of expected system response, it is difficult to ascertain the degree of confidence with which the models can be used to support specific management and policy decisions. An example of a specific scenario is limitations on net pumpage within certain distances from the Platte River. Examples of defined response metrics are the amount of change in baseflow in a given reach of the Platte River and the response time between changes in stresses and changes in baseflow.

The only such scenario found to review was the computation of stream depletion factors (SDF) using the one-mile grid. As noted elsewhere in this review, the report on that effort documented several difficulties with the clear identification of which river and stream had been impacted by the unit pumpage used. None of the reports reviewed documented any attempt to include features or capabilities in the current one-half mile grid models to address these.

6.1.1.2 Use of Previous Model Studies

Over thirty previous models of parts or all of the COHYST study area have been constructed and used to support a variety of groundwater and surface water management systems. While the COHYST overview documents lists these models and Tasks 202 and 307 in the 1998 COHYST Work Plan were included to determine what information could be used from them in building the COHYST models, no documentation has been provided that summarizes conditions or questions from these models that required an improved understanding of the hydrologic and geologic conditions in the study area. This should have included the post audit of the Blue River Basin that concluded that “Considerable uncertainty about the basic conceptualization of the hydrology of the Blue River basin greatly limits the reliability of groundwater models developed for the basin.” (Alley and Emery, 1986).

Without such a summary, it can be inferred from the three model reports and the COHYST Overview document that COHYST either did not complete the tasks to assess the value of past models or that it was determined that meeting the COHYST objectives required construction of models from scratch without using previous model knowledge.

6.1.1.3 Convergence Difficulties

Complex numerical models that include processes that attempt to simulate real world processes, often exhibit difficulties in convergence of the iterative method(s) used to solve the groundwater flow equations. These difficulties are typically caused by including simulation of one or more of the following:

- Thin model layers that have high hydraulic conductivities;
- Wetting and drying of layers by rising and falling water tables; and
- Steady state conditions.

These conditions may cause the solution to oscillate around the correct solution but to never converge within the specified iteration error tolerance.

According to the model reports, the COHYST models encountered such convergence difficulties. The initial model strategy called for simulation of the Pre-Settlement period as steady state. However, convergence problems required this approach to be abandoned and a quasi-steady state initial condition in 1895 for all models was achieved by simulations for greater than 1000 years using initial estimates of rangeland recharge.

This is a reasonable approach, but probably could have been avoided if different model construction had been used that did not result in arbitrary thin layers (model layers corresponding to hydrostratigraphic units even if they were physically missing). Another approach would have been to have used the Hydrologic Unit Flow package (Anderman and Hill, 2000) that is available for MODFLOW. However that package became available in 2000 during the period that the COHYST models were developed, and the versions of the GMS modeling shell used for COHYST did not include it.

6.1.2 Model Calibration

The processes used to calibrate the models appear to be reasonable and conformant with industry standards. Although not stated in the model reports, the methods used appear to have relied completely upon the professional judgment of the modelers and did not use any of the automated calibration processes such as PEST and UCODE that are available with the current version of GMS and MODFLOW 2000. The COHYST Model Strategy Document (pp 7-11) includes a discussion of how calibration was to proceed. However, the model reports do not discuss how the process in that document was implemented or which changes to that process were used.

6.1.2.1 Calibration to Observed Heads

The models are better calibrated to observed heads than demonstrated by the use of only tables of the three calibration statistics used that are included in the model reports. The reports did not include scatter plots and additional commonly used calibration statistics for the fit between simulated and observed heads. Preparation of these for this review shows that the simulated Pre-Development heads fit observations well and further, that statistical fits are generally well within limits considered acceptable by industry standards. For example the normalized root mean square error generally should be less than 10% (References 27, 28, and 29), and many regulatory agencies have a goal of 7% to 8% for models used for permitting support. The results shown in Figures 2 through 6 illustrate that this statistic was always less than 5% and generally less than 2%.

6.1.2.2 Calibration to Water Level Changes

The degree of calibration to water level changes as shown by scatter in plots of observed vs. simulated water level changes is high and the normalized root mean square error (RMS divided by the range of observed change) is almost always greater than the generally accepted industry standard of 10%. See Figures 7 through 21. Further, the water level change scatter plots for all model units and for all but the 1973-85 period for the Western Model Unit show a consistent bias in that observed water level declines are greater than calculated and observed water level rises are less than calculated rises. These may be attributable to differences between actual and simulated pumpage and recharge, including the additional cultivated land recharge added during calibration, to values of specific yield that are too high in areas of decline and too low in areas of rise, or combinations of these. Confidence in the ability of the models to predict water level changes would be significantly improved by additional analysis and explanation of bias and the degree of scatter.

6.1.2.3 Recharge and Net Pumpage Determined Independently from Calibration

The advantage of using independently determined recharge is that it reduces the number of calibration variables, which in turn improves confidence in the models. Recharge computed using water balance methods has been used to this advantage in numerous previous modeling projects in the COHYST study area and elsewhere.

The model strategy called for Pre-Development period calibration analyses *"…to determine if the very complex spatial variation in recharge due to surface-water irrigation and precipitation that is being calculated external to the groundwater flow model improves the fit between simulated and observed water levels."* (p. 10). In addition, Figure 14 of the Overview document implies that recharge for all land use classes; including rangeland was computed by CropSim for both the Pre-Development and Development periods and used in the models.

However, according to the three model reports and the overview document, CropSim was not used to compute rangeland recharge for the Pre-Development period, nor was any discussion included as to why the model strategy document was not followed. The model documents need clarification that CropSim was not used for the Development period and the reasons why it was not.

Spatially distributing recharge during Pre-Development calibration on the basis of large-scale soil and topographic conditions is reasonable. The Eastern Model Unit also used rangeland recharge that was a function of known decreases of precipitation from east to west. However, the Eastern Model unit also used arbitrary north south and east west subdivisions that are based upon arbitrary county boundaries, and does not provide a reasonable explanation for this choice.

While some differences in calibrated recharge exist between models in the areas where they overlap, the differences are slight and are not likely to contribute to differences in either the calibrated values of hydraulic conductivity or the fit to observed heads.

Adequate development period calibration required additional recharge on cultivated land both dryland and irrigated crops. The validity of using CropSim for computing pumpage for future land use change scenarios has not been adequately demonstrated because pumpage used for development period calibration was determined with CropSim using the same methodology, equations, parameters, and variables used to compute recharge which was deemed by the authors of the model unit reports to be ‘infeasible’ or otherwise unacceptable.

Further analyses and documentation of the reasons why CropSim recharge was unacceptable may provide information that can be used to correct CropSim variables and allow it to be used with confidence in computing recharge and net pumpage for future scenarios. Based upon our experience with models that are conceptually identical to CropSim, and our review of the CropSim datasets and computer code, it is likely that CropSim recharge that is is too low (and similarly, the net irrigation requirements that are too high) can be explained by lowering the storage capacity of the modeled soil layers, or including a method to increase the rate of drainage as a function of water content, in accordance with the principles of variably saturated flow.

Analyses of the reasons for having to add additional Development period recharge to cultivated land should also evaluate whether the method used to determine whether the amount of cultivated land to which recharge was applied by extrapolating backward in time from 1997 could explain the need to add additional recharge.

6.1.2.4 Unique Combinations of Parameters

The model strategy called for avoiding non-unique combinations of hydraulic conductivity and recharge by calibrating to hydraulic heads in observation wells and to groundwater discharge estimates at the end of the Pre-Development period using periods when stream flow should be predominately base flow. However the non-uniqueness has not been adequately demonstrated because streambed conductance was also used as a calibration variable to calibrate the models to base flow estimates. Because it directly controls the amount of water exchanged between groundwater and surface water, it is likely a more important calibration variable than the hydraulic conductivity of the hydrostratigraphic unit into which the stream channel is incised.

Non-unique combinations of model calibration parameters likely resulted from the pre-Development calibration because more parameters were used as independent variables in the calibration process than the two dependent variables that were used (heads and groundwater discharge to streams). Use of CropSim, or a similar independent methodology to estimate rangeland recharge would have reduced the number of independent variables, and provided more confidence that the hydraulic conductivity and stream leakance values resulting from calibration better represented the modeled system.

6.1.2.5 Calibration to River and Stream Gains and Losses

The degree to which the models can reproduce measured gains and losses to surface water requires additional documentation. Analyses of model datasets as part of this review illustrated that simulated changes in reach gains are qualitatively consistent with known changes in the hydrologic system (Figures 22 through 32). Examples of this response are increased recharge and subsequent reach gains to the Platte River from the Tri County Canal system and reductions in reach gains correlated with water level declines in the central Platte area in the late 1970s.

As shown by examples for the Eastern Model Unit in Figures 33 through 37, the models appear to be better calibrated than documented in the model reports which only report the calculated 1950 baseflow. However, to be consistent with industry standards for calibration to groundwater discharge targets, the project should have performed more rigorous analyses to document the degree to which estimated baseflow for the reaches used was stationary in time. Simple mass curve analyses performed as part of this review (Figures 33 through 37) shows that this is not the case for reaches of the Platte River. The model documentation should have included charts and tables to illustrate the degree to which these changes can be reproduced during the development period.

6.1.2.6 Continuity of Calibrated Stream and River Gains between Pre-Development and Development Periods

As shown in Figures 22 through 27, computed flows at the end of Pre-Development and start of development periods do not match. While in some cases the differences are small compared to the magnitude of the computed gains, in others the differences are a significant percentage of the gains. The reasons for the mismatch need to be documented, and a methodology or protocol developed to assure matching between 1998 simulated gains and future simulations that extend beyond 1998.

6.1.2.7 Documentation of Parameters Changed During Calibration

The reports did not include maps or tables showing where and by how much calibration parameters were changed during model calibration. Preparation of such maps for changes in hydraulic conductivity as part of this review shows that reasonable changes were made (Figures 33 through 35). The inclusion of these maps would improve the support that the model reports provide for the DSS.

6.1.2.8 Specific Yield and Calibrated Pre-Development Models

Because the Pre-Development models were transient, they required the use of storage parameters. These parameters were not changed during model Pre-Development period calibration. However, they were changed during development period calibration. The model reports did not include analyses that checked the effects on the Pre-Development calibration using the values of specific yield that were determined during development period calibration. Model files provided for the Central Model Unit included sensitivity analyses to Specific Yield for the Pre-Development Period, but the report did not discuss the results of these analyses.

6.1.2.9 Allowing Simulated Heads to Fall Below Base of Layer 1

Review of the model datasets shows that the Eastern Model unit was apparently calibrated and sensitivity analyses were run in a manner that did not allow the watertable to drop below the base of Layer 1. This resulted from using the GMS/MODFLOW option to allow cells to go dry, but also using the option of setting the heads on cells that try to go dry to the elevation of the bottom of the cell. The latter option should only be used when automated model calibration methods such as PEST are used, as it is a technique to force model convergence. However, it results in unrealistic vertical head gradients, and shallow watertables where layer 1 is thin. The Central and Western model unit models used the correct cell drying options.

Model runs made as part of this review in which this restriction was removed showed differences in computed heads, ET from groundwater, and stream and river gains and losses. While the differences in ET and stream gains and losses may not be a significant fraction of the magnitude of the flows, that is not the case for differences in discharges to drains, Pre-Development streams and rivers, and water level changes. See Figures 22 through 25 and 58 through 61. .Figures 45 through 50 show the comparison of water table position with and without the correct cell dying option for several three north – south cross sections.

6.1.3 Sensitivity Analyses

The sensitivity analyses documented in the reports are very limited and do not provide the level of completeness that would be expected by industry standards. The analyses apparently were completed manually, and did not use the tools and methods that are available in the current versions of GMS and MODFLOW 2000. The following sections provide our assessment of additional sensitivity analyses that are required to improve their completeness. Addressing these issues will also significantly improve the confidence in the use of the models for their intended uses.

6.1.3.1 Sensitivity Analysis for All Calibration Parameters

No analysis was included in the reports to explain why sensitivity analyses were not performed on all calibration parameters. Sensitivity analyses to other parameters that may significantly affect model conclusions that were not varied during calibration were not included. For example sensitivity analyses to streambed conductance, drain conductance, and ET variables were not included. The sensitivity analyses were limited to the effect of uncertainty on three model calibration statistics. Table 2 shows a checklist of the potential sensitivity analysis parameters that should have been evaluated and for which the reasons any not included should have been described in the model reports.

6.1.3.2 Analysis of Sensitivity of Platte River Gains and Losses

The reports do not document the degree to which uncertainty in the models affects simulated system responses important to the intended uses of the models such as reach gains and losses to the Platte River, although the model datasets include the information to perform such analyses. For all three models, sensitivity analyses on reach gains and losses are limited to small tributaries, most of which are not tributary to the Platte River.

6.1.3.3 Boundary Condition Sensitivity Analysis

No sensitivity analyses were performed to assess the magnitude of the groundwater inflow and outflow rates that were specified as boundary conditions along arbitrary model boundaries. Sensitivity analyses to the use of a General Head Boundary condition instead of a Specified Flow Boundary Condition at arbitrary model boundaries, including those where models overlap was not documented in the reviewed documents, and apparently has not been completed.

6.1.3.4 Mass Balance Component Sensitivity Analysis

One of the stated purposes of developing the COHYST models is an improved understanding of the hydrologic system. Understanding changes to the relative magnitude of components of the water budget of the system over time is an important tool to document both the operation of the system and the impact on flows within the system that may result from the result of water management changes. Consequently, it is important to demonstrate an understanding of the uncertainty in components of the water budget by sensitivity analyses of their changes due to uncertainty in model parameters and boundary conditions. Inclusion of such analyses would have significantly improved the documentation of the reliability of the models to meet their intended uses.

6.1.3.5 Sensitivity Error Analysis

The reports do not include a demonstration that the models do not contain so-called Type IV errors. These errors occur when changes in model parameters cause significant changes in simulated system response but cause insignificant changes in model calibration statistics. Figure 51 illustrates the four categories of combinations of potential model errors and their consequences. Existing and additional sensitivity analyses should include the error categorization of each result.

6.1.3.6 Use of Sensitivity Analyses to Map Confidence in Models

Sensitivity analyses have not been used in conjunction with the professional judgment of the model team to prepare maps showing the degree of confidence in simulated model output. Such maps were prepared for at least one other model study that covered the COHYST study area (Platte River Level B Study, 1975, Reference 24). Preparation of similar maps for COHYST would be an effective means to demonstrate both improved understanding of the operation of the hydrogeologic system and improved confidence in the use of models as part of the COHYST DSS.

6.1.4 Verification Analyses

Many groundwater modeling projects do not include a verification process in which models are tested against measures and targets for time periods and conditions that were not used for calibration. However, most such projects do not have the benefit of the large, consistent, and long term record of stream flows and water levels that have been assembled for COHYST. Performing and documenting such verification analyses would have significantly improved the credibility of the models. For example, the calibration of specific yield during the development period could have been performed for the period when the largest observation well dataset was available for all models, and verification analyses could have been made using the calibrated models for the other three subdivisions of the development period.

6.1.5 Acceptable Model Precision

Model precision as used in this context is different from model accuracy, which is assessed by calibration analyses. Model precision was reviewed by using a Visual Basic™ program written for this review to extract the mass balance components for all time steps recorded in the xxx.OUT files for each model for the calibrated Pre-Development and Development periods. The precision was assessed by plotting time charts of the difference between total inflows and total outflows for each time step as a percentage of total outflows. These charts show that the model precision is well within the 1% to 2% limits considered acceptable by industry standards (Figures 52 -54.). Larger errors than the industry standard were present between 1950 and 1973 for the Eastern Model Unit model, but the errors after 1973 were within the limits. In addition, there is no time trend in the error which would indicate a systematic and persistent error.

Model	Simulation Period	Candidate Sensitivity Analysis Parameters	Calib-ration Para-meter?	Sensitivity Analysis Metrics Used and Reported					Comment
				Reviewed Model File Name Root	Fit Statistics		System Responses		
					Head or Water Level Change	Stream & River Gain and Loss	Water Level Changes	Stream & River Gain & Loss	
WMU	pre-Develop-ment 1895 - 1950	Kh	X	Test_326_sensivity (supplied information did not specify which sensitivity parameter this run applied to)	X			X	Gains to Platte not analyzed
		Kh/Kv							
		Sy							
		Streambed Conductance	X						
		Stream Stage (set or computed)							
		Riverbed Conductance	X						
		River Stage							
		Drain Conductance							
		Maximum ET Rate	X						
		ET Surface vs Land Surface	X						
		ET Extinction Depth							
		Rangeland Recharge	X		X			X	Gains to Platte not analyzed
		Cultivated Land Recharge							
		Canal Seepage							
	GW Develop-ment 1950 - 1998	Kh		Test_327_sensivity (supplied information did not specify which sensitivity parameter this run applied to)					
		Kh/Kv							
		Sy	X		X			X	Gains to Platte not analyzed
		Streambed Conductance							
		Stream Stage (set or computed)							
		Riverbed Conductance							
		River Stage							
		Drain Conductance							
		Maximum ET Rate							
		ET Surface vs Land Surface							
		ET Extinction Depth							
		Rangeland Recharge							
		Cultivated Dryland Recharge	X		X			X	Gains to Platte not analyzed
		Cultivated Irrigated Recharge	X		X			X	Gains to Platte not analyzed
		Canal Seepage							
		Pumpage by CROPSIM			X			X	Gains to Platte not analyzed
		Pumpage by NEBGUIDE							

Table 2.--Sensitivity Analysis Checklist for Reviewed COHYST Models.

Model	Simulation Period	Candidate Sensitivity Analysis Parameters	Calib-ration Para-meter?	Sensitivity Analysis Metrics Used and Reported					Comment
					Fit Statistics		System Responses		
				Reviewed Model File Name Root	Head or Water Level Change	Stream & River Gain and Loss	Water Level Changes	Stream & River Gain & Loss	
CMU	pre-Develop-ment 1895 - 1950	Kh	X	PSTThm_Kh_20pct_dec	X			X	Gains to Platte not analyzed
		Kh/Kv		PSTThm_KhKvratio_20pct_dec	X				
		Sy		PSTThm_Sy_20pct_dec					
		Streambed Conductance	X						
		Stream Stage (set or computed)							
		Riverbed Conductance	X						
		River Stage							
		Drain Conductance	X						
		Maximum ET Rate	?						
		ET Surface vs Land Surface	?						
		ET Extinction Depth							
		Rangeland Recharge	X	hm_PSTT_Rch_20pct_dec	X			X	Gains to Platte not analyzed
		Cultivated Land Recharge							
		Canal Seepage	X	hm_PSTT_CanSeep_20pct_dec					
	GW Develop-ment 1950 - 1998	Kh							
		Kh/Kv							
		Sy	X	hm_Sy_20pct_dec	X				
		Streambed Conductance							
		Stream Stage (set or computed)							
		Riverbed Conductance							
		River Stage							
		Drain Conductance							
		Maximum ET Rate							
		ET Surface vs Land Surface							
		ET Extinction Depth							
		Rangeland Recharge							
		Cultivated Dryland Recharge	X	hm_drylandrch_20pct_dec	X				
		Cultivated Irrigated Recharge	X	hm_irrigatedlandrch_20pct_dec	X				
		Canal Seepage	X	hm_canalseep_20pct_dec	X				
		Pumpage by CROPSIM		hm_pumpage_20pct_dec	X				
		Pumpage by NEBGUIDE							

Table 2.(continued)— Sensitivity Analysis Checklist for Reviewed COHYST Models

Model	Simulation Period	Candidate Sensitivity Analysis Parameters	Calib-ration Para-meter?	Sensitivity Analysis Metrics Used and Reported					Comment
					Fit Statistics		System Responses		
				Reviewed Model File Name Root	Head or Water Level Change	Stream & River Gain and Loss	Water Level Changes	Stream & River Gain & Loss	
EMU	pre-Develop-ment 1895 - 1950	Kh	x	STRKh120	X			X	Gains to Platte not analyzed
		Kh/Kv			X				
		Sy							
		Streambed Conductance	X						
		Stream Stage (set or computed)							
		Riverbed Conductance							
		River Stage							
		Drain Conductance	?						
		Maximum ET Rate	?						
		ET Surface vs Land Surface	?						
		ET Extinction Depth							
		Rangeland Recharge	X		X			X	Gains to Platte not analyzed
		Cultivated Land Recharge							
		Canal Seepage							
	GW Develop-ment 1950 - 1998	Kh							
		Kh/Kv							
		Sy	X		X				
		Streambed Conductance							
		Stream Stage (set or computed)							
		Riverbed Conductance							
		River Stage							
		Drain Conductance							
		Maximum ET Rate							
		ET Surface vs Land Surface							
		ET Extinction Depth							
		Rangeland Recharge							
		Cultivated Dryland Recharge	X	devdlrech120	X				
		Cultivated Irrigated Recharge	X		X				
		Canal Seepage							
		Pumpage by CROPSIM			X				
		Pumpage by NEBGUIDE							

Table 2.(concluded)— Sensitivity Analysis Checklist for Reviewed COHYST Models

6.2 *Adequate Representation of Modeled System for Intended Uses*

This section addresses the following question posed in the COHYST Request for Proposals:
Do the models adequately represent the regional properties and processes for the physical settings that were modeled and for the intended uses?

6.2.1 Improved Understanding of Hydrologic and Geologic Conditions

From our review of the model data sets provided, we conclude that the three models comprise the most consistent and detailed tools developed to date that can be used to understand the operation of the interconnected groundwater and surface water system in the Platte River basin above Columbus. However, the model reports only included brief discussions (under the topic of Model Calibration) of the how the models are able to simulate the operation of the modeled system. Because no documented list of components of the system that required improved understanding based upon previous model studies was included in the documentations, the degree to which the models have provided an improved understanding of the operation of the hydrologic system has not been documented.

6.2.1.1 Changes in Water Balance Components over Time

The calibrated model datasets contain a significant amount of information that can be used to advantage to document the past operation of the hydrologic system, but which has not been included in the model documents. This information includes simulated temporal changes in mass balance components for the entire modeled areas as well as for smaller areas as shown in charts prepared for this review (Figures 55 through 62). Analysis of such changes is often very useful in evaluating the effects of changes in pumpage and recharge. For example, a time plot of mass balance components for the Eastern Model Unit (with the correction to allow the watertable to drop below the base of layer 1) shows that simulated ET from groundwater increased over time from 1900 to 1966 decreased for the next ten years and then increased again until 1998. An apparent explanation of this pattern is increased areas of shallow groundwater caused by increased recharge from surface water irrigation system losses followed by heavy groundwater pumping, and drought conditions, followed by lower pumping and wetter climatic conditions. However no such explanations are presented in the model reports.

6.2.1.2 Changes to Platte River Interaction with Groundwater

COHYST developed conceptual models that appear to be focused principally upon the hydrostratigraphy of the aquifer system. The documentation of the conceptual models does not include a discussion of the importance of various processes and factors that are important to answering groundwater-surface water interaction questions to meet project objectives. Conceptual models should have included discussion of significant changes to the operation of the hydrologic system as a result of the development of irrigated agriculture. For example, the Platte River became perennial as a result of increased seepage and drain discharge cause by canal leakage and excess surface water irrigation south of the river.

The conceptual model sections should have included a discussion of the interrelationships and relative importance of river stage, evapotranspiration, depth to water, gradients to and from the Platte River, groundwater pumping, and how these have changed over time. The recent report by Saunders (2001) provides such a discussion, and similar concepts should have been included in the COHYST conceptual models, and used to guide construction, calibration, verification, and sensitivity analyses. Because such a discussion is lacking in the conceptual models and because specific scenarios which the models are intended to evaluate were not defined, it is indeterminate whether the models are consistent with the intended uses.

Reported sensitivity analyses did not include measures of the impact on simulated reach gains of the Platte River in response to uncertainties in calibration parameters and other quantities that were assumed to be correct (such as the additional amount of recharge added to cultivated land). Consequently, the uncertainty in the degree of understanding of the interaction of the Platte River and groundwater has not been demonstrated to have been reduced or improved over that provided by previous studies.

6.2.1.3 Need for Level of Complexity That Was Built into Models

The COHYST model strategy document stated that additional detail and complexity was to be added to the models until there was no further improvement in their accuracy. However, this process and the improvements in accuracy that were achieved were not discussed in the model reports. Without such a discussion, it appears that an *a priori* assumption was made and followed that multiple layer models are better then simpler models. This violates the fundamental principal of modeling natural systems that the simplest model that explains the important processes with the accuracy and precision necessary for the intended purposes is always the best model.

Apparent disagreements between the conceptual and numerical models are built into the models as a result of the use of options and methods used with the GMS modeling shell. These include the method in GMS that was used to model each hydrostratigraphic unit as continuous over the entire model area, and setting the thickness of layers that are not physically present to one foot. For all model units, this causes numerical problems, and is the probable reason that a steady state solution could not be achieved. For the single layer Western Model Unit, the continuous layer requirement resulted in the entire model area having some degree of saturation, even if only a one-foot thick layer was draped over significant bedrock highs. This may not be a reasonable representation of the actual system.

Many irrigation and municipal wells in the COHYST project area are completed across and interconnect multiple hydrostratigraphic units. Many of these apparently were used as observation wells used for model calibration. Therefore, the real world system often operates as a single, interconnected layer and observations of that single interconnected system have been used for calibration. The COHYST models were constructed such that extraction wells were open only to one hydrostratigraphic unit or model layer. This is not a restriction of MODFLOW, although the GMS modeling shell does not include generating the MODFLOW datasets that allow wells to be open to more than one layer. This fact was not discussed in the conceptual model section of any reports.

A single, one-layer model that uses either the Hydrologic Unit Flow concept or thickness-weighted average hydraulic conductivities from the calibrated model may be as representative of the physical system as the individual models. Such a model would likely eliminate numerical solution difficulties caused by thin layers, and would eliminate the need to use and explain differing results in overlapping portions of the models, and would be a simpler, consistent tool for their intended uses.

The level of complexity built into the models also resulted in the need to use three overlapping models to cover the COHYST project area. This has resulted in the need to explain model differences in the overlap areas, to run the same management scenarios on multiple models, and to demonstrate that the differences do not significantly affect model predictions.

6.2.1.4 Method(s) Used to Compute Net Pumpage

Two methods of computing net pumpage were used for the development period models for the Western and Central Model units: The CropSim and NEBGUIDE methods. The Eastern Model Unit reported only the use of CropSim. The reports do not include a recommendation as to which method should be used in future simulations. The high amounts of recharge that had to be added to irrigated land shows that both NEBGUIDE and CropSim over estimate net irrigation requirements. Both methods compute the net irrigation requirement as that needed to meet crop requirements in addition to that provided by effective precipitation (precipitation less runoff and interception losses) with no deep percolation. Therefore, The reasons for this are either that crop demands as specified by ET computed by CropSim are too high, that specified soil moisture holding capacities are too low, or that computed runoff is too high, or a combination of all three. Therefore, if either CropSim or NEBGUIDE are to be relied upon for computing recharge and net pumpage to analyze future condition scenarios, a method needs to be developed that uses the correlation developed between values resulting from model calibration with CropSim values.

6.3 Reliable Estimation of Impacts to Platte River and Groundwater Supplies

This section provides the review response to the following question provided by COHYST:

Can the regional groundwater flow models provide ability to determine reliable estimates of the quantity, timing, and location of impacts on Platte River & tributary stream flow and on groundwater supplies from: existing or new wells pumping in a given area or in the vicinity of the Platte River Basin; recharge projects used for flow augmentation; and surface water supply projects and activities used to increase their water use efficiency?

The models that have been developed provide the best tools to use in improving the understanding of hydrologic conditions throughout the study area. Unfortunately the model reports do not take advantage of information that is contained in the model datasets to document this understanding with regard to the relative importance of physical processes that are important to assessing the impacts of changes in water management policies on the flow of the Platte River and adjacent riparian areas.

6.3.1 Reliability in Simulated Impacts on Platte River

Based upon review of the model datasets provided for review, the models appear to simulate changes in groundwater discharge to and recharge from streams and rivers better than documented in the model reports. For the Platte River these simulated changes are both plausible and consistent with known changes in the hydrologic regime such as increased drain and baseflows caused by increased water levels south of the river in response to loses from surface water irrigation systems (Figures 22 through 27). Additional analysis and documentation of this data from the existing model datasets would further demonstrate the reliability of the models for this purpose.

6.3.2 Reliability in Simulated Water Level Changes

The Development period fit between simulated and observed water level changes exhibits considerable scatter and uncertainty. Further, these fits show a bias that implies that the net recharge to the system is too high. The model documents do not address either the degree of scatter or the bias. An analysis of this bias in conjunction with an analysis of and further justification of the amounts of recharge added to cultivated land should improve the reliability of the models.

6.3.3 Quantitative Scenarios and Metrics

Reliability and confidence in the ability of the models to assess impacts on the Platte River and tributaries and on groundwater supplies should be further established by developing specific, quantitative water management scenarios and metrics of these impacts that managers and policy makers find useful. For example, such scenarios would include changes in river stage during flow augmentation events.

6.3.4 Additional Sensitivity and Verification Analyses

Reliability of the models in predicting impacts on the Platte River and tributaries and on groundwater supplies has not been documented because the reviewed reports and datasets do not include the level and completeness of sensitivity analyses necessary to account for uncertainty in model parameters, boundary conditions, pumpage, and recharge. As discussed in section 6.1.3 sensitivity analyses were not included in the reports for all parameters that were varied during model calibration. Sensitivity analyses were not reported that assessed the effects of uncertainty on predicted gains and losses of the Platte River, or to components of the water balance for model domains or portions of such domains that may be of interest in assessing future scenarios.

Confidence in model reliability would be further demonstrated by performing and documenting verification analyses using calibration to the period with the most observed data (1973-85) and using the results to simulate the other three Development periods.

6.3.5 Reliability in Model Overlap areas

The utility and reliability of the models to be used to reliably assess the impacts of management scenarios is constrained by the existence of three overlapping models. Confidence in the results of analyses of scenarios for areas that include model overlap areas would be significantly increased if the calibrated models were used as the basis to construct for a simpler single model that includes fewer layers. Review of the model datasets shows that such a model may be justified because differing hydraulic conductivities of the layers as used in the models do not result in significant vertical gradients and flow. Construction and checking of such a model using GMS should not be a significant undertaking.

6.3.6 Method Used to Determine Recharge and Pumpage for Future Scenarios

The COHYST Decision Support System will require consensus on the methods and protocols to be used to simulate conditions from 1998 on that preserves the existing transients in the simulated system This will include consideration of the adequacy of the methods used to set recharge and net pumpage prior to 1998.

6.3.7 River Boundary Conditions instead of Stream Boundary Conditions.

Use of the river boundary condition for the Platte, Republican, Loup, and South Loup Rivers and for Frenchman Creek uses pre-defined river stage elevations as the driving head for the interaction between groundwater and surface water and does not allow the models to simulate conditions that would cause these rivers to go dry. This limits the applicability of the models. This problem could have been avoided by the use of a stream boundary condition with specified flows at the upstream points where these rivers enter the model domains and using the option to compute stream stage.

6.3.8 Importance of ET from Groundwater

Because most ET from groundwater occurs in riparian and wetland areas, understanding its role in capturing groundwater before it reaches the Platte River is essential to understanding the operation of the hydrologic system to meet project objectives. As reported in the model documents and further shown by examination of model datasets for this review, ET from groundwater computed by the Eastern Unit models is approximately equal to the discharge of groundwater to surface water, and is one third to one half of that amount for the Western and Central Model Units (Figures 55 through 57).

Many previous models and reports for the COHYST study area show that the so-called salvage of ET by lowering the watertable may be a viable management tool that allows water to be withdrawn from wells with a consequent reduction in ET. However, whether such an option can be implemented without causing unacceptable reductions in stream and river flow has apparently not been assessed with the models. While the models have been constructed to be able to assess ET salvage, the reports do not include a discussion of its importance.

Review of the model datasets shows that ET was simulated during the entire year, and the analysis of water balance components shown in Figures 55 through 57 included for this report show that simulated ET during the winter months was significant. Because this is not realistic, reliability of the models to assess scenarios in which ET is important has not been established and this limitation needs to be addressed to demonstrate the reliability of the models.

Review of the model datasets shows that ET is simulated in cells occupied by drains, streams and rivers. Because of the computational sequence for flow to each of these boundary conditions used by MODFLOW, this may result in overestimation of ET from river and stream cells, and underestimation of flow to drains.

The *a priori* specification of areas where ET from groundwater can occur unnecessarily constrains the models. Because ET from groundwater does not occur when the watertable depth is greater than the specified extinction depth, there is not reason not to include ET in all model cells.

Additional analysis of ET from groundwater for the Eastern Model should only be conducted after correcting the ET surface presently contained in the model datasets so that is consistent with that used for the Western and Central models. The surface contained in the Eastern model may underestimate ET over approximately one third of the area to which ET was simulated.

6.4 Ability to Develop Sub-Models

This section provides the review response to the following question provided by COHYST:
Do models provide ability to develop sub-models for specific projects or specific sub-areas of the regional models to determine the quantity, timing, and location of impacts on Platte River and tributary streamflow?

The development of sub-models that are contained entirely within the boundaries of any of the three COHYST mode units and which do not extend into areas where the models overlap should be a straightforward process. If the sub-models are developed using GMS, this process should be straightforward, as GMS includes several tools and methods to automate this process, refine grids, and assure that boundary conditions for the sub-model are consistent with and developed from the regional model.

6.4.1 Needed Protocols for Developing Sub-Models

Any model analysis going forward, whether performed using the three regional models or sub-models developed from them will also require the following:

- A consensus protocol for assuring that sub-models properly preserve mass at boundaries with regional model(s);
- A consensus protocol for methods be used to simulate conditions from 1998 on that preserves the existing transients in the simulated system;
- A consensus protocol for methods used to specify recharge and pumpage going forward, including resolution of the recharge predicted by CropSim and additional recharge added to cultivated land;
- A method to eliminate ET from groundwater during the non-growing season;
- Development, documentation, and protocols for using data from the model archive and database to assure consistency and maximum information use from the regional models; and
- A consensus protocol to keep regional models updated using additional field data, additional calibration of the regional models, and changes resulting from the development and additional calibration of sub-models.

6.4.2 Sub-Models in Areas where Regional Models Overlap

The utility and reliability of the models to be used to assess the impacts of management scenarios is constrained by the existence of three overlapping models. The use of three models to build sub-models and analyze scenarios in the areas of overlap will require resolution of differences in the models as they exist today. Resolution will be required for the following:

- Differing number of layers and elevation of the tops and bottoms of layers;
- Differing calibrated values of hydraulic conductivity and specific yield;
- Differing amounts of recharge added above CropSim values for cultivated land; and
- Resolution of the ET surface (overlap area between the Eastern and Central Model units only).

6.4.3 Simplified Regional Model

Confidence in the results of analyses of scenarios for areas that include model overlap areas would be significantly increased if the calibrated models were used as the basis to construct a simpler single regional model that includes fewer layers. Review of the model datasets shows that such a model may be justified because differing hydraulic conductivities of the layers as used in the models do not result in significant vertical gradients and flow. Construction and checking of such a model using GMS should not be a significant undertaking.

Once the calibration of the Eastern Model is checked using a version of the model that correctly simulates cell drying, the calibrated values of aquifer parameters for all models should be used to construct a single, model of the entire study area with one to three layers. This model should use thickness-weighted values for hydraulic conductivity and values of specific yield for the units that correspond to the reasonably anticipated range in water level fluctuations based upon historical data. This model should be able to quickly resolve differences in simulated aquifer parameters in the overlap area of adjacent models. Construction of such a model using the tools in GMS and ArcGIS should be a straight forward process based upon the effort it took for the review team to construct a one-layer model.

A single layer model of the entire study area will be smaller (fewer cells) than the Central or Eastern models alone and will facilitate its ease of use and increase the number of scenarios that could be analyzed. Such a model would eliminate the need for running the same management scenario on overlapping models and the consequent need for justifying or explaining differences in computed results such as changes in base flows of Platte River reaches that will occur with the separate models.

6.5 Adequacy of Supporting Data and Methodologies

This section of the review addresses the following question provided by COHYST:

Were data collection methods, use of data, and selection and use of various tools and algorithms described in the reports for Streamflow Data Analysis and Development of Model Input Coverages on Hydrogeology, Land Use, Recharge, Evapotranspiration, and Pumpage: performed within the standards of the industry for the topic; and appropriate for subsequent use in regional groundwater flow models of the modeled area of Nebraska?

This section summarizes the results of Task 5 of our approach to the peer review.

6.5.1 Comprehensive Database / Geodatabase

COHYST Work Plans published in 1998 and 2001 called for developing, populating, documenting, and publishing a DSS database that contained all model support information No reference is made to such a database in the model reports, and no database was provided for review, rather multiple spreadsheets, text files, partial databases, and GIS coverages were provided.

6.5.2 Streamflow data and analysis

The common purpose of the three reports is to present estimates of ground-water discharge from the High Plains aquifer to the streams of the individual study units. That purpose is clearly stated in the introduction of each report. The statement of purpose notes that most stream-flow data are affected to some degree by diversions through canals that have been in existence throughout most of the data collection period; furthermore, large-scale development resulting from changing pump technology and 1950s and 1970s droughts is reflected in flow data collected since about 1960.

6.5.2.1 Overview of the Review Process

The reports follow a common format and outline. The introduction and most of the description of the procedures followed are the same in all three reports, changing only the portions that discuss issues specific to the individual study units.

Procedures followed for the review:

1. Reports were read for content and compared for consistency between study units.

2. Lists of gauging stations identified in the reports as being available to the study were compared to the lists of data available from USGS and the State of Nebraska databases.

3. Conceptual models were evaluated, and computations (in this case, low-flow statistical analyses and mass-balance computations) were reviewed for conformance to generally accepted procedures.

4. Computations presented in tables 3 and 4 were spot checked.

Data were downloaded from the USGS and State databases for the alternative analyses needed to assess the validity of the low-flow statistics concept of defining ground-water discharge.

6.5.2.2 Available Data

An independent search of surface-water databases of both the USGS and the Nebraska DNR shows that all available data were considered in each of the model units. Because of the desire to use common periods of record to the extent possible, some short records were not used to determine ground-water discharges; those sites are identified in Table 2 for each report.

A few stations that were used in the analysis are no longer available for electronic retrieval from the internet. Those sites include 06688500 Otter Creek near Lamoyne in the western unit, 06837300 Red Willow Creek above Harry Strunk Lake in the central unit, and 06770000 Platte River near Odessa in the eastern unit. These data were available on-line until USGS revised the on-line databases after year 2000. The reason the data are no longer available on-line is not known; however, the Odessa data are important to the analysis and were obtained directly from USGS.

The reliability of computations that use canal data is reduced because of the condition of the canal records. The State canal databases have unexplained gaps in the records for many of the canals. Specific canals, such as the Gothenburg Canal (570000) that was added to the Cozad data, have only seasonal records for some periods. For example, the Gothenburg Canal in 1969 shows no data for October, November, and 25 days in December. Beginning about 1973, seasonal data are shown that exclude the winter months. The missing periods vary from year to year, but generally range from October – April. Similarly, the Kearney Power and Irrigation diversion (00730) is added to the flow at Odessa. The record retrieved from the State Canal Database contains numerous missing days; those days may have been zero flow, but that is unclear as other periods of zero flow days are contained in the records. Examples of missing days are given in the specific comments about Tables 3 and 4.

The following note included in the Eastern Model Unit directory under Platte\canal\process.notes.txt acknowledges the missing data: "*In several instances, the discharges for flow records are missing for periods of days to months at a time. Therefore, the day notation was deleted where the associated October or November discharge measurement was missing. In cases where those days fell in the month of October or November, the entire set of October and November measurements were deleted, so that that year would not be included in the low flow analysis. This avoids creating a built-in bias that may result from using incomplete October or November results*."

6.5.2.3 Conceptual Models of Baseflow Generation

There is general agreement that the base flows of perennial streams in the study area are derived from ground water. The task is to define those base flows. Doing so, however, is complicated because the Platte River and its principal forks (North and South Platte) are regulated and are affected by diversions and return flows.

The study assumes the impacts of diversions and return flows are minimal during the non-irrigation season, generally October to March. However, because winter-flow data are generally of poorer quality than data for the rest of the year, the studies used data only for the fall of the year, defined herein as October and November. As the study progressed, the investigators recognized that the October flows for many gauged sites showed evidence of the effects of diversions. At those sites, the data were further restricted to just the month of November.

The study uses two concepts to determine ground-water discharge in the study area. The first concept is that low-flow characteristics at gauging stations during the fall are indices to the ground-water discharge passing those points. The second concept is that gains or losses of flow in a reach of stream between gauged points can be determined from a mass-balance approach as the difference between outflow from the reach and inflow to the reach.

Estimated ground-water discharges at individual sites in table 3 of each report are based on the assumption that annual fall-season average 7-day and 14-day low flows are representative of ground-water discharge to the streams. The low-flow determinations were restricted to the months of October and November because those months are believed to be relatively free from diversions and return flows. The studies define the fall 7-day average low flow with a 5-year recurrence interval (0.2 annual non-exceedence probability) as equal to the minimum ground-water flow; the fall 14-day average low flow with a 2-year recurrence interval (0.5 annual non-exceedence probability) as equal to the maximum ground-water flow. The reports explain the process used, but do not establish the basis for the assumption. The validity of this assumption is crucial to the COHYST study. Therefore, in addition to reviewing the computations presented in the reports, this review included an alternative computational approach to test the assumption.

The reach gain/loss computations presented in table 4 of each report also used a frequency-based approach, but relied on the monthly averages rather than the 7-day and 14-day low flows. The reports describe the process in general terms, but leave out the detail that the mass-balance is actually done on a daily basis. A daily-flow mass balance for the reach was computed by subtracting reach inflows from reach outflows. The annual daily net gains or losses were averaged for the fall period (many were restricted to November only), and the frequency analysis was performed on the resulting annual data series. The daily mass-balance computations do not make any allowance for transit time through a reach. Transit times could range from a few hours to more than a day. That may affect the accuracy of gains or losses for individual days, but should have no effect on the final results that are based on averages over 1 or 2 months.

The reach computations could have been done using the results for the individual sites from Table 3. Doing so, however, would have required an assumption that the tributaries experience the 7-day 5-year and 14-day 2-year flows at the same time as the main stem. Given the degree to which the main stem of the Platte River system is controlled, that would have been a poor assumption.

Specific comments on the low-flow computations reported in Table 3 of the reports are summarized Attachment H as are comments on the mass-balance computations used to define reach gains and losses.

6.5.3 Hydrogeology Coverages

The review of hydrogeology coverages included the following:

- Review of the Hydrostratigraphic unit report (Cannia, Woodward, and Cast, 2004) for consistency and content;

- Review of the Microsoft Access™ database (files iotwceksy061302.mdb and iotwce061202b.mdb) used to develop hydrostratigraphic unit coverages;

- Review of GIS coverages of the basal elevation, thickness, and hydraulic conductivity by loading into ArcGIS™ 9.0 and using them to compare to ArcGIS coverages for the same variables that were either provided by COHYST or exported from GMS datasets from each of the regional models; and

- For the Eastern and Central Model Unit, using the hydraulic conductivity coverages within ArcGIS to assess changes made as a result of Pre-Development calibration (See Figures 38 through 40 of this report).

COHYST included the most comprehensive and detailed project to date to define hydrostratigraphic units using a consistent methodology applied to test hole and other well logs. While the hydrostratigraphic units were defined using general considerations of hydraulic properties, these properties were not used quantitatively to define the units. Rather, the units were based upon general considerations of hydraulic properties based upon depositional history, followed by the assignment of hydraulic properties to the units by correlation with grain-size and textural descriptions.

The methods used to develop Hydrostratigraphic units are complete, rationale and consistent, and the most comprehensive that the reviewers are aware of that have been used to date. However, the documentation of the methodology would be improved if the tables relating grain-size to hydraulic conductivity from Reed and Piskin were included. Additional explanation regarding the source of the specific yield values used in the GeoParm documentation and how those values relate to those developed by Peckenpaugh that have been previously used in the Central Platte area would also improve the documentation.

6.5.4 Recharge and Pumpage

Recharge and net pumpage computed by CropSim are a major component of the regional groundwater models. As shown in the sensitivity analyses in the reports, water level changes are directly proportional to the magnitude of the balance between recharge and pumpage at any location within the models. Review of the available documentation for CropSim and the computer code used for several COHYST runs shows that it is comparable to other similar water balance models of the climate/crop/soil system such as the Soil and Water Assessment Tool (SWAT) developed by the U.S. Department of Agriculture (Neitsch, 2002).

6.5.4.1 CropSim Documentation

The CropSim model does not presently include a finished theoretical or users manual. The copy of the CropSim documentation provided for review is fragmentary, not complete, and has not been peer reviewed or published. Significant sections of the report that are important to assessing the adequacy of CropSim were not complete in the report provided. These include:

- Runoff by the SCS curve number method, including a method used to adjust curve numbers
- Deep percolation, including transpiration while draining
- Relative Yield Modeling
- Irrigation System Inputs
- Tillage Inputs

6.5.4.2 Inconsistent Documentation of Method Used to Compute ETr

There are multiple inconsistencies between the various reports that refer to the use of CropSim with regard to the method actually used to compute values of potential evapotranspiration for the reference crop, ETr: the three regional groundwater modeling reports states that a calibrated Blaney-Criddle method was used; the CropSim documentation provided for review states that review states that the Penman Monteith method is used; the Fortran computer code provided shows that the Hargreaves method was used, and the report by the Flatwater group (2004) states that the method used was the Hargreaves method calibrated to regional coefficients based upon the Penman-Monteith Method.

6.5.4.3 Inadequacy of Recharge Computed by CropSim for Model Calibration

As discussed multiple other places in this report, the reasons that recharge from CropSim was deemed by the model authors to be unacceptable for model calibration require further analysis if CropSim is to be used to provide pumpage input to COHYST models because the same methodologies, equations, parameters, and variables are used by CropSim to compute the net irrigation requirement and recharge. One possible explanation of low recharge rates and high net irrigation requirements is that CropSim may overestimate ET and hence pumpage from year day 235 to end of growing season by as much as 20% compared to methods that compute crop coefficients using a Leaf Area Index (LAI) approach (see Figure 4 on p 2.15 of Martin [undated]).

6.5.5 Land Use

COHYST used historical land use distributions as a component in computation of recharge and net pumpage applied to the models during the Development Period (1950 -1998). The methodology used land use mapped in 1997 from satellite imagery from the CALMIT program to prepare maps and datasets of the distribution of each of 24 land use categories in each one-half mile model grid cell used for the regional models, as well as their distribution in 10-acre cells over the model area. The method used to prepare the 1997 distributions represents the most comprehensive and completed land use mapping performed for that period, and provides an excellent basis for using to estimate crop water needs for purposes of estimating pumpage for the groundwater models.

The method used by COHYST to project the 1997 distribution of cultivated dryland and irrigated land backward in time from 1997 also appears to made use best of historical county agricultural statistics as a check and constraint.

The method used to project cultivated and irrigated land backwards in time using a random selection process constrained by physiographic and topographic location of a model cell is also appropriate and reasonable.

Elsewhere in this report we have noted the need for further analyses to resolve and explain the why recharge generated by CropSim was inadequate or unacceptable to calibrate the models. Those analyses should include evaluation of the increase in cultivated land to assure that the problem is with CropSim, and not also with the method used to extrapolate cultivated land use backwards in time.

6.5.6 Quality Control and Data Validation Methods

No document was provided for review that described data quality control processes and procedures that have been used for COHYST, although the Work Plans (COHYST 1998, 2001) include tasks that refer to Data Quality (Tasks 108 and 302).

The model datasets provided did not include metadata for many of the coverages used for model construction and calibration. Metadata for some of the coverages used to support model documentation are available on the COHYST website, but these are not complete and up to date.

7 Alternative Approaches and Methodologies

The construction, calibration, and use of models of large, complex groundwater systems can be approached using different but comparable methodologies and tools. While we have concluded that in general the approaches and tools used by COHYST are consistent with industry standards, our review assessed alternatives in the following three areas as a further check on the reliability and utility of the models and modeling tools that have been used:

- Estimates of baseflow to use as calibration targets for groundwater discharge surface water;
- Running MODFLOW using modeling shells other than GMS or using no modeling shell; and
- Methods used by CropSim to compute recharge and net pumpage.

7.1.1 Alternative Approach to Estimating Groundwater Discharge to Surface Water

The base flow of unregulated streams during periods of minimal evapotranspiration is generally indicative of ground-water flow. Several computerized methods exist for using hydrograph-separation techniques to estimate base flow from daily-mean discharges of streams. The BFI model uses Fortran code developed by Wahl and Wahl (1988. 1995, http://www.usbr.gov/pmts/hydraulics_lab/twahl/bfi/) to estimate the base flow of streams from daily-mean discharge records. The program is based on a computational procedure first described by the Institute of Hydrology (1980). In the original Institute of Hydrology approach, the flow hydrograph for a year was divided into 5-day segments, and the minimum flow in each 5-day segment was flagged as a possible point of the base-flow hydrograph. The minimum points were then compared to adjacent minimums in a rate-of-change test; if 90-percent of a given minimum was less than both adjacent minimums, that minimum was a point on the base-flow hydrograph. The selected points, when joined with straight lines on semi-logarithmic paper, formed the base-flow hydrograph. The BFI code automated this procedure and permitted the user to specify segment lengths other than 5 days and to modify the rate-of-change test. For the current application, however, 5-day segments and the 90-percent test were used.

Hydrograph separation is not usually done on regulated streams because a relatively constant release from a reservoir will be interpreted as base flow. However, the purpose of the COHYST study was to define gains from or losses to ground water in the respective reaches. Therefore, BFI was run for selected main-stem stations used in the reports under the assumption that irregularities caused by regulation will be reflected on stations at each end of the respective reaches. Because of the regulation, the resulting values do not necessarily represent base flow; instead they are simply daily values that have had short-duration, high-flow values filtered out. That being the case, however, differences in the estimated base flows between the ends of a reach should be representative of flow to or from the ground-water system.

Daily average base flows for both the fall (October-November) and winter (October-March) seasons were defined for most of the sites. The COHYST reports estimated minimum and maximum ground-water discharges, and define the mean as the average of the minimum and maximum. In the alternative approach, the 1st quartile (25th percentile), median (50th percentile), and 3rd quartile (75th percentile) values were defined from all estimated daily base flow values for the individual seasons. The 1st quartile is assumed to be an index to the minimum seasonal base flow and was compared the COHYST minimum; the 3rd quartile is assumed to be representative of the maximum seasonal base flow and is compared to the COHYST maximum. The median flow is compared to the COHYST mean.

The relation between the base flows estimated from BFI and from average 7-day, 5-year and 14-day, 2-year low flows shown in the reports was examined in order to determine the validity of the assumption that the frequency-based estimates represent ground-water flow. Tables showing the base flow estimates for the individual model units are at the end of the report. Figures 39 through 41 compare the minimum, mean, and maximum estimates, respectively.

The comparisons of the estimated minimum, mean, and maximum ground-water discharges with estimated base flows are very good for discharges of less than about 300 cfs and for the Loup River system. These are the sites that are largely unregulated. With the exception of the Loup River system, the BFI-estimated base flows at sites with discharges greater than 300 cfs are greater than the COHYST estimated ground-water discharges. Sites with discharges greater than about 300 cfs are generally the North Platte, South Platte, and main-stem Platte sites. Those are regulated in varying degrees, and BFI will likely overestimate base flows because relatively constant discharges over a period of days are labeled as base flows regardless of magnitude.

For these larger, more regulated streams, the comparisons are best for the estimated minimum discharges and worst for the estimated maximum discharges. That is not unexpected given that the COHYST estimates are based on frequencies of monthly (November) or seasonal (October-November) mean values and the alternative approach is based on statistics of all daily mean values for the season.

A second assumption, that the fall (Oct.-Nov.) low flows were representative of non-irrigation season flows was addressed by comparing base flow estimates from BFI for the fall and winter (Oct.-Mar.) seasons. Figure 42 shows that the fall base flows are generally representative of base flows for the longer winter season. The upper points on the plot where fall flows exceed winter flows by substantial amounts represent the North Platte River gauges that are regulated. The higher fall flows may represent deliveries from upstream to downstream reservoirs. The overall conclusion, however, is that fall flows are a reasonable representation of winter-season flows.

Summary of Findings of the Alternative Analysis

The conclusion of the alternative analysis is that the frequency-based approach based on the fall season produces acceptable estimates of winter-season base flow. For unregulated streams, those estimates should represent ground-water discharge to the streams. For regulated streams, low flows have no hydrologic basis as they are simply the result of the regulation pattern. As such, the low-flow frequencies probably do not reflect ground-water discharges. However, gains or losses in flow over specific reaches should be reflective of ground-water discharge or recharge. Therefore, a mass-balance approach with the correct model should permit estimation of ground-water effects on a stream reach.

7.1.2 Groundwater Modeling Alternative Approach Assessment

Because the construction, calibration, verification testing, and documentation of groundwater models is complex, standard industry practice is to use so-called modeling ‘shells’ that are used to prepare model input datasets, execute the underlying simulation code, and to read and analyze model output. These modeling shells provide for increased flexibility and accuracy in generating large model datasets that represent the conceptual model, and greater ability to implement calibration and sensitivity analyses, as well as to view and assess model output.

Even when the modeling shells execute the same simulation code, the best way we have found to assess the validity of model datasets is to import selected MODFLOW datasets into different modeling shells and run the same simulations with each. If the model datasets are consistent, the output should be the same. If they are not, this method allows the identification of the origin of such inconsistencies. These can arise from different methodologies used to assign boundary conditions, initial conditions, hydraulic properties, and sources and sinks from spatial datasets and other tabular information.

As discussed in section 6.4 of this review document, we recommend continuing the use of GMS as the COHYST tool because the models were developed from the conceptual stage to the present stage with them. GMS is one of the most comprehensive and powerful modeling shells available within the groundwater industry. The reason this tool is so powerful and the advantage it has over other such tools is the ability to build quantitative conceptual models of hydrostratigraphy, boundary conditions, sources and sinks of water using GIS mapping technology that is independent of the numerical model chosen for use. The conceptual model coverages thus constructed are then translated seamlessly into the required datasets for the numerical model chosen for a particular application.

As has been demonstrated by this review , the MODFLOW 96 datasets developed for COHYST using GMS 3.1 can be directly read and processed to give identical results using MODFLOW 2000 and the current latest release of GMS (Version 5.1).

Because the model datasets may be used by those that do not have access to GMS, and because COHYST eventually is to make the datasets and the models available to others, this review evaluated the ease with which the datasets generated by GMS can be run using another industry standard modeling shell and by using no modeling shell at all (running MODFLOW2K from a command line).

7.1.2.1 Use of Visual MODFLOW Pro 4.1™ Instead of GMS

The recommendation included in the 1998 Workplan (COHYST, 1998) recommended the use of Visual MODFLOW™ from Waterloo Hydrogeologic as the modeling shell, although subsequent to the publication of that workplan, the Groundwater Modeling System (GMS) shell version 3.1 was selected and used by COHYST modelers. This review assessed the use of Visual MODFLOW Pro™ version 4.1 (VMP41) to run the MODFLOW datasets provided by COHYST that were developed using GMS. VMP41 is one of a few industry standard modeling shells currently available and uses MODFLOW2000(MF2K) as the modeling engine. It is generally more available to a larger group of potential users because of its lower cost and less steep learning curve than GMS. It includes the ability to simulate all the processes included in the current version of MODFLOW2000, as well as several of the more recently developed add-on packages. However, it does not currently support the Hydrologic Flow Unit package.

MODFLOW96 datasets developed for COHYST must be imported into VMP41/MF2K. This process required conversion of the MODFLOW96 datasets to MD2K format using the MF96to2K conversion program provided by the USGS with MODFLOW 2000. The COHYST datasets for the Central and Eastern Model Units are too large to be used with the executable version of the MD96to2K program on the U.S.G.S. website. The array dimensions have to be increased and the program recompiled for these datasets. as it Following this conversion, there are additional manual edits required to the header records in the .BCF and .STR files. These edits are documented in the Users Manual for VMP41.

GMS and VMP41 use a similar approach to generating the stream package input files for MODFLOW. Both of these approaches generate stream systems as linked line segments with nodes at the ends of the reaches that are maintained independent of the MODFLOW gridded data set used for streamflow simulation. However, there is no method in VMP41 to generate the independent stream representations by reading in gridded stream data from MODFLOW datasets. VMP41 will detect the stream package dataset and use it, however, the modification of the stream parameters and locations cannot be done from within VMP41.

The Pre-Development dataset for the Western Model was successfully imported into VMP41 and successfully run. Attachment I provides additional detail of the importation process.

7.1.2.2 Running MODFLOW 2000 with no Modeling Shell

The same edits and file modifications to the MODFLOW96 datasets discussed above to run with VMP41/MF2K are required to run the COHYST datasets with no modeling shell at all.

7.1.3 Alternative Methods to Development of Recharge, Evapotranspiration, and Pumpage

This review initially proposed to assess the reasonableness of the methods used by COHYST to develop recharge and net pumpage datasets generated by CropSim by using a similar industry standard water balance model developed by the U.S. Department of Agriculture (USDA). That model, the Soil and Water Assessment Tool (SWAT) was developed to predict the impact of land management practices on water, sediment, and agricultural chemical yields in large, complex watersheds with varying soils, land use, and management conditions over long periods of time.

SWAT is a custom extension to ArcView 3.x™ which is used to prepare all necessary input datasets, to execute the simulation model, and to view and analyze model output. The model is a public domain code that is actively supported by the USDA Agricultural Research Service at the Grassland, Soil and Water Research Laboratory in Temple, Texas.

We have compared the modeled processes, and methods used in SWAT with the unpublished CropSim documentation and the FORTRAN computer code for several CropSim runs that were provided by COHYST. Our assessment is that the computer code uses appropriate methods to simulate the daily water balance components of the climate/soil/plant system, and that the equations used in the code agree with published methodologies in SWAT or similar models.

The methods used to simulate hydrologic and plant growth and water use are similar in both CropSim and SWAT. However, SWAT includes multiple optional methods that can be used for separation of rainfall and runoff, for potential evapotranspiration, and for deep percolation and groundwater recharge.

SWAT is a distributed parameter watershed model that computes daily water, nutrient, and pesticide balances for unique combinations of soil and land use or crop cover within each defined sub-watershed. Because SWAT output includes daily streamflow generation, it can be calibrated to measurements of streamflow. CropSim does not simulate the overland flow and channel accumulation of runoff and cannot be calibrated to streamflow.

Our review of the CropSim documents provided shows that an appropriate methodology was used to generate recharge and net pumpage, and that the methods developed and applied by Rich Kern of Nebraska DNR comprise a reasonable method to combine these estimates with land use.

However, as we have noted elsewhere in this report, the reasons that CropSim was deemed to be inadequate, or otherwise unacceptable for determining recharge, while at the same time being considered acceptable for determining net irrigation requirement have not been adequately analyzed. Until this issue has been resolved, the use of CropSim to generate net pumpage for management scenarios is questionable.

8 Summary of Review Findings

The purpose of the Independent Peer Review was to evaluate the credibility of the model reports, the underlying model datasets, and supporting data and information by providing answers to the following questions provided by COHYST:

1) Were the development, calibration, sensitivity analyses, and documentation performed within industry standards for regional groundwater flow models?

2) Do the models adequately represent the regional properties and processes for the physical settings that were modeled and for the intended uses?

3) Can the regional groundwater flow models provide ability to determine reliable estimates of the quantity, timing, and location of impacts on Platte River & tributary stream flow and on groundwater supplies from: existing or new wells pumping in a given area or in the vicinity of the Platte River Basin; recharge projects used for flow augmentation; and surface water supply projects and activities used to increase their water use efficiency?

4) Do models provide ability to develop sub-models for specific projects or specific sub-areas of the regional models to determine the quantity, timing, and location of impacts on Platte River and tributary streamflow?

5) Were data collection methods, use of data, and selection and use of various tools and algorithms described in the reports for Streamflow Data Analysis and Development of Model Input Coverages on Hydrogeology, Land Use, Recharge, Evapotranspiration, and Pumpage: performed within the standards of the industry for the topic; and appropriate for subsequent use in regional groundwater flow models of the modeled area of Nebraska?

The following sections summarize our findings with regard to each of these questions.

8.1 Conformance with Industry Standards

Our summary findings with regard to how well the model development, calibration, sensitivity analyses, and reporting conform to industry standards are:

8.1.1 Modeling Processes and Procedures

The processes and procedures used are generally conformant with industry standards.

The model reports include most information normally expected by industry standards, but an increased use of suggested subheadings would significantly improve ability to locate this information and would make the three model reports more consistent with each other.

8.1.2 Conceptual Models

The descriptions of the conceptual models are generally complete and adequate with the exception of the role of the importance of evapotranspiration from groundwater in riparian areas important to meeting project objectives.

The conceptual models did not include adequate analyses to document any significant historical changes in baseflow of streams and river reaches. The numerical models computed such changes, and they can be documented using reasonably simple analyses of the series of annual November low flows developed for the project. Such changes should have been used to demonstrate model reasonableness.

The conceptual models overemphasized the importance of the hydrostratigraphic framework compared to the interaction of groundwater and surface water.

8.1.3 Numerical Models

Construction of numerical models is consistent with the conceptual models, and the reviewed model datasets agree with descriptions in the model reports with some exceptions. The significant exceptions include:

- No inclusion in the reports of the values used for storage coefficients for layers below the uppermost watertable layer;
- The use of multiple boundary conditions (River and Head-Dependent) to represent Lake McConaughy in the Western Model;
- Use of an ET surface in the Eastern Model that is higher than the mean land surface over one third of the area where ET is specified;
- Not allowing water levels in the Eastern Model to fall below the bottom of the layer that was initially saturated at the start of any simulation; and

8.1.4 Model Calibration

Calibration processes generally were conformant with industry standards. However the strategy to avoid non-unique combinations of hydraulic conductivity during the Pre-Development calibration was weakened by the use of streambed conductance as a calibration parameter. The Development period strategy to avoid non unique combinations of specific yield and the balance between recharge and net pumpage by using CropSim was weakened by the need to add additional recharge, and no analyses were included to quantify the reasons why CropSim recharge was too low.

Additional goodness of fit statistics and scatter plots that are considered industry standards were not included in the reports. Such statistics and plots prepared for and included in this review document show that the fit to Pre-Development and Development period heads is quite good, and better illustrated than the tables of three statistics included in the reports. However similar statistics and scatter plots for changes in water levels show considerable scatter and a bias that implies recharge rates that are too great. This scatter and bias is not addressed in the model reports.

8.1.5 Sensitivity Analyses

The sensitivity analyses documented in the reports are very limited and do not provide the level of completeness that would be expected by industry standards. The reasons for this include:

- No documented sensitivity analyses to simulated changes in gains and losses from Platte River, which is the focus of the COHYST Study;
- No documented sensitivity analyses to all parameters used for calibration;
- No sensitivity analyses to methods used to compute net recharge and pumpage (CropSim and methods used to extrapolate land use backward in time); and
- No Type IV Error Analysis (changes in parameters cause significant changes in model output, but do not significantly affect model calibration statistics).

8.1.6 Verification Analyses

Many groundwater modeling projects do not include a verification process in which models are tested against measures and targets for time periods and conditions that were not used for calibration. However, most such projects do not have the benefit of the large, consistent, and long term record of stream flows and water levels that have been assembled for COHYST. Performing and documenting such verification analyses would have significantly improved the credibility of the models.

8.1.7 Predictive Simulations

The predictive simulation sections contained in industry standard reports usually are included to describe the results of analyses and simulations that address questions posed as part of stated project purposes and objectives. If example scenarios had been developed at the outset of the COHYST project, and the models used to predict their likely effects on water levels and streamflow, the confidence and credibility of the models would have been significantly improved.

8.2 Adequate Representation of Conceptual Models and Intended Uses

From our review of the model data sets provided, we conclude that the three models comprise the most consistent and detailed tools developed to date that can be used to understand the operation of the interconnected groundwater and surface water system in the Platte River basin above Columbus. However, the model reports only included brief discussions under the topic of Model Calibration that discuss how the models simulate the operation of the modeled system.

Because no documented list of components of the system that required improved understanding based upon previous model studies was included in the model reports, the degree to which the models have provided an improved understanding of the operation of the hydrologic system cannot be ascertained.

The calibrated model datasets contain a significant amount of information that can be used to advantage to document the past operation of the hydrologic system, but which has not been included in the model documents. This information includes: simulated changes in simulated streamflow and river gains and losses from 1900 to 1998; and changes in the magnitude of individual components of the water balance, as well as the relative magnitude of the components to each other.

The need for additional cultivated land recharge over that computed by CropSim without adequate analysis of the conditions within the CropSim/Land Use process used limits the models application for their intended uses.

8.3 Ability to Estimate Impacts on the Platte River and Groundwater Supplies

The models that have been developed provide the best tools to use in improving the understanding of hydrologic conditions throughout the study area. Unfortunately the model reports do not take advantage of information that is contained in the model datasets to document this understanding with regard to the relative importance of physical processes that are important to assessing the impacts of changes in water management policies on the flow of the Platte River and adjacent riparian areas.

The models provide better fits to heads and stream and river gains and losses than are documented in the model reports. However, the fits to water level changes show considerable scatter and bias that implies recharge rates that are too high. This scatter and bias require additional analysis and documentation to be able to assess the reliability of the models in simulating water level changes.

Reliability of the models in predicting impacts on the Platte River and tributaries and on groundwater supplies has not been documented because the reviewed reports and datasets do not include the level and completeness of sensitivity analyses necessary to account for uncertainty in model parameters, boundary conditions, pumpage, and recharge. The sensitivity analyses do not include an analysis of which of the four types of errors are present in the model, including Type IV error, in which changes to input parameters significantly affect model outputs to be used for decision making, but the parameter changes do not significantly affect the measures used to determine model calibration.

Reliability and confidence in the ability of the models to assess impacts on the Platte River and tributaries and on groundwater supplies should be further established by developing specific, quantitative water management scenarios and metrics of these impacts that managers and policy makers find useful. For example, such scenarios would include changes in river stage during flow augmentation events.

Additional analyses are needed to demonstrate the models' abilities to reliably assess scenarios and conditions for which ET from groundwater is or may be a significant component of the water balance.

Additional analysis is needed to assess the reasonableness of the additional recharge added during calibration above that computed by CropSim. This analysis needs to include an evaluation of how this added recharge limits water level declines and stream/river depletions.

8.4 Ability to Develop Sub-Models

Any model analysis going forward, whether performed using the three regional models or sub-models developed from them will also require the preparation of protocols to assure that: the new models properly preserve mass at boundaries with regional model(s); and that transients that are in the system are preserved or accounted for.

Sub-models that are developed in areas where models overlap will require resolution of issues including: differing number of layers and elevation of the tops and bottoms of layers; differing calibrated values of hydraulic conductivity and specific yield; differing amounts of recharge added above CropSim values for cultivated land; and resolution of the ET surface in the overlap area between the Eastern and Central Model units.

Confidence in the results of analyses of scenarios for areas that include model overlap areas would be significantly increased if the calibrated models were used as the basis to construct a simpler single regional model that includes fewer layers. Such a model would be smaller (fewer cells) than the Central or Eastern models alone and will facilitate its ease of use and increase the number of scenarios that could be analyzed. Such a model would eliminate the need for running the same management scenario on overlapping models and the consequent need for justifying or explaining differences in computed results.

8.5 Adequacy of Supporting Data and Methodologies

8.5.1 Hydrostratigraphic Units

COHYST included the most comprehensive and detailed project to date to define hydrostratigraphic units using a consistent methodology. While the hydrostratigraphic units were defined using general considerations of hydraulic properties, these properties were not used quantitatively to define the units. Rather, the units were based upon general considerations of hydraulic properties based upon depositional history, followed by the assignment of hydraulic properties were assigned to the units by correlation with grain-size and textural descriptions.

8.5.2 Groundwater Discharge Estimates

The conclusion of the alternative analysis is that the frequency-based approach based on the fall season produces acceptable estimates of winter-season base flow. For unregulated streams, those estimates should represent ground-water discharge to the streams. For regulated streams, low flows have no hydrologic basis as they are simply the result of the regulation pattern. As such, the low-flow frequencies probably do not reflect ground-water discharges. However, gains or losses in flow over specific reaches should be reflective of ground-water discharge or recharge. Therefore, a mass-balance approach with the correct model should permit estimation of groundwater effects on a stream reach. Time trends in baseflow were not adequately assessed and used to demonstrate model reasonableness and reliability.

8.5.3 Recharge, Discharge, and Evapotranspiration

Recharge and net pumpage computed by CropSim are a major component of the regional groundwater models. As shown in the sensitivity analyses in the reports, water level changes are directly proportional to the magnitude of the balance between recharge and pumpage at any location within the models. However, the documentation of the CropSim model is incomplete, fragmentary, and unpublished.

There are multiple inconsistencies between the various reports that refer to the use of CropSim with regard to the method actually used to compute values of potential evapotranspiration for the reference crop.

The reasons why recharge computed by CropSim was considered unacceptable that but net pumpage computed using the same methods, equations, parameters and variables was considered acceptable by the model authors requires additional analysis and resolution if CropSim is to be used as part of the COHYST DSS.

ET computed by CropSim was not used as the basis for values of the maximum ET rate from groundwater, and no analysis or explanation was provided to explain this discrepancy.

9 References

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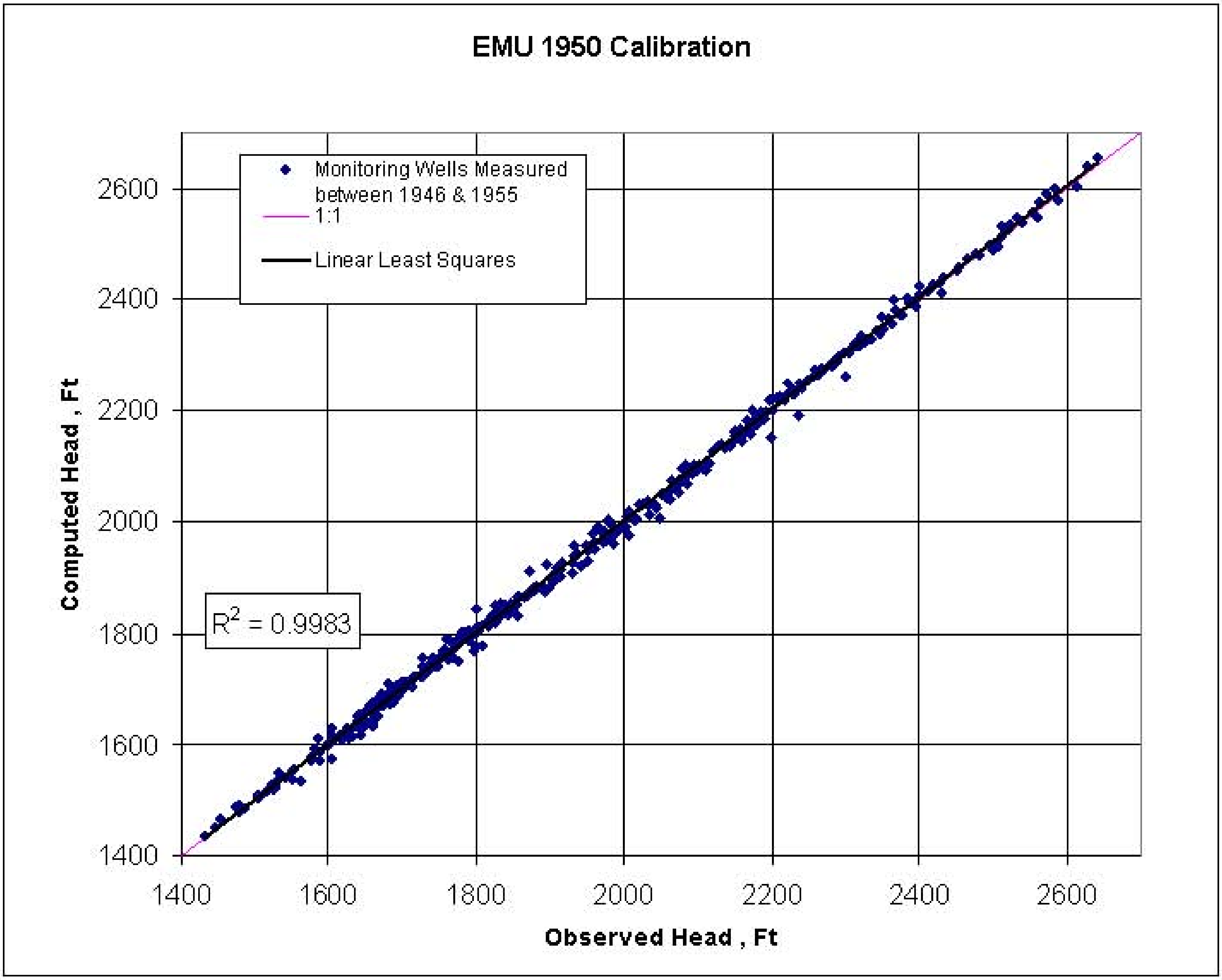
Figures



Calibration Statistics	
No Points	424
Maximum Difference	43.86
Minimum Difference	(45.75)
Residual Mean	2.18
Absolute Residual Mean	9.04
Std Error of the Estimate	0.58
RMS	12.20
Normalized RMS	1%
Corr. Coefficient, R^2	0.9983

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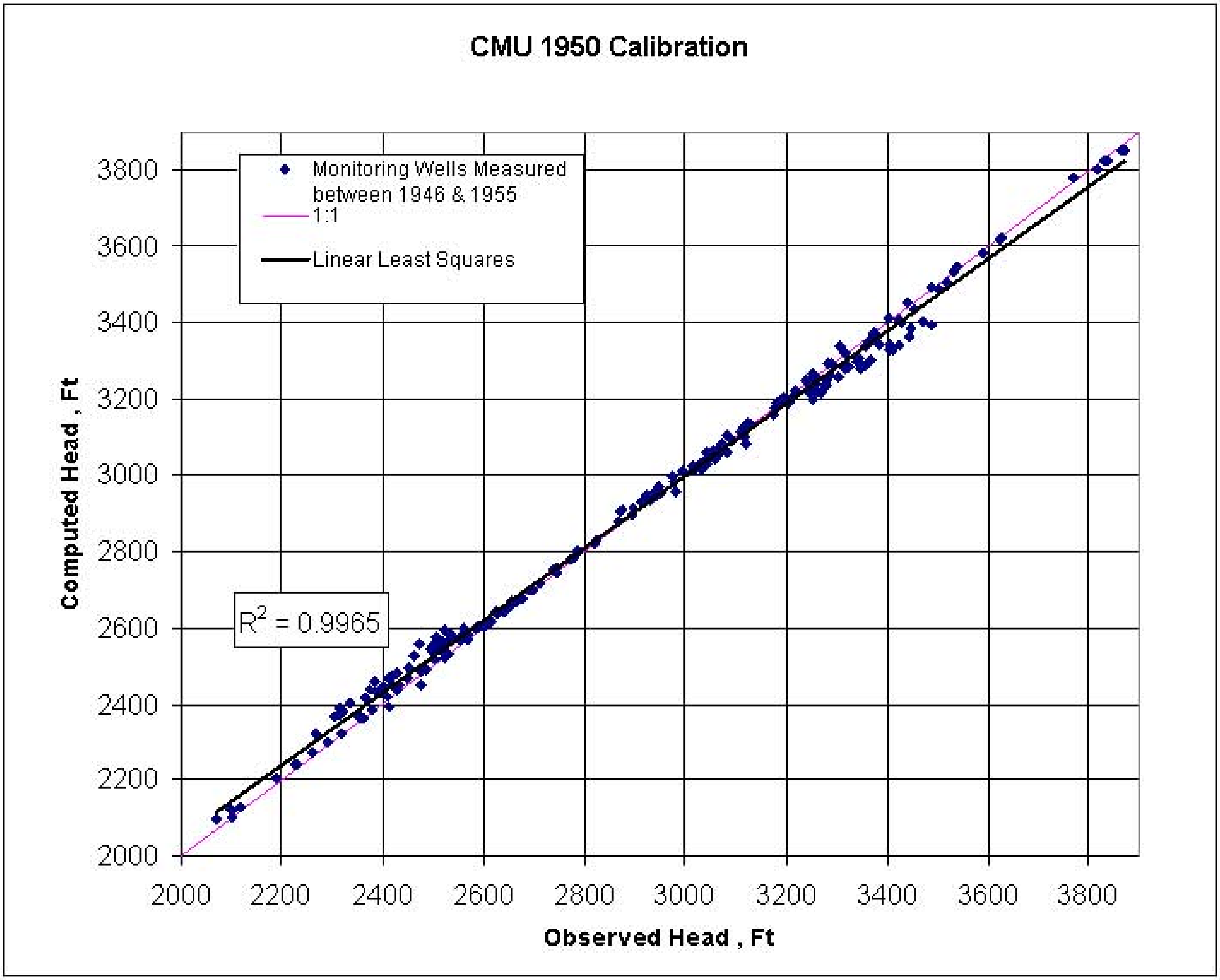
Eastern Model Unit Pre-Development Period Calibration Observed and Calculated Heads Measured Between 1946 and 1955.		
Date	Project Number	Approved:
8/22/05	13009.1	E.G.Lappala

Figure 2



Calibration Statistics	
No Points	201
Maximum Difference	83.90
Minimum Difference	(91.41)
Residual Mean	3.58
Absolute Residual Mean	23.65
Std Error of the Estimate	2.30
RMS	32.56
Normalized RMS	2%
Corr. Coefficient, R^2	0.9965

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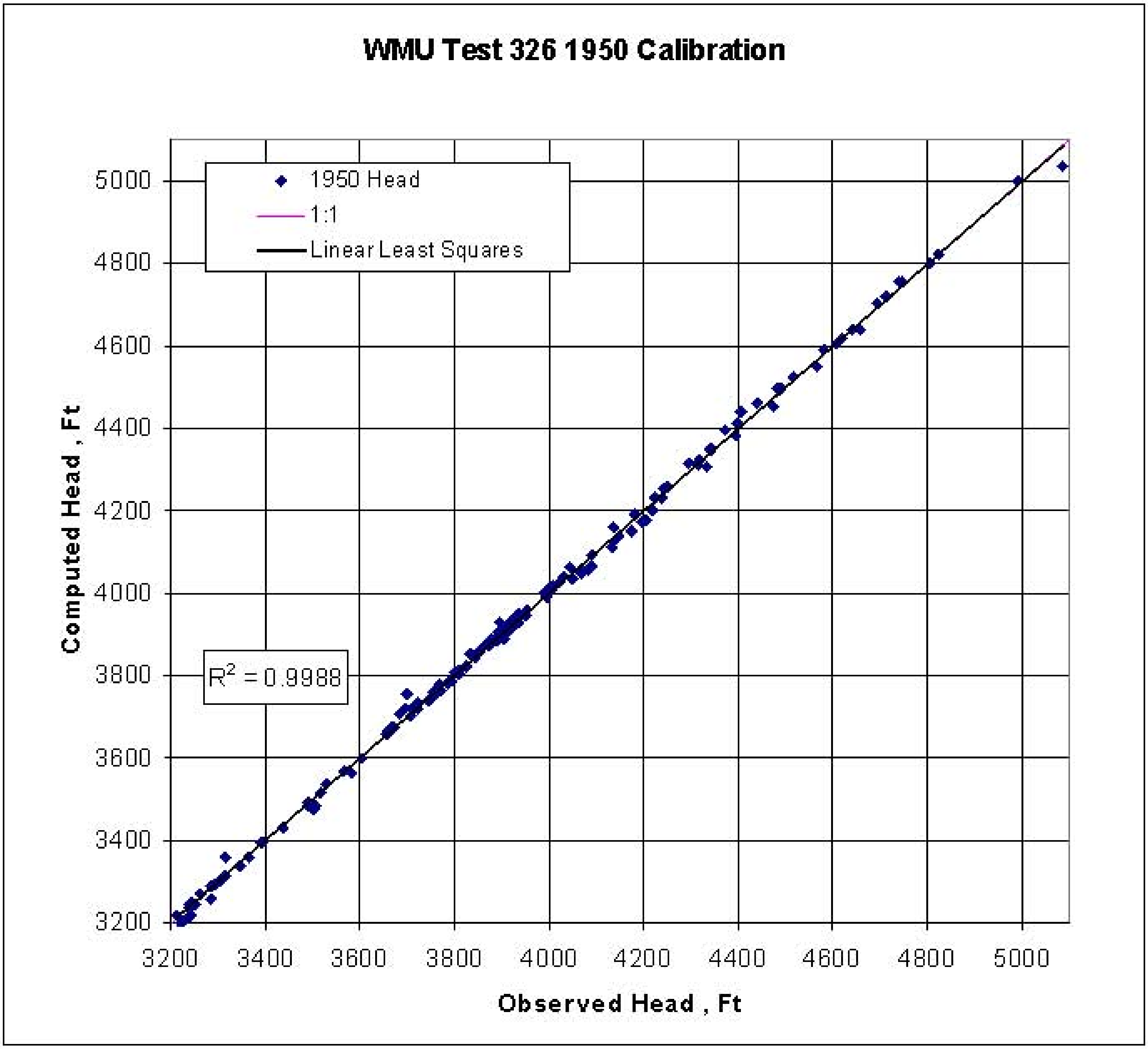
Central Model Unit Pre-Development Period Calibration Observed and Calculated Heads Measured Between 1946 and 1955.		
Date	Project Number	Approved:
8/22/05	13009.1	E.G.Lappala

Figure 3



Calibration Statistics	
No Points	145
Maximum Difference	54.93
Minimum Difference	(51.08)
Residual Mean	1.08
Absolute Residual Mean	10.62
Std Error of the Estimate	1.20
RMS	14.45
Normalized RMS	1%
Corr. Coefficient, R^2	0.9988

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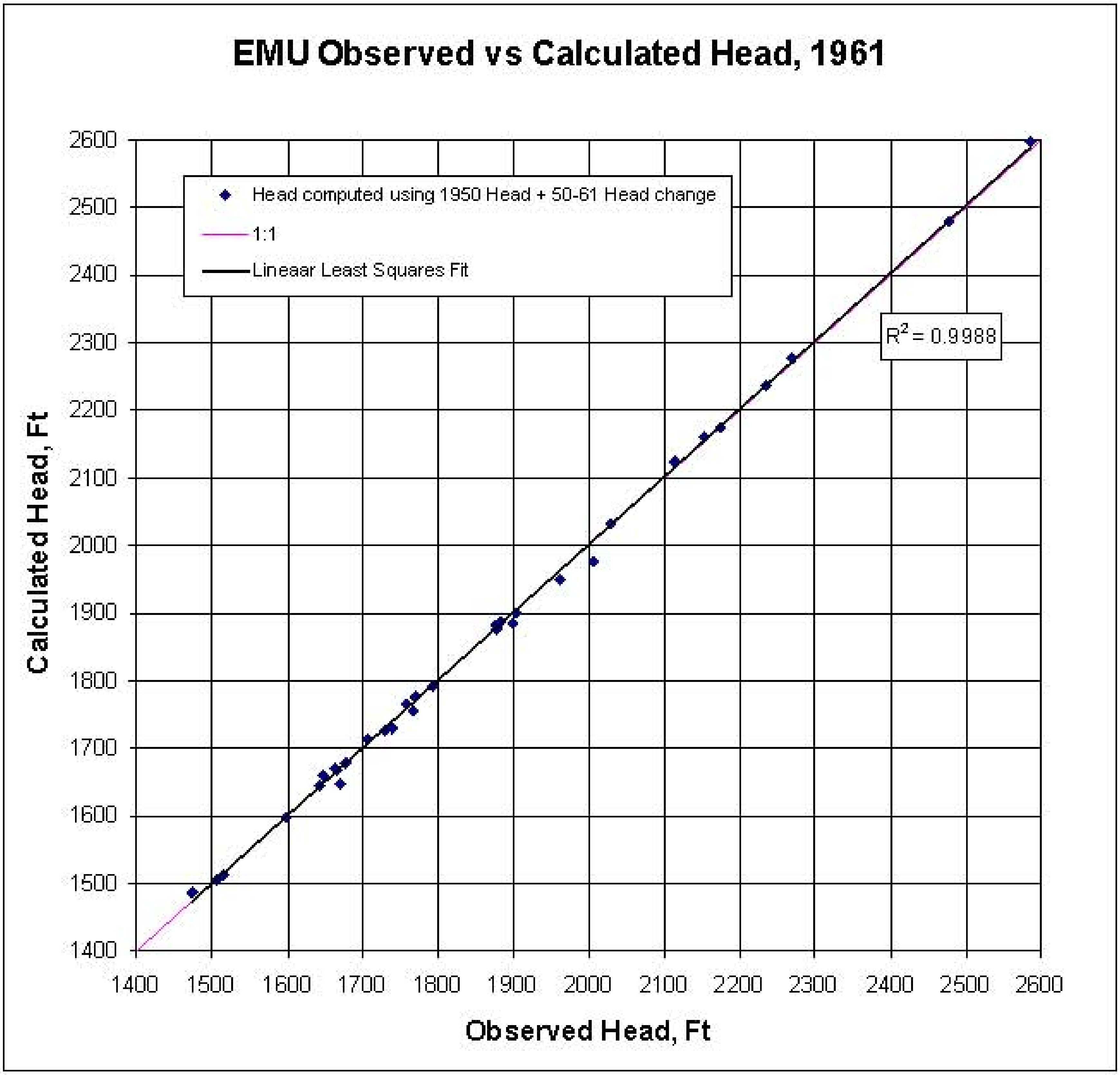
Western Model Unit Pre-Development Period Calibration
Observed and Calculated Heads
Measured Between 1946 and 1955.

Date	Project Number	Approved:
8/22/05	13009.1	E.G.Lappala

Figure 4



Calibration Statistics	
No Points	33
Maximum Difference	28.90
Minimum Difference	(13.69)
Residual Mean	0.19
Absolute Residual Mean	6.83
Std Error of the Estimate	1.67
RMS	9.43
Normalized RMS	1%
Corr. Coefficient, R^2	0.9988

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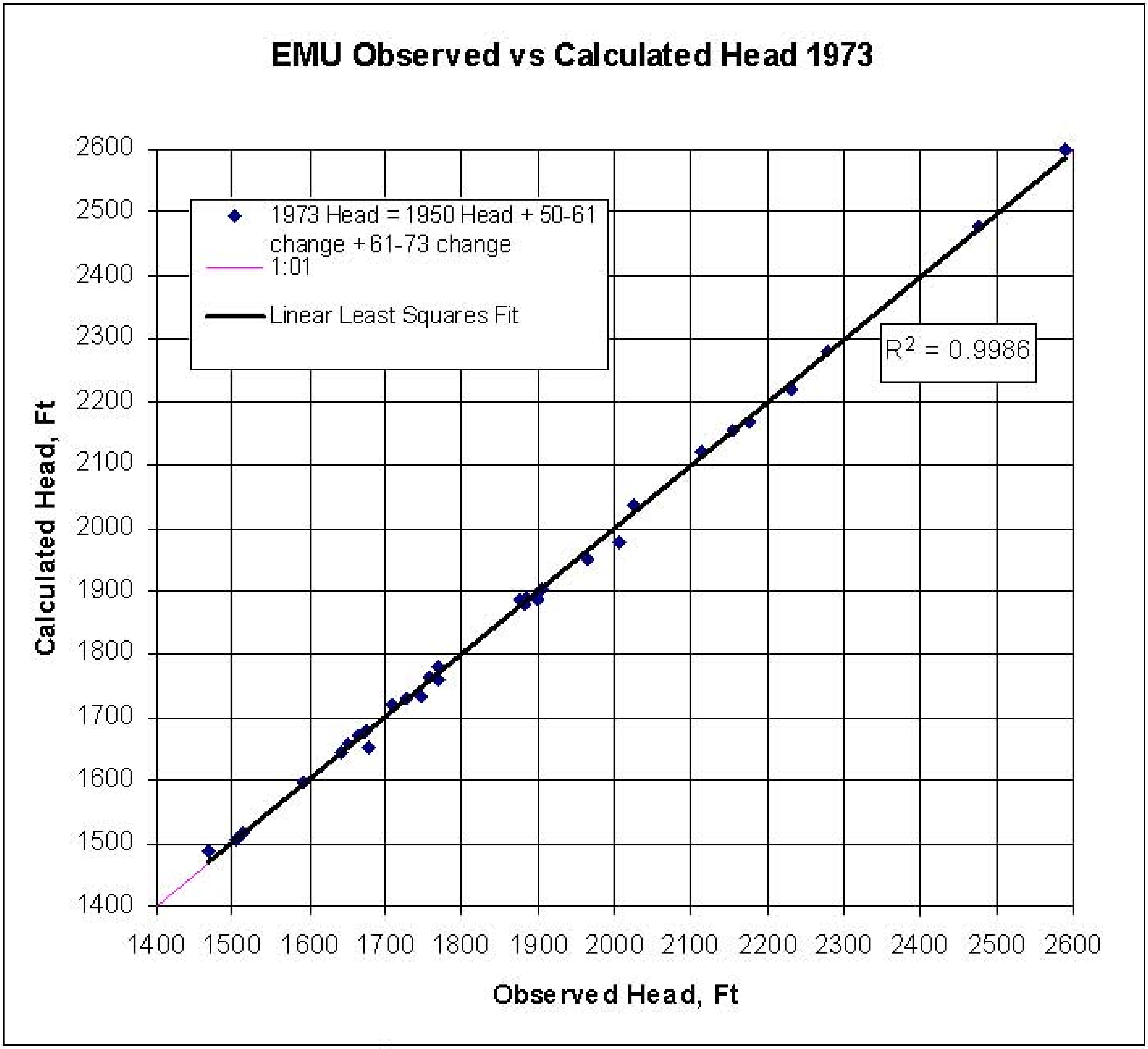
Eastern Model Unit Development Period Calibration Observed and Calculated Heads in 1961 (Computed as 1950 Head + 1950 to 1961 Head Change.)		
Date	Project Number	Approved:
8/22/05	13009.1	E.G.Lappala

Figure 5



Calibration Statistics	
No Points	31
Maximum Difference	20.07
Minimum Difference	(26.44)
Residual Mean	0.27
Absolute Residual Mean	8.16
Std Error of the Estimate	1.91
RMS	10.46
Normalized RMS	1%
Corr. Coefficient, R^2	0.9986

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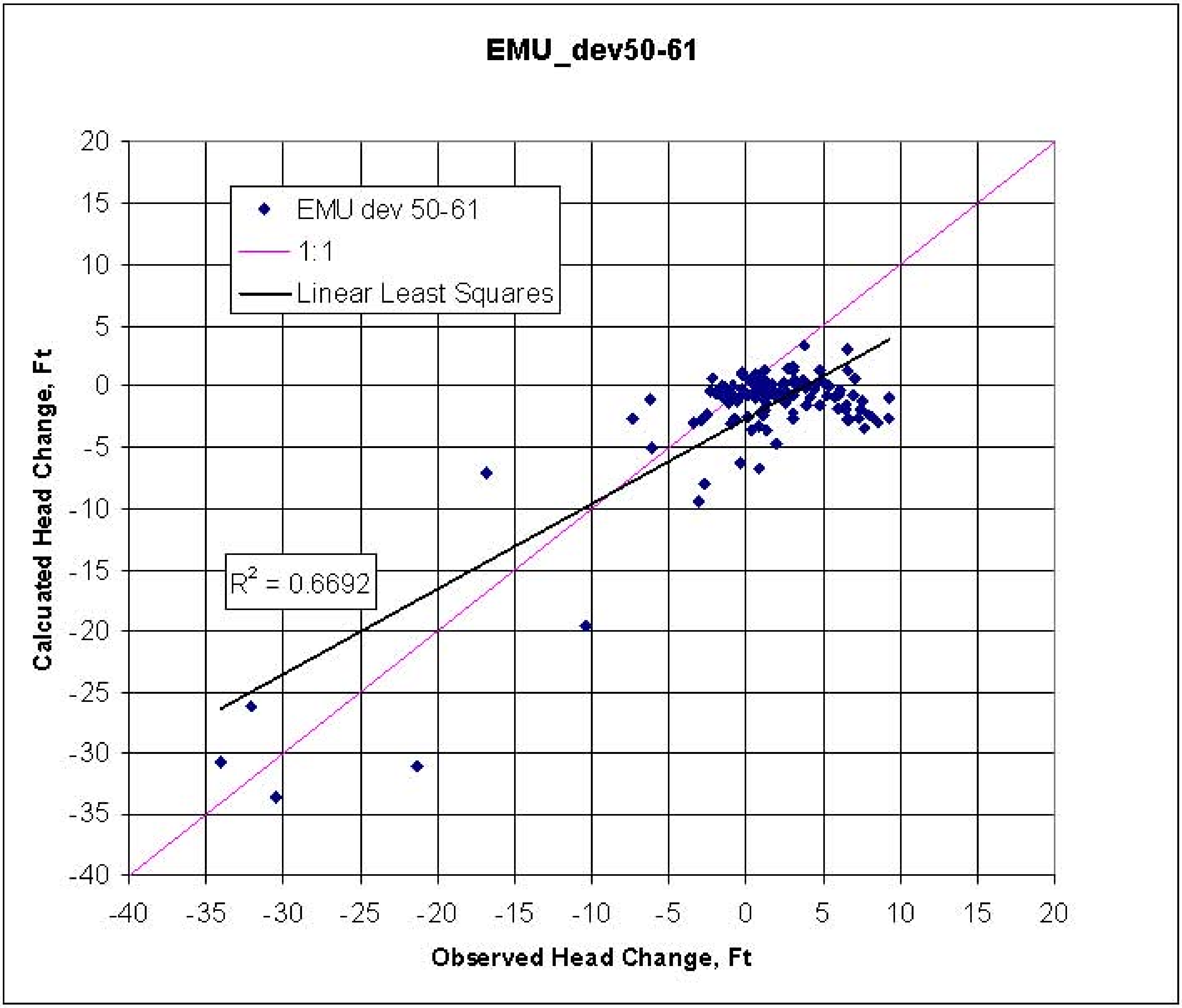
Eastern Model Unit Development Period Calibration Observed and Calculated Heads in 1973 (Computed as 1950 Head + 1950-61 Head Change + 1961-73 Head Change.)		
Date	Project Number	Approved:
8/22/05	13009.1	E.G.Lappala

Figure 6



Calibration Statistics	
No Points	131
Maximum Difference	9.84
Minimum Difference	(11.98)
Residual Mean	(2.92)
Absolute Residual Mean	3.74
Std Error of the Estimate	0.33
RMS	4.79
Normalized RMS	11%
Corr. Coefficient, R^2	0.6692

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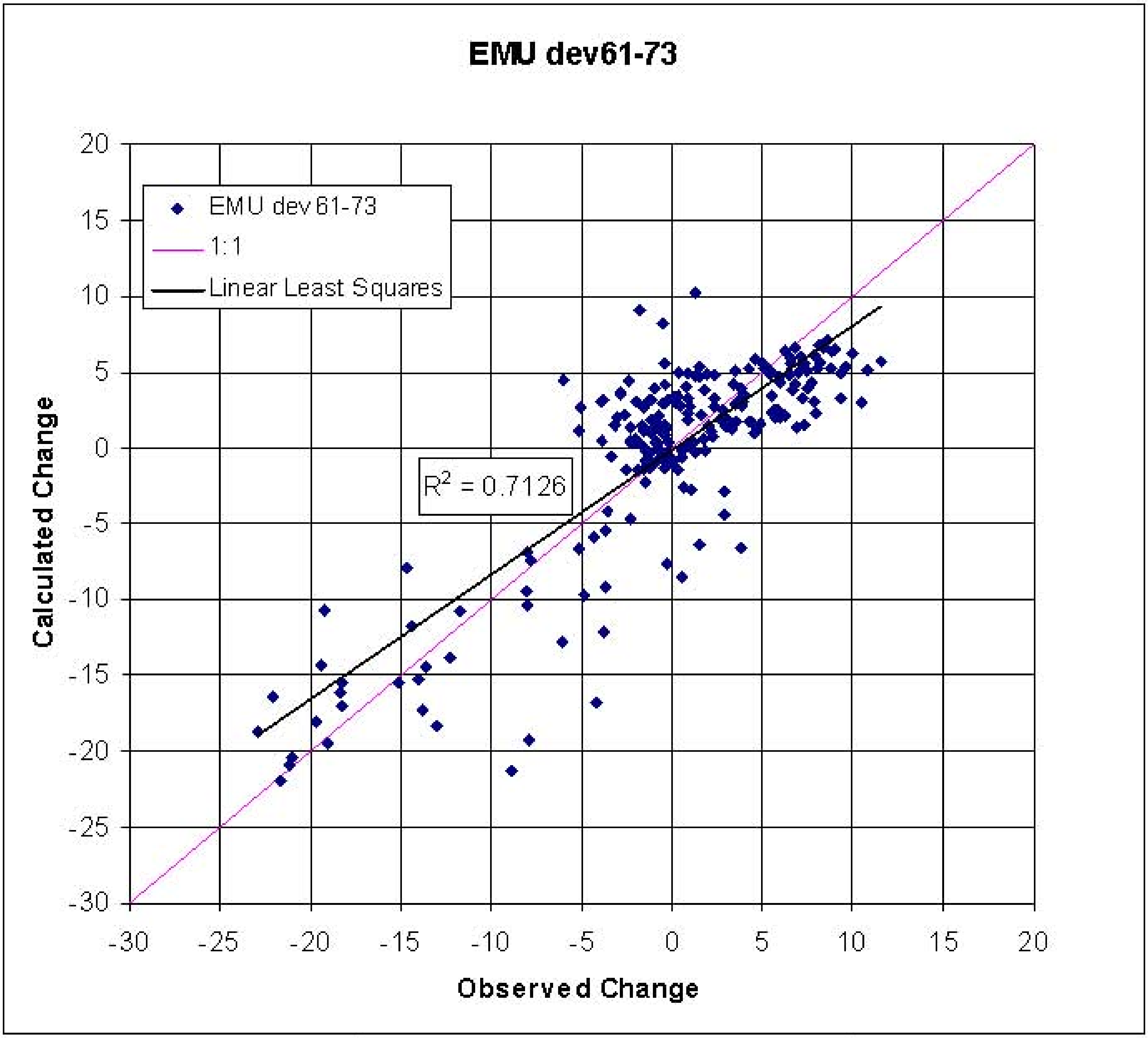
Eastern Model Unit Development Period Calibration Observed and Calculated Head Change Measured Between 1950 and 1961.		
Date	Project Number	Approved:
8/22/05	13009.1	E.G.Lappala

Figure 7



Calibration Statistics	
No Points	219
Maximum Difference	10.88
Minimum Difference	(12.64)
Residual Mean	(0.10)
Absolute Residual Mean	2.92
Std Error of the Estimate	0.26
RMS	3.85
Normalized RMS	11%
Corr. Coefficient, R^2	0.7126

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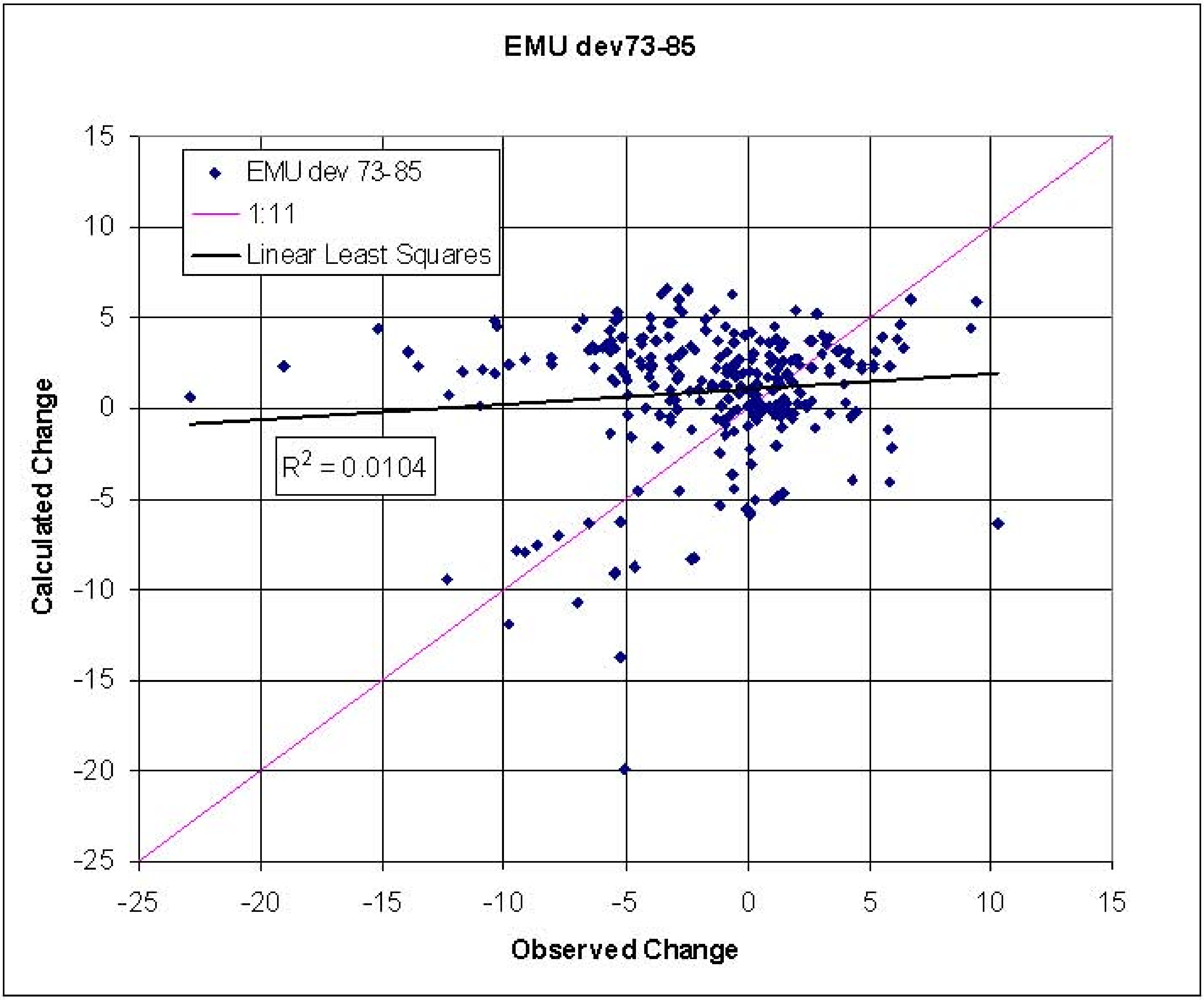
Eastern Model Unit Development Period Calibration Observed and Calculated Head Change Measured Between 1961 and 1973.		
Date	Project Number	Approved:
8/22/05	13009.1	E.G.Lappala

Figure 8



Calibration Statistics	
No Points	280
Maximum Difference	23.47
Minimum Difference	(16.64)
Residual Mean	2.26
Absolute Residual Mean	4.28
Std Error of the Estimate	0.33
RMS	5.91
Normalized RMS	18%
Corr. Coefficient, R^2	0.0104

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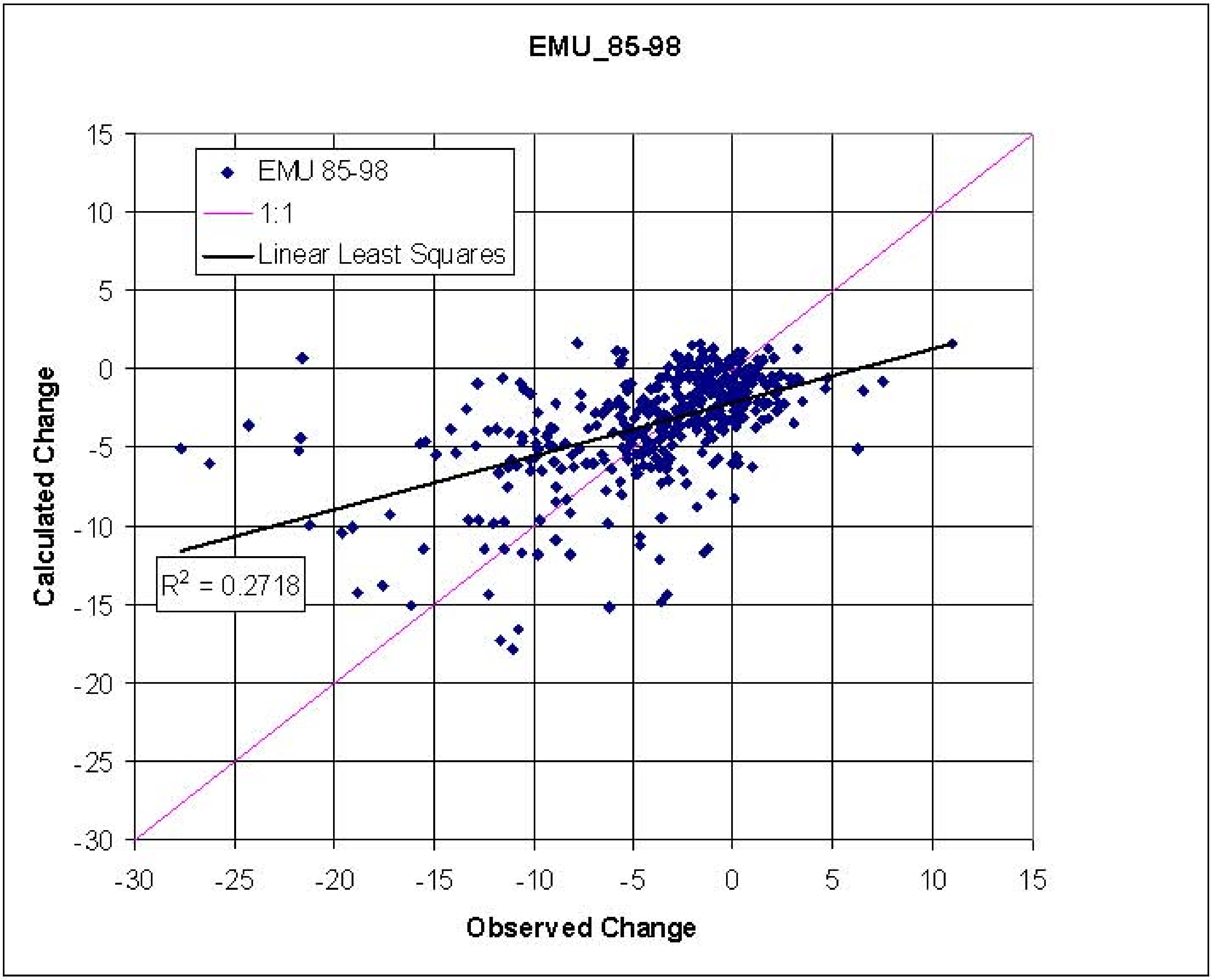
Eastern Model Unit Development Period Calibration Observed and Calculated Head Change Measured Between 1973 and 1985.		
Date	Project Number	Approved:
8/22/05	13009.1	E.G.Lappala

Figure 9



Calibration Statistics	
No Points	405
Maximum Difference	22.56
Minimum Difference	(11.22)
Residual Mean	0.45
Absolute Residual Mean	3.15
Std Error of the Estimate	0.23
RMS	4.56
Normalized RMS	12%
Corr. Coefficient, R^2	0.2718

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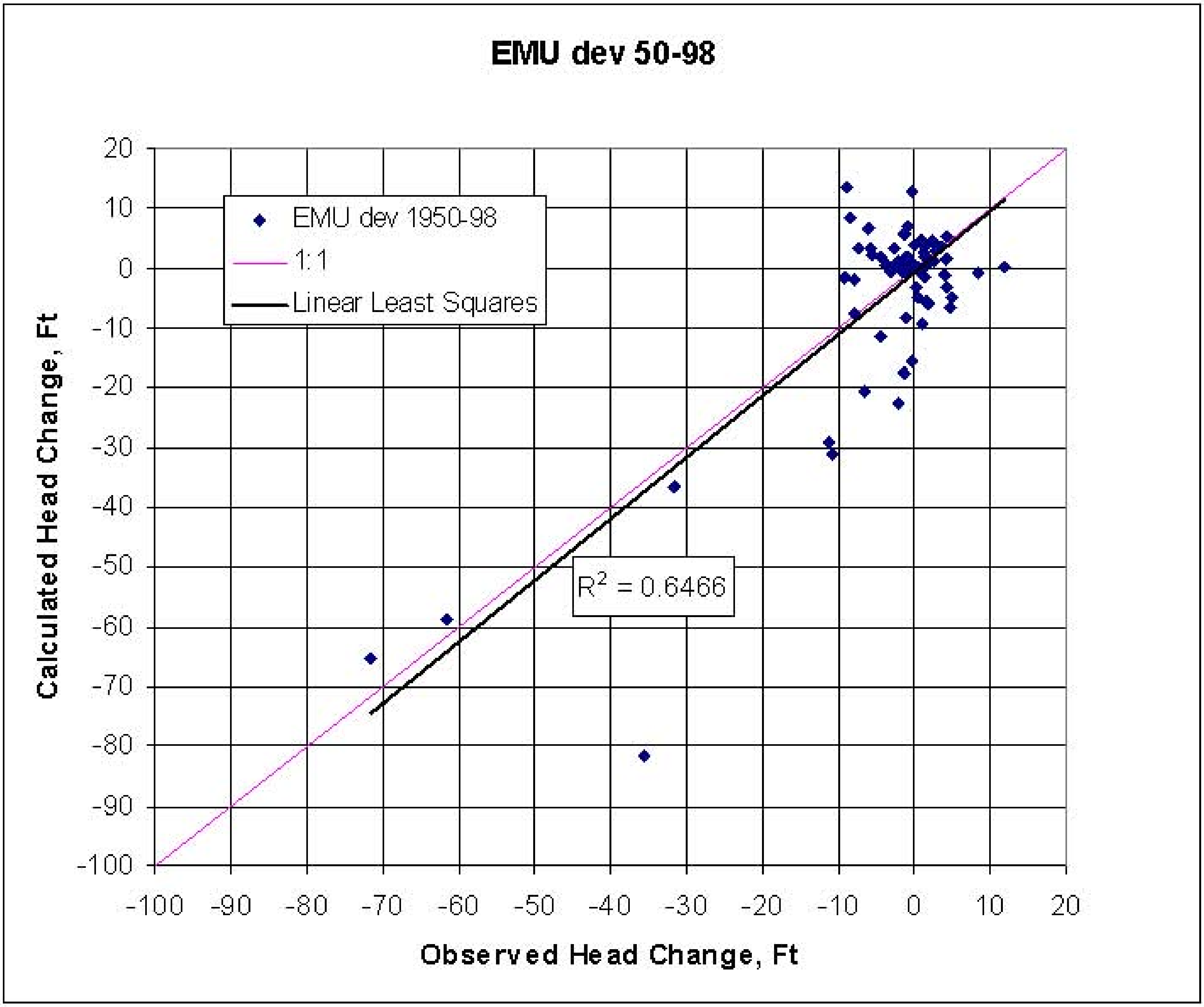
Eastern Model Unit Development Period Calibration Observed and Calculated Head Change Measured Between 1985 and 1998.		
Date	Project Number	Approved:
8/22/05	13009.1	E.G.Lappala

Figure 10



Calibration Statistics	
No Points	78
Maximum Difference	22.28
Minimum Difference	(46.10)
Residual Mean	(0.71)
Absolute Residual Mean	6.16
Std Error of the Estimate	1.06
RMS	9.36
Normalized RMS	11%
Corr. Coefficient, R^2	0.6466

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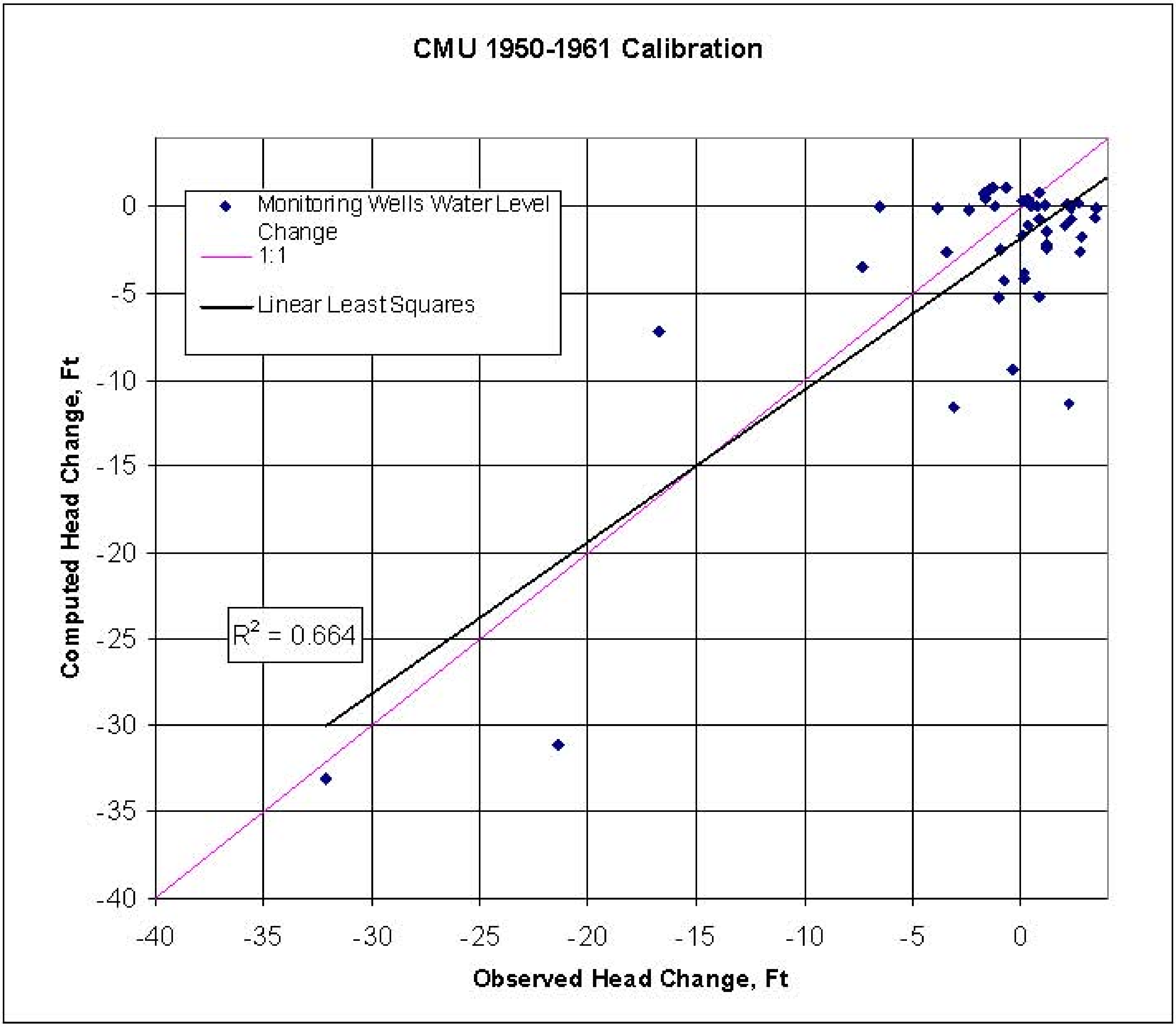
Eastern Model Unit Development Period Calibration Observed and Calculated Head Change Measured Between 1950 and 1998.		
Date	Project Number	Approved:
8/22/05	13009.1	E.G.Lappala

Figure 11



Calibration Statistics	
No Points	47
Maximum Difference	9.61
Minimum Difference	13.59
Residual Mean	(1.54)
Absolute Residual Mean	3.33
Std Error of the Estimate	0.64
RMS	4.37
Normalized RMS	12%
Corr. Coefficient, R^2	0.6640

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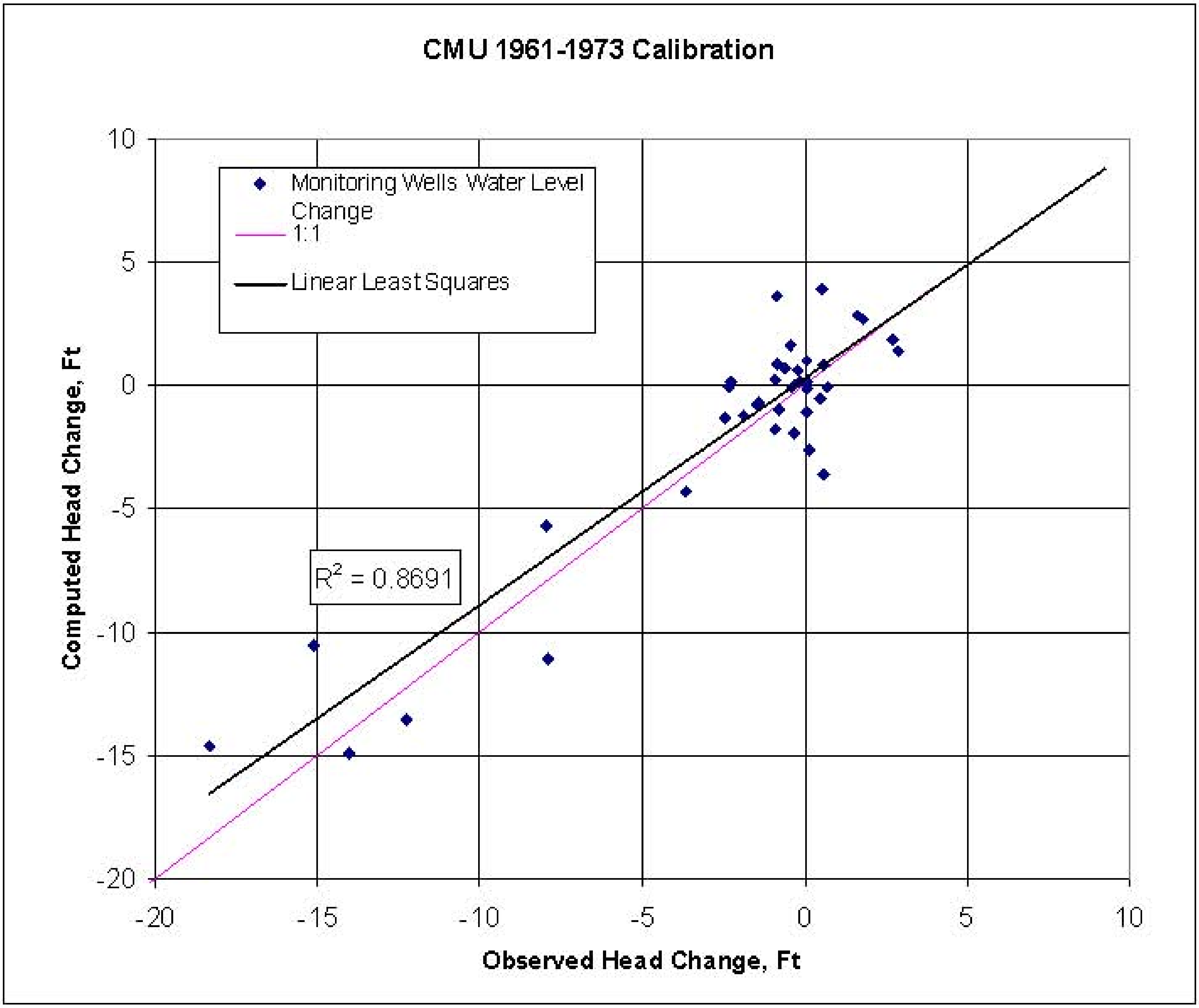
Central Model Unit Development Period Calibration Observed and Calculated Head Change Measured Between 1950 and 1961.		
Date	Project Number	Approved:
8/22/05	13009.1	E.G.Lappala

Figure 12



Calibration Statistics	
No Points	40
Maximum Difference	4.57
Minimum Difference	(4.16)
Residual Mean	0.43
Absolute Residual Mean	1.49
Std Error of the Estimate	0.31
RMS	1.92
Normalized RMS	7%
Corr. Coefficient, R^2	0.8691

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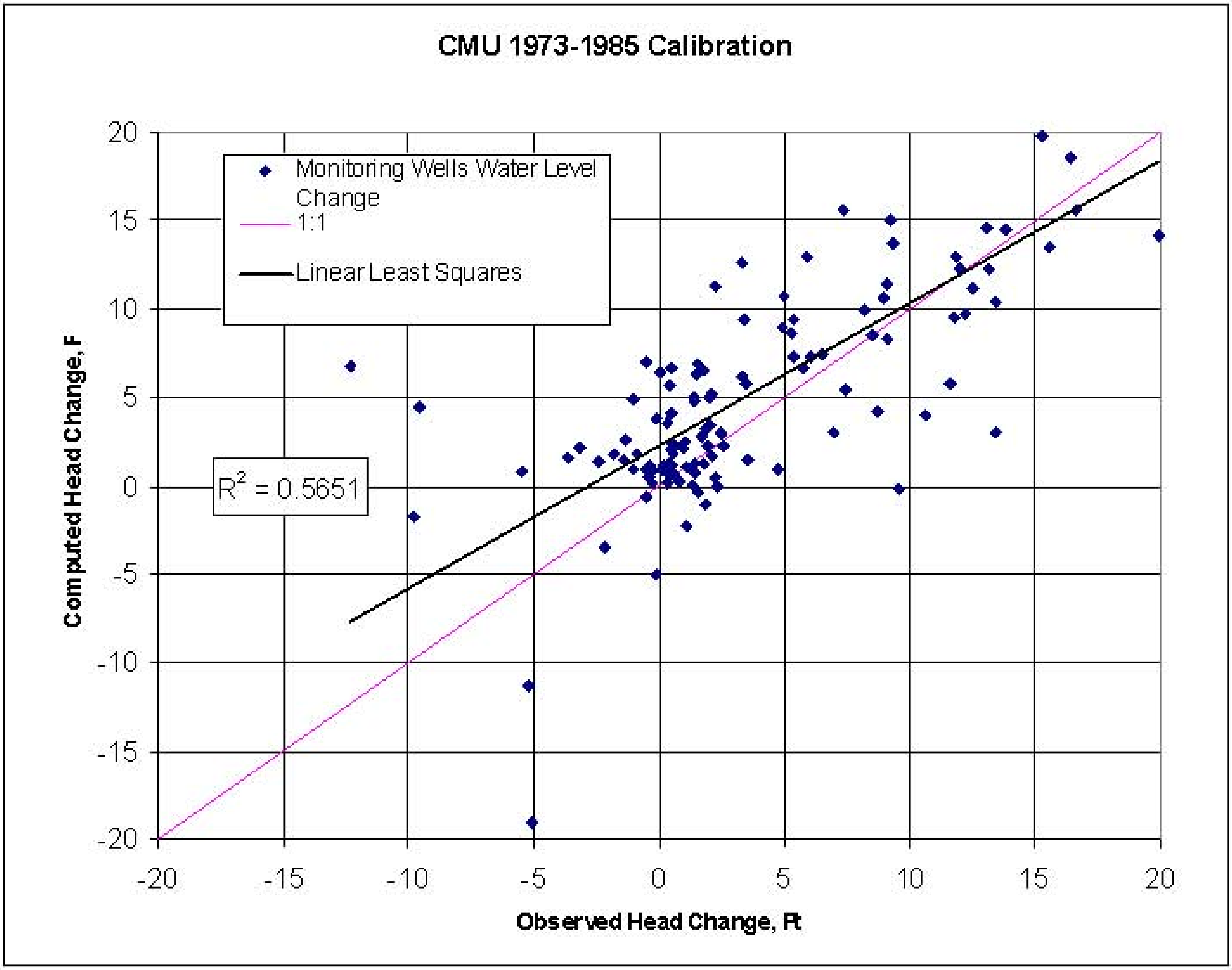
Central Model Unit Development Period Calibration Observed and Calculated Head Change Measured Between 1961 and 1973		
Date	Project Number	Approved:
8/22/05	13009.1	E.G.Lappala

Figure 13



Calibration Statistics	
No Points	122
Maximum Difference	19.07
Minimum Difference	(13.91)
Residual Mean	1.55
Absolute Residual Mean	3.38
Std Error of the Estimate	0.42
RMS	4.66
Normalized RMS	14%
Corr. Coefficient, R^2	0.5651

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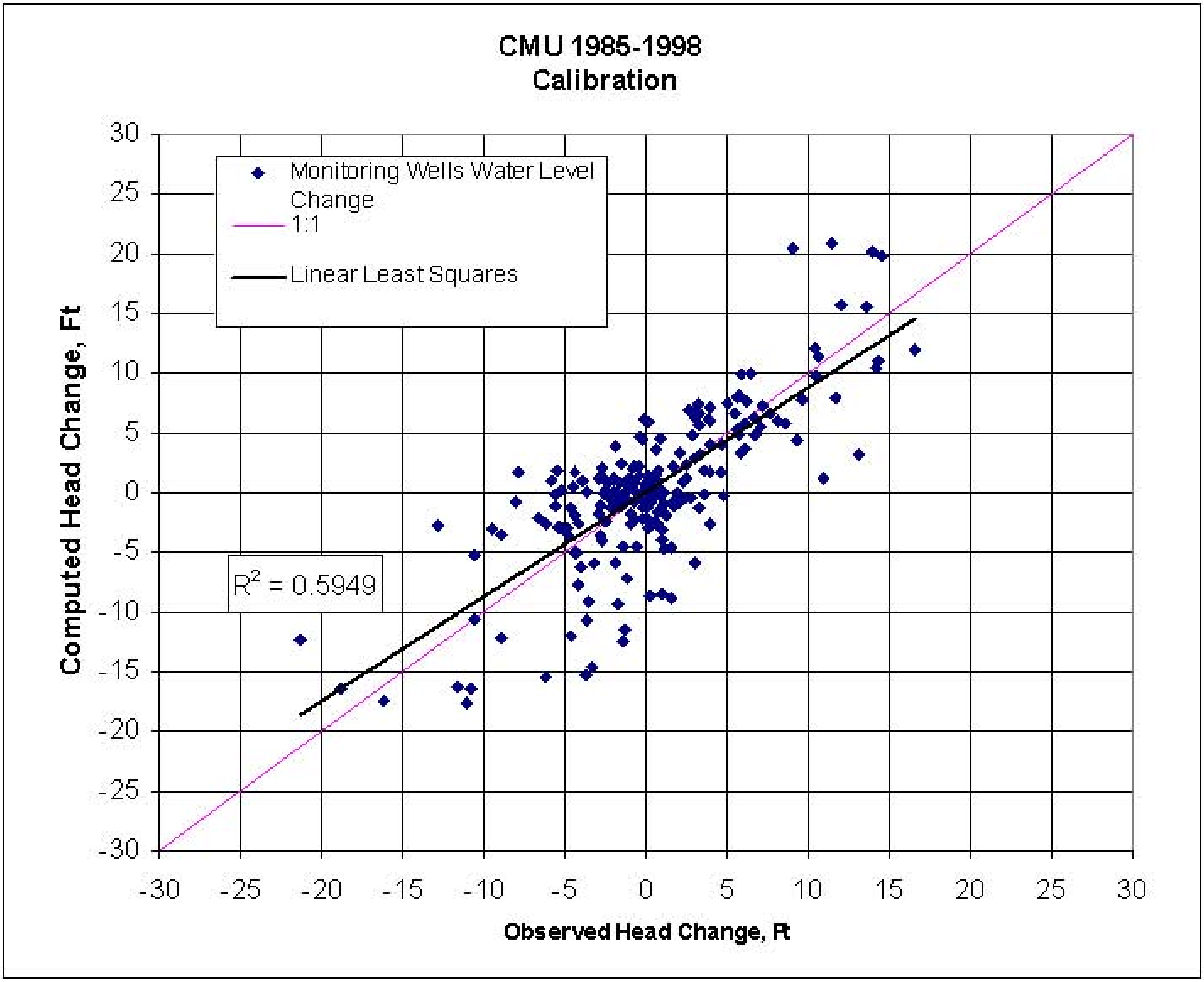
Central Model Unit Development Period Calibration
Observed and Calculated Head Change
Measured Between 1973 and 1985

Date	Project Number	Approved:
8/22/05	13009.1	E.G.Lappala

Figure 14



Calibration Statistics	
No Points	221
Maximum Difference	11.32
Minimum Difference	(11.61)
Residual Mean	(0.02)
Absolute Residual Mean	3.07
Std Error of the Estimate	0.27
RMS	4.06
Normalized RMS	11%
Corr. Coefficient, R^2	0.5949

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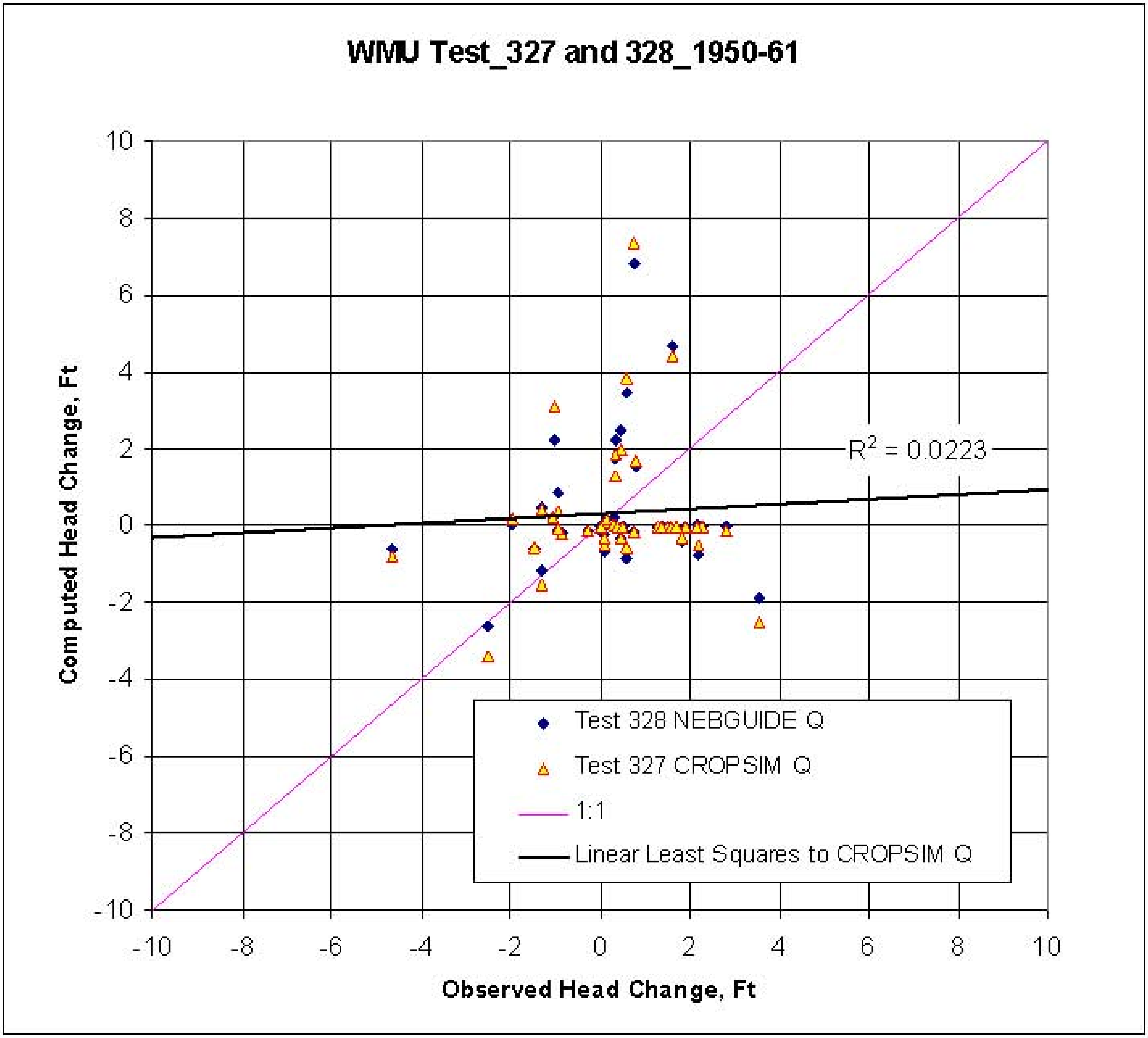
Central Model Unit Development Period Calibration Observed and Calculated Cead change measured Between 1985 and 1998		
Date	Project Number	Approved:
8/22/05	13009.1	E.G.Lappala

Figure 15

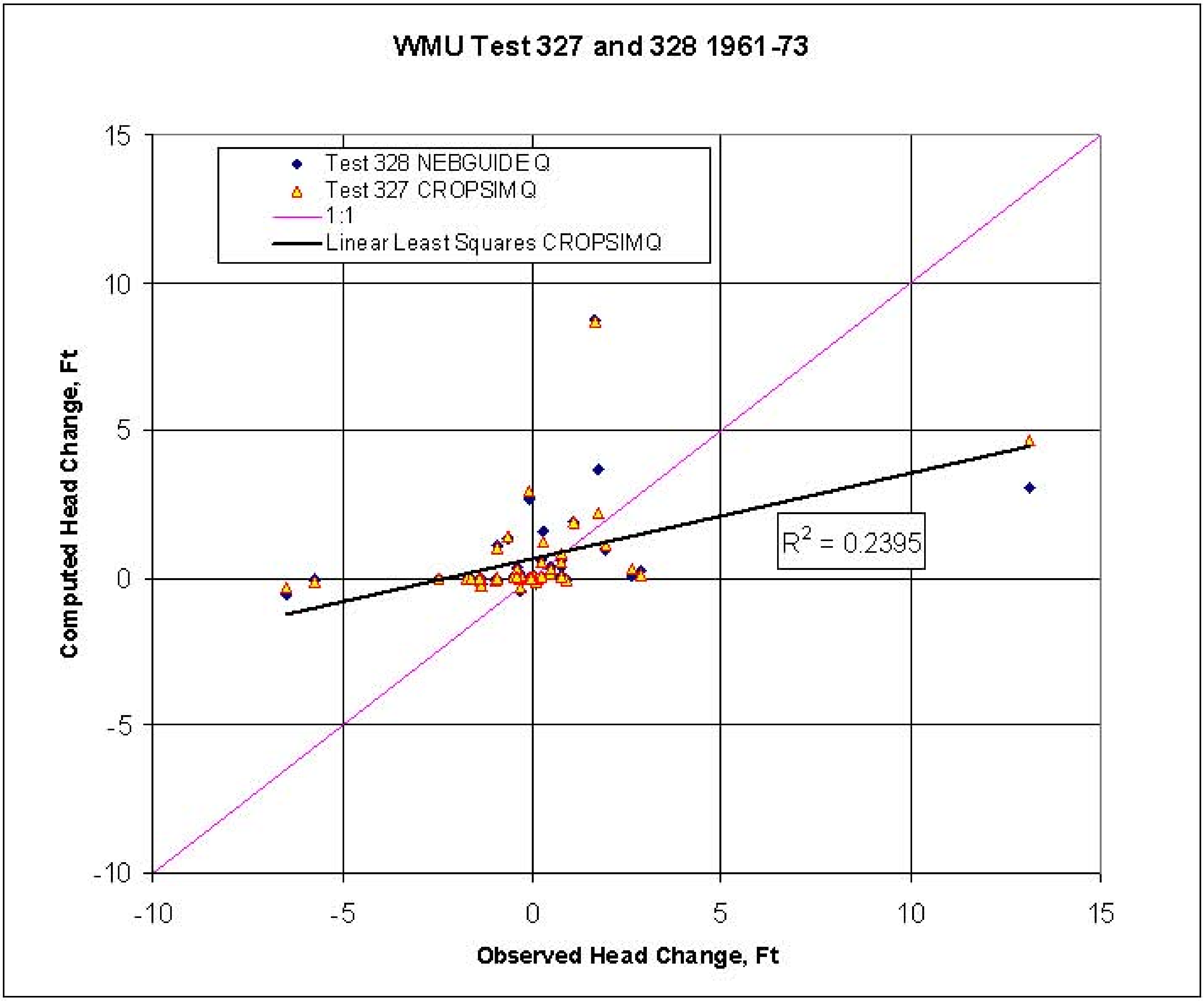


Calibration Statistics		
	NEBGUIDE Q	CROPSIM Q
No Points	45	45
Maximum Difference	10.57	10.46
Minimum Difference	(23.42)	(22.24)
Residual Mean	(0.28)	(0.29)
Absolute Residual Mean	2.30	2.28
Std Error of the Estimate	0.65	0.81
RMS	4.34	4.23
Normalized RMS	13%	12%
Corr. Coefficient, R^2	0.0033	0.0223

Eagle Resources
Advocacy → Sound Science → Innovation → Solutions

Western Model Unit Development Period Calibration Observed and Calculated Head Change Measured Between 1951 and 1961.		
Date	Project Number	Approved:
8/22/05	13009.1	E.G.Lappala

Figure 17

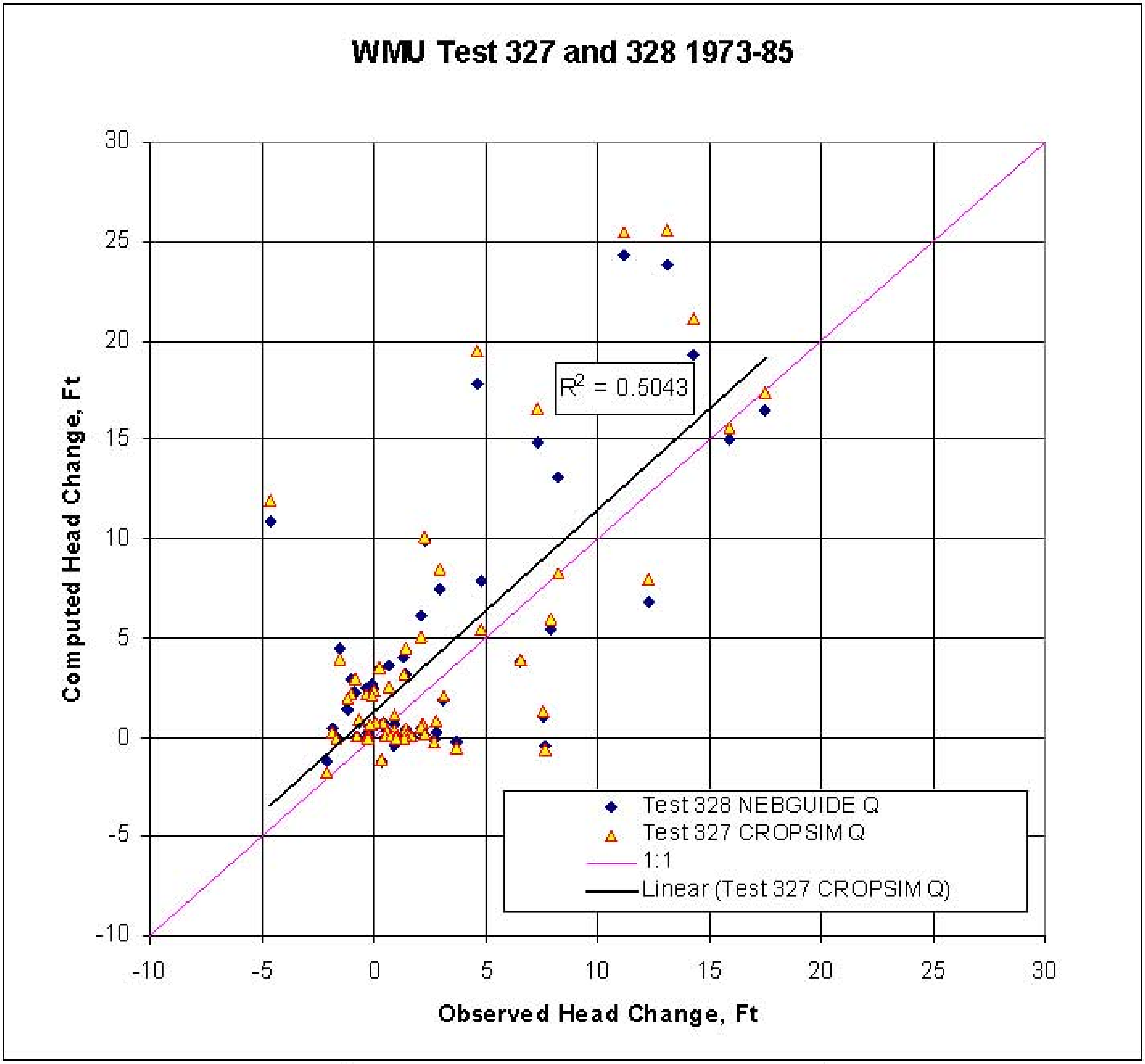


Calibration Statistics		
	NEBGUIDE Q	CROPSIM Q
No Points	42	42
Maximum Difference	13.13	7.03
Minimum Difference	(6.48)	(8.49)
Residual Mean	0.60	0.61
Absolute Residual Mean	1.54	1.46
Std Error of the Estimate	0.39	0.37
RMS	2.57	2.42
Normalized RMS	13%	12%
Corr. Coefficient, R^2	0.1578	0.2395

Eagle Resources
Advocacy → Sound Science → Innovation → Solutions

Western Model Unit Development Period Calibration Observed and Calculated Head Change Measured Between 1961 and 1973		
Date	Project Number	Approved:
8/22/05	13009.1	E.G.Lappala

Figure 18

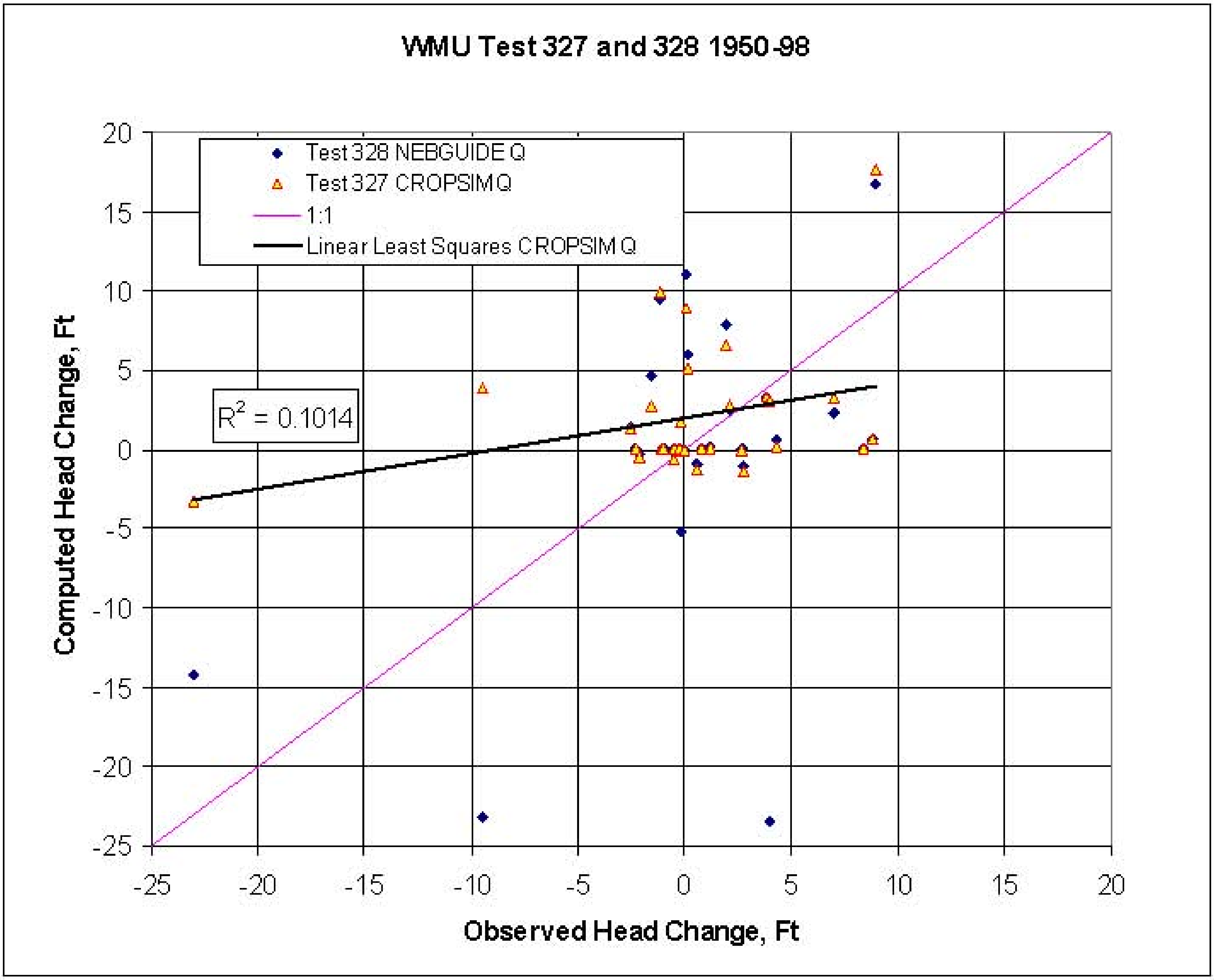


Calibration Statistics		
	NEBGUIDE Q	CROPSIM Q
No Points	61	61
Maximum Difference	15.51	16.62
Minimum Difference	(8.08)	8.26
Residual Mean	1.23	1.32
Absolute Residual Mean	3.13	3.05
Std Error of the Estimate	0.56	0.60
RMS	4.53	4.80
Normalized RMS	21%	22%
Corr. Coefficient, R^2	0.5075	0.5043

Eagle Resources
Advocacy → Sound Science → Innovation → Solutions

Western Model Unit Development Period Calibration Observed and Calculated Head Change Measured Between 1973 and 1985		
Date	Project Number	Approved:
8/22/05	13009.1	E.G.Lappala

Figure 19

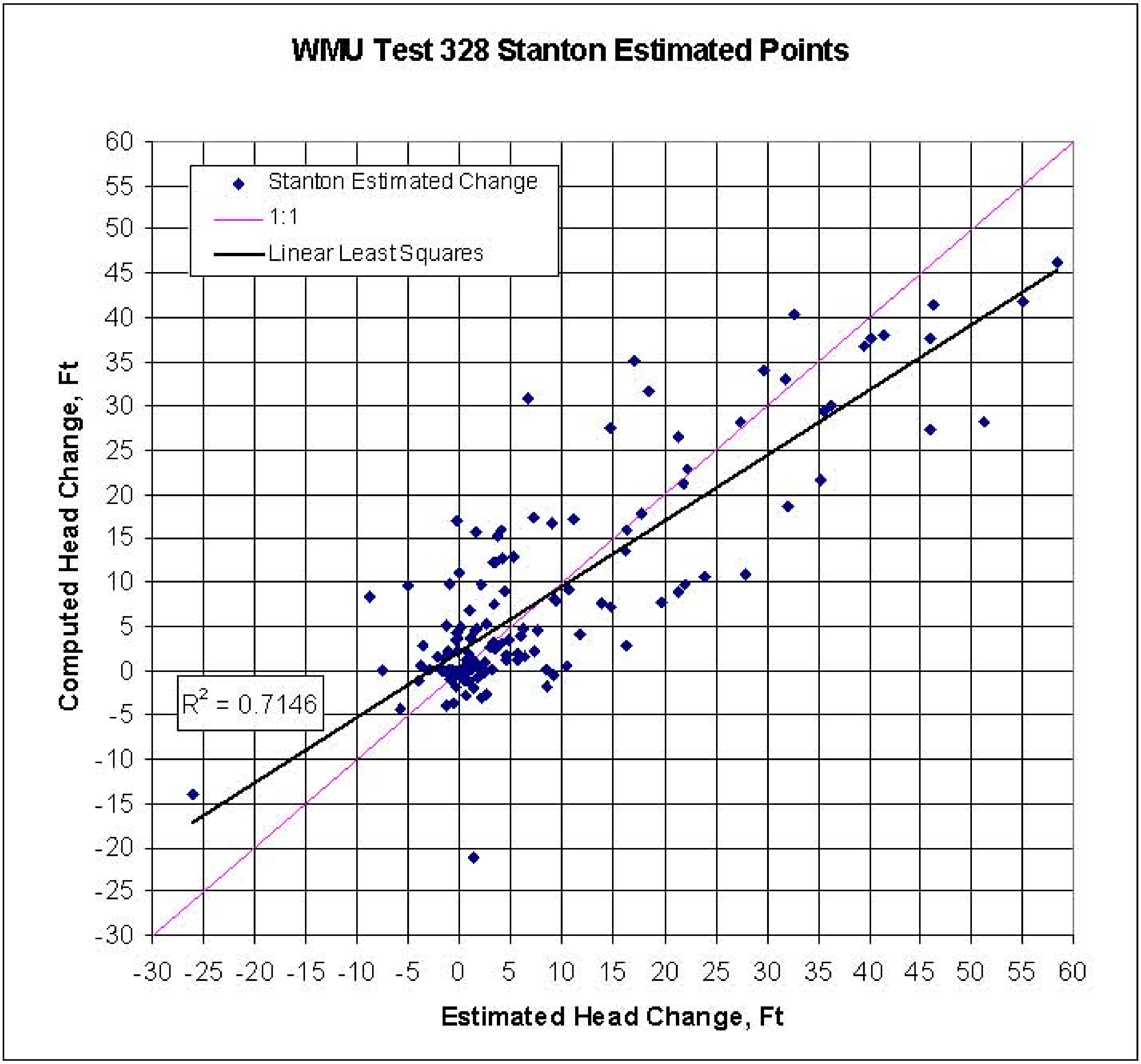


Calibration Statistics		
	NEBGUIDE Q	CROPSIM Q
No Points	31	31
Maximum Difference	8.99	19.68
Minimum Difference	(23.00)	(22.24)
Residual Mean	(0.42)	1.71
Absolute Residual Mean	4.82	4.06
Std Error of the Estimate	1.34	1.18
RMS	7.34	6.05
Normalized RMS	23%	17%
Corr. Coefficient, R^2	0.2132	0.1014

Eagle Resources
Advocacy → Sound Science → Innovation → Solutions

Western Model Unit Development Period Calibration Observed and Calculated Head Change Measured Between 1950 and 1998		
Date	Project Number	Approved:
8/22/05	13009.1	E.G.Lappala

Figure 20

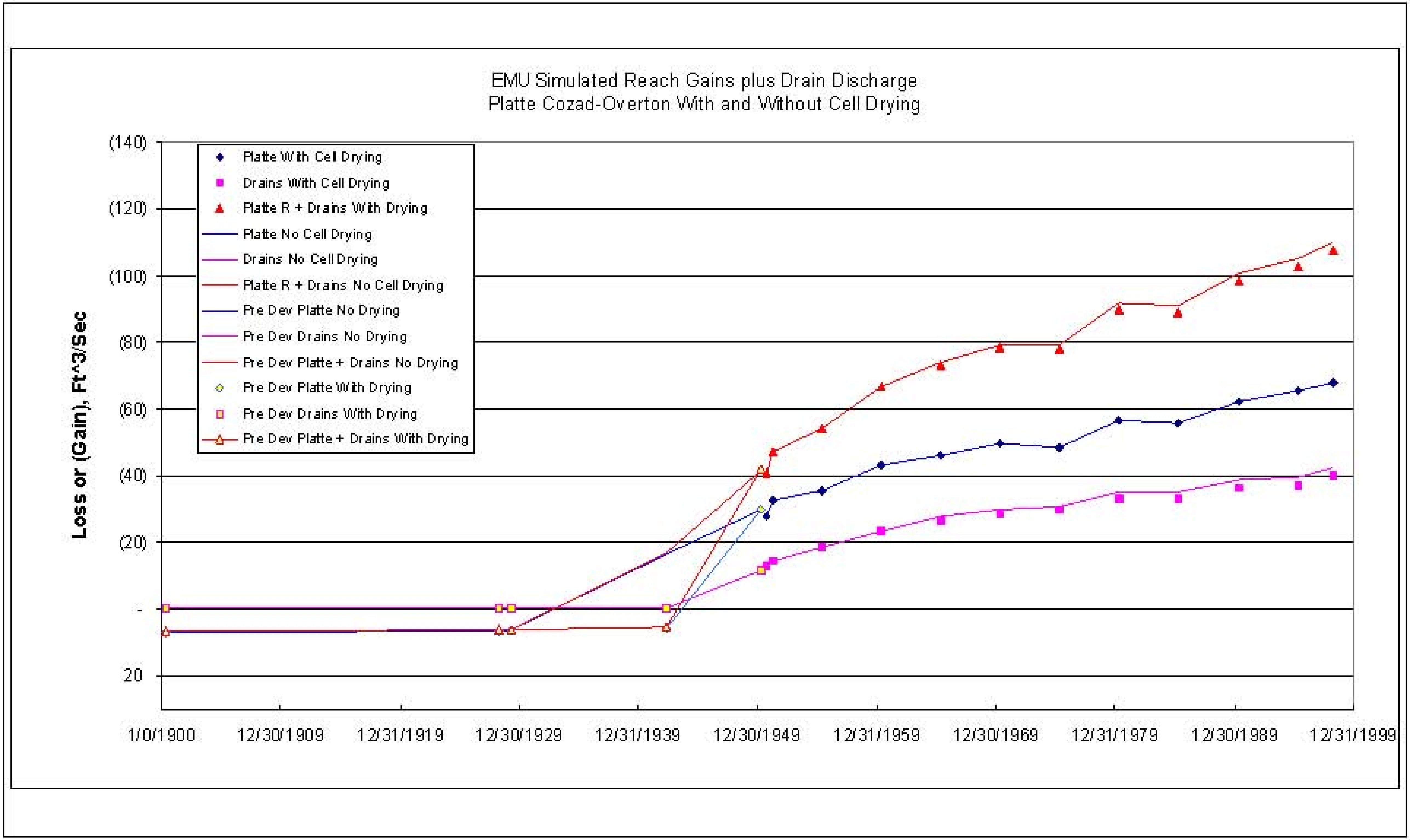


Calibration Statistics	
No Points	145
Maximum Difference	58.45
Minimum Difference	(26.10)
Residual Mean	0.05
Absolute Residual Mean	5.26
Std Error of the Estimate	0.63
RMS	7.50
Normalized RMS	9%
Corr. Coefficient, R^2	0.7146

Eagle Resources
Advocacy → Sound Science → Innovation → Solutions

Western Model Unit Development Period Calibration Estimated and Calculated Head Change1950-1998		
Date	Project Number	Approved:
8/22/05	13009.1	E.G.Lappala

Figure 21



Eastern Model Unit Platte River Cozad to Overton Changes in Simulated Stream and River Reach Gains		
Date	Project Number	Approved:
8/21/05	13009.1	E.G.Lappala

Figure 22

Eagle Resources
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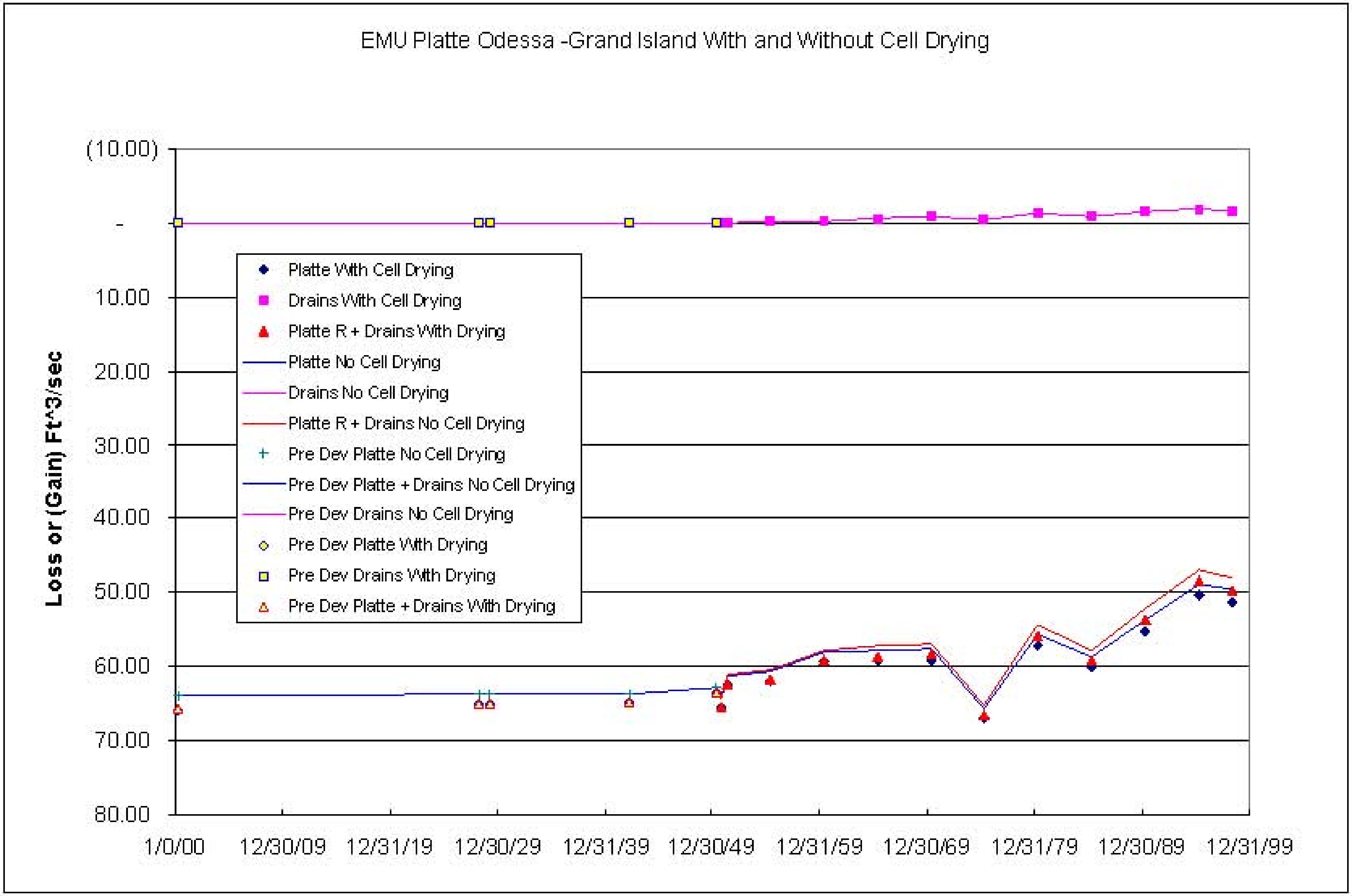
Eagle Resources
Advocacy → Sound Science → Innovation → Solutions

Eastern Model Unit Platte River Overton to Odessa Changes in Simulated Stream and River Reach Gains		
Date	Project Number	Approved:
8/21/05	13009.1	E.G.Lappala

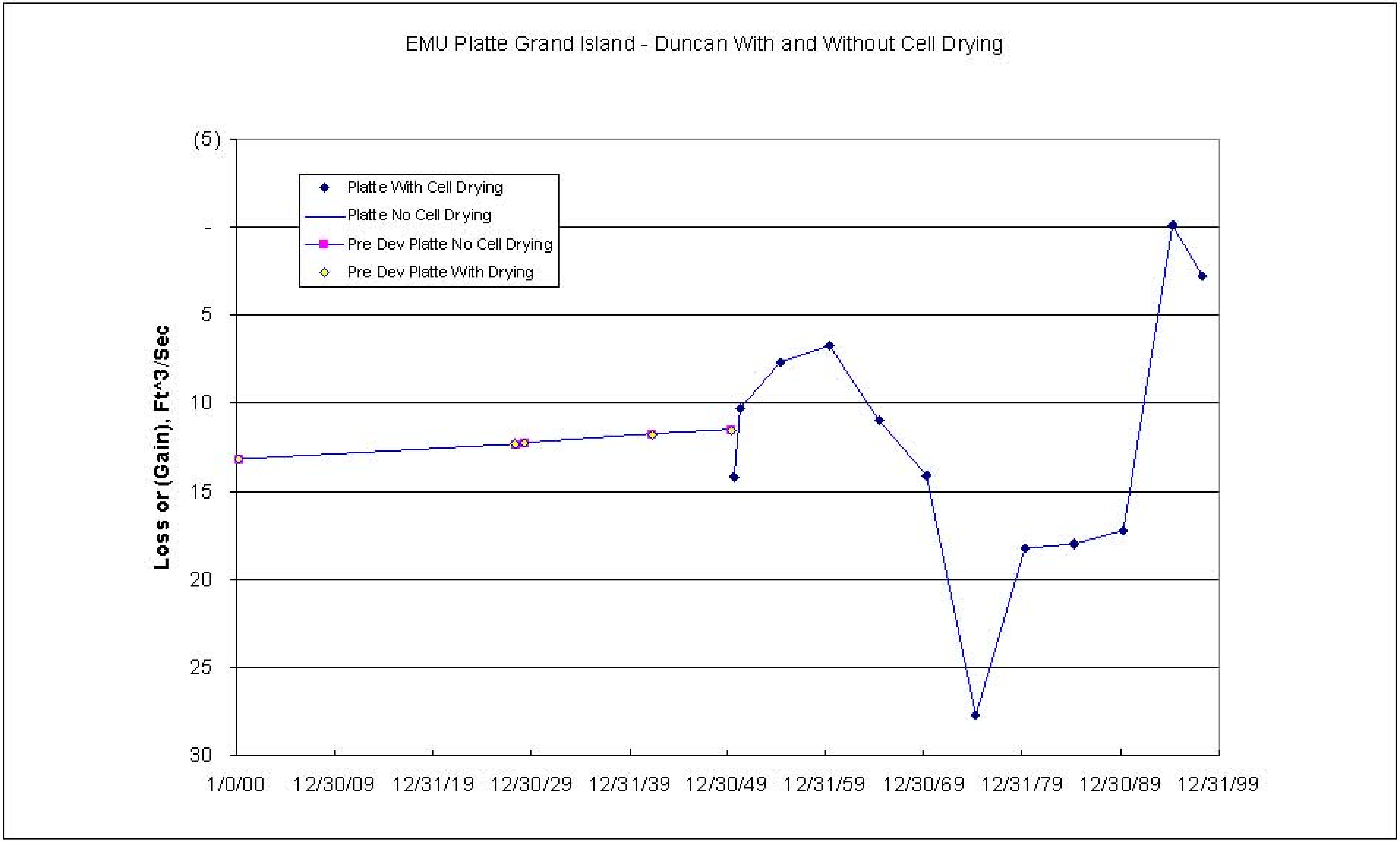
Figure 23



Eagle Resources
Advocacy → Sound Science → Innovation → Solutions

Eastern Model Unit Platte River Odessa to Grand Island Changes in Simulated Stream and River Reach Gains		
Date	Project Number	Approved:
8/21/05	13009.1	E.G.Lappala

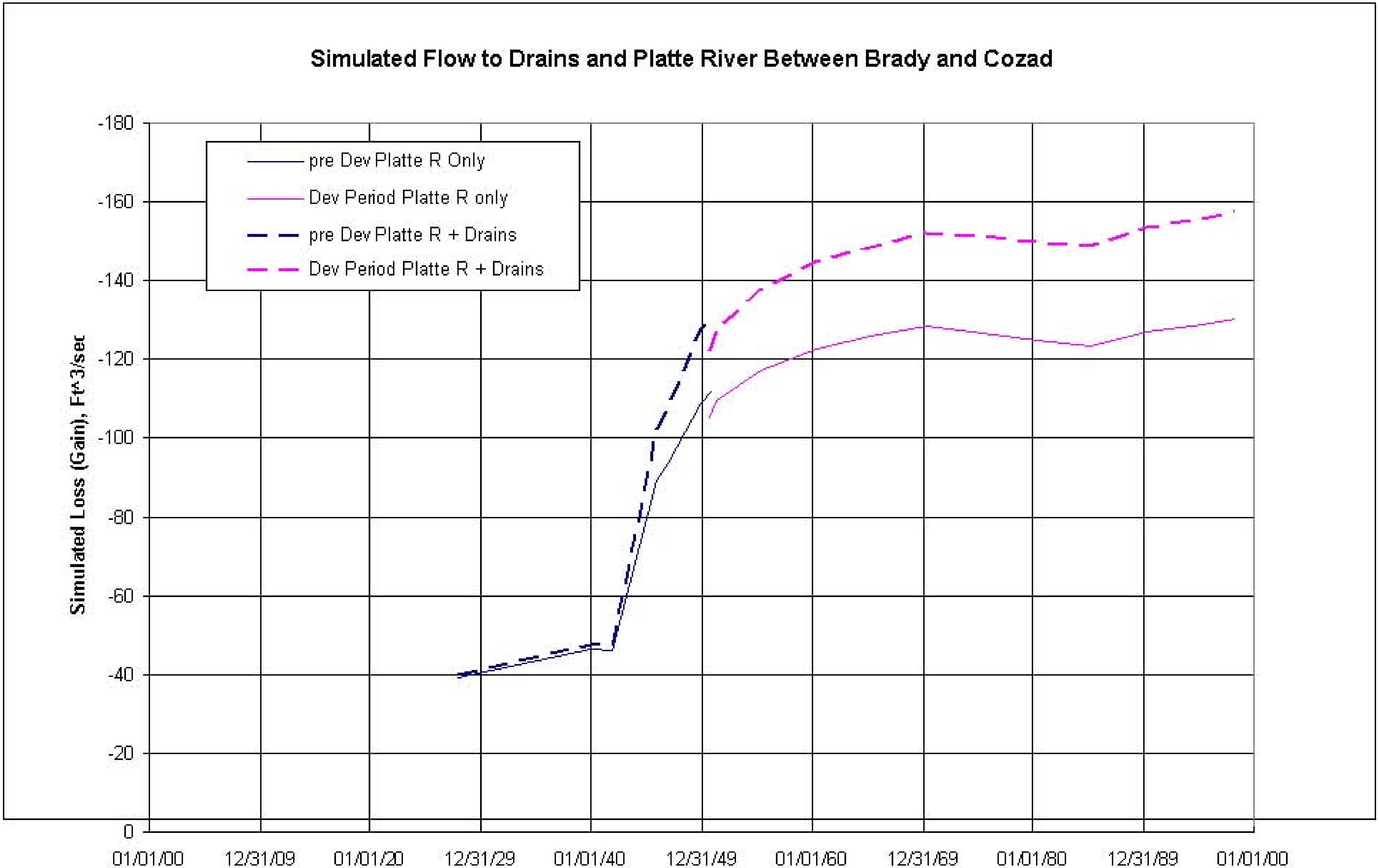
Figure 24



Eagle Resources
Advocacy → Sound Science → Innovation → Solutions

Eastern Model Unit Platte River Grand Island to Duncan Changes in Simulated Stream and River Reach Gains		
Date	Project Number	Approved:
8/21/05	13009.1	E.G.Lappala

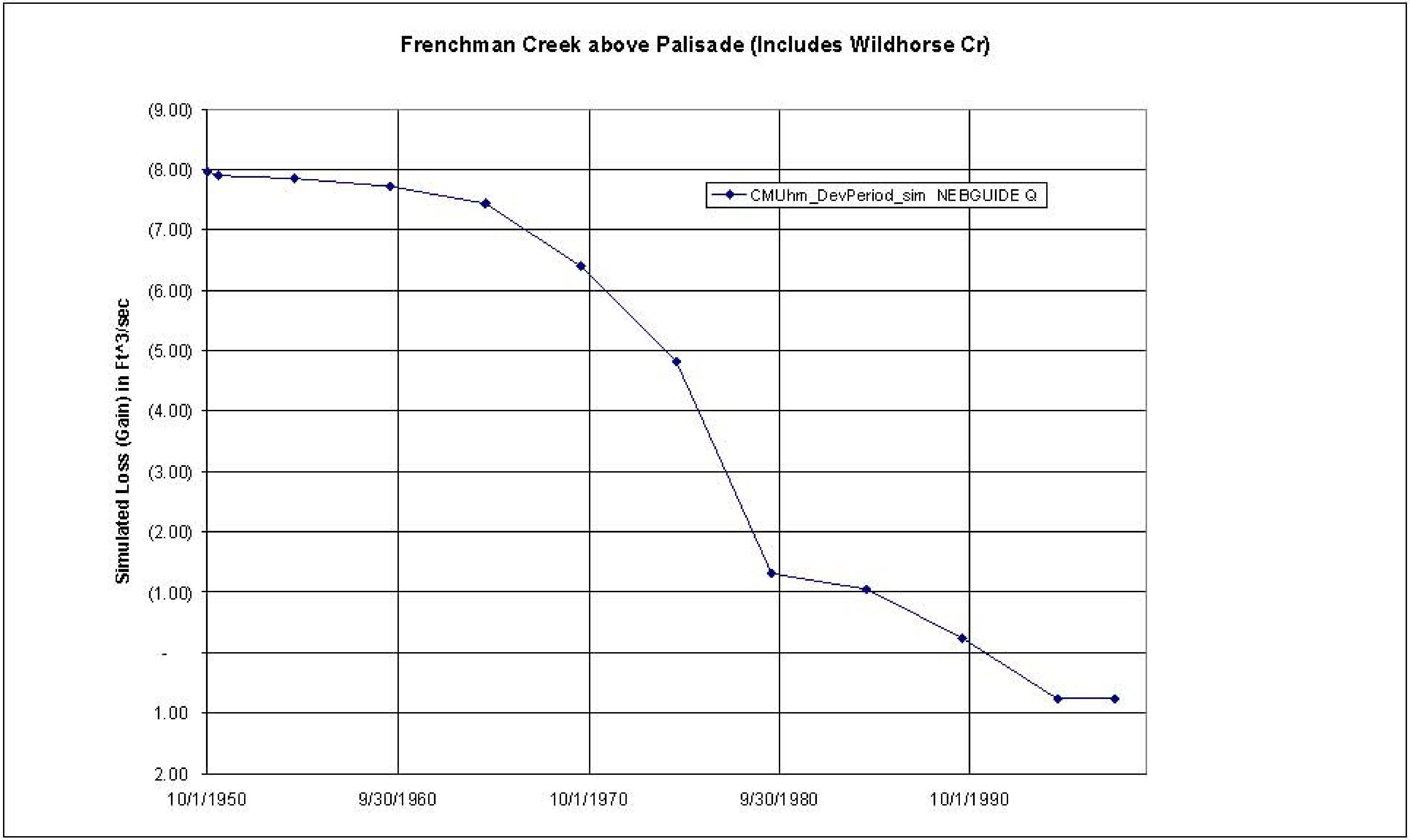
Figure 25



Eagle Resources
Advocacy → Sound Science → Innovation → Solutions

Central Model Unit Platte River Brady to Cozad Changes in Simulated Stream and River Reach Gains		
Date	Project Number	Approved:
8/21/05	13009.1	E.G.Lappala

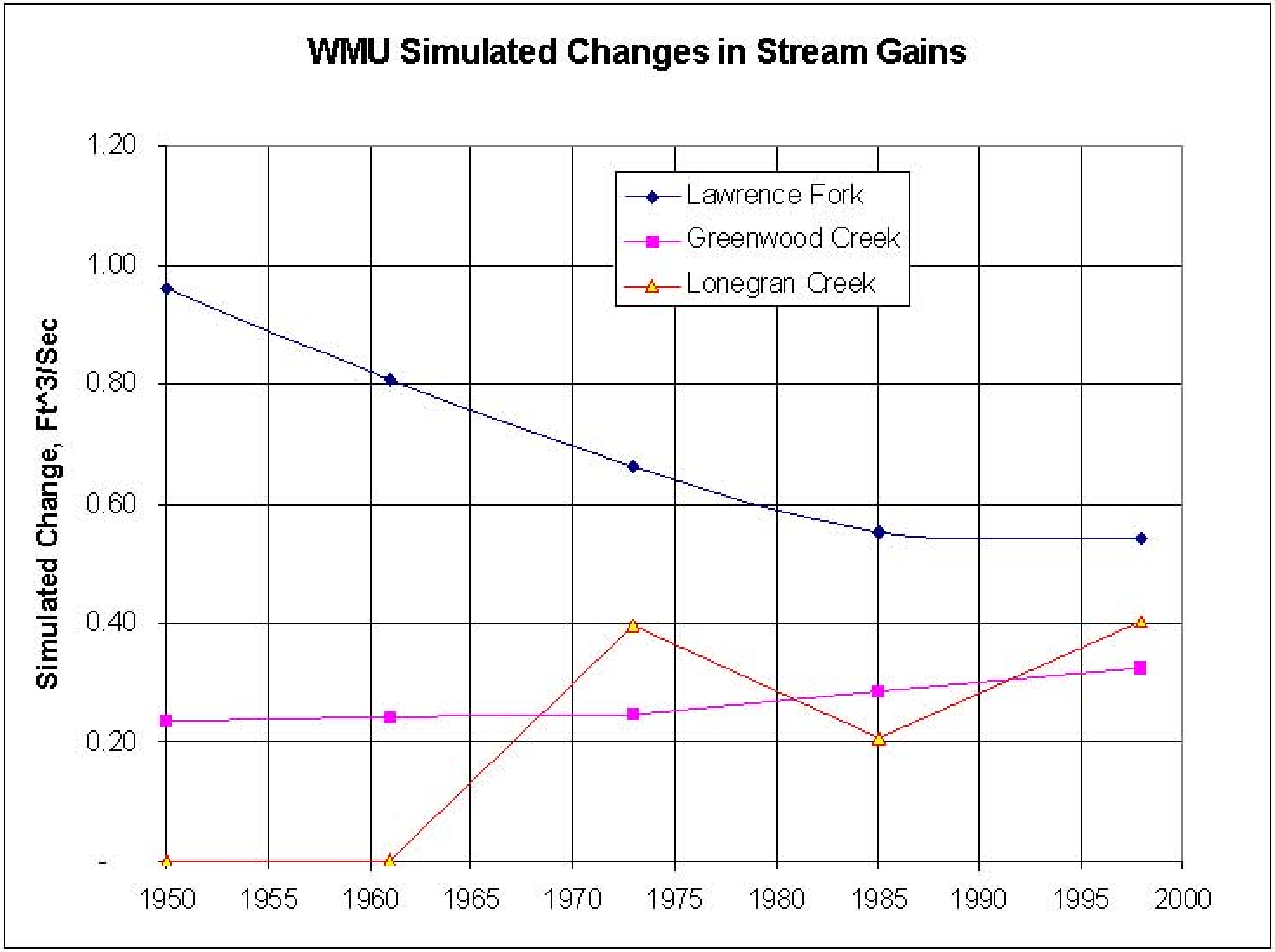
Figure 26



Eagle Resources
Advocacy → Sound Science → Innovation → Solutions

Central Model Unit Frenchman Creek above Palisade Changes in Simulated Stream and River Reach Gains		
Date	Project Number	Approved:
8/21/05	13009.1	E.G.Lappala

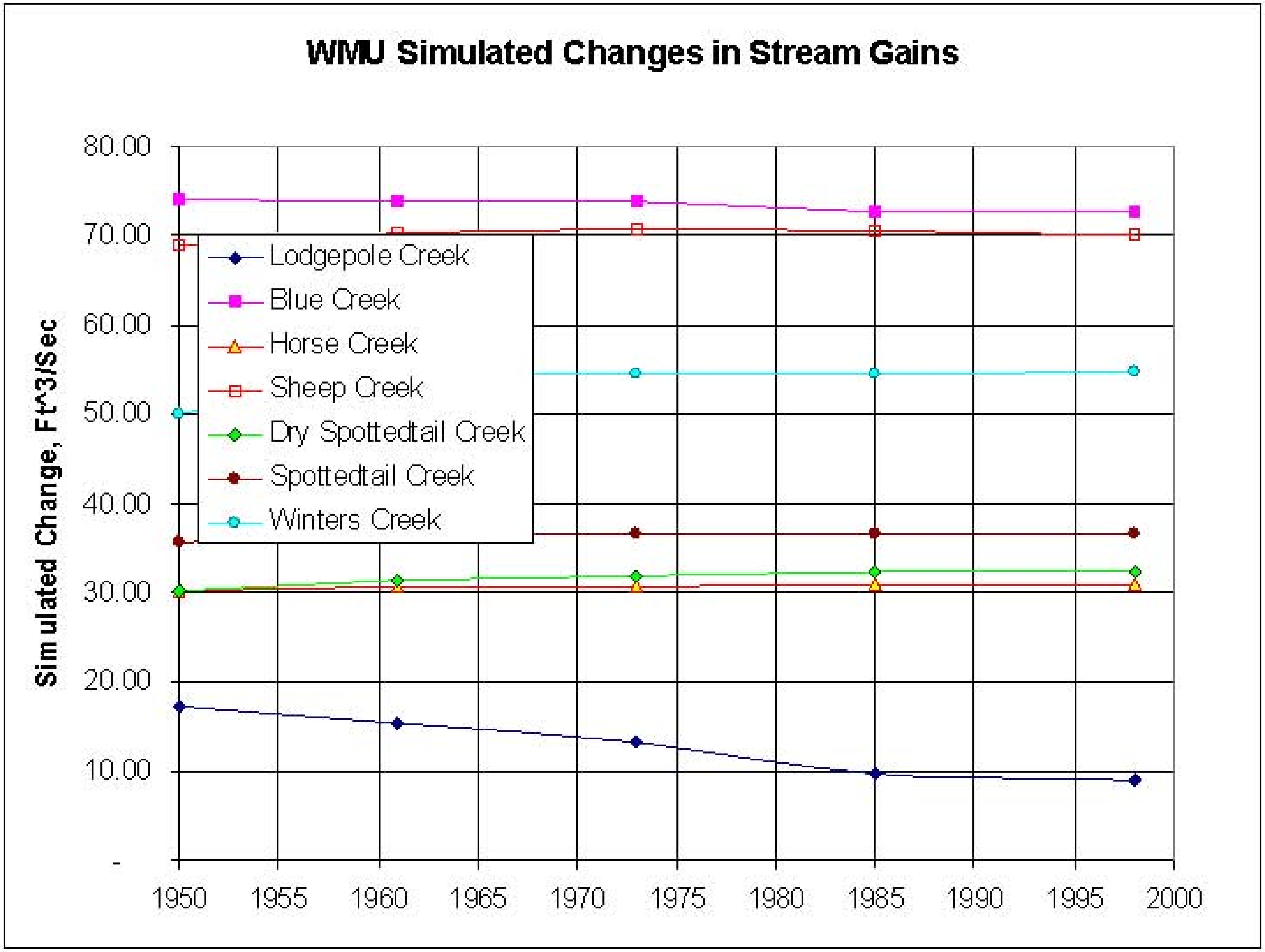
Figure 27



Western Model Unit Changes in Simulated Stream Gains		
Date	Project Number	Approved:
8/21/05	13009.1	E.G.Lappala

Figure
28

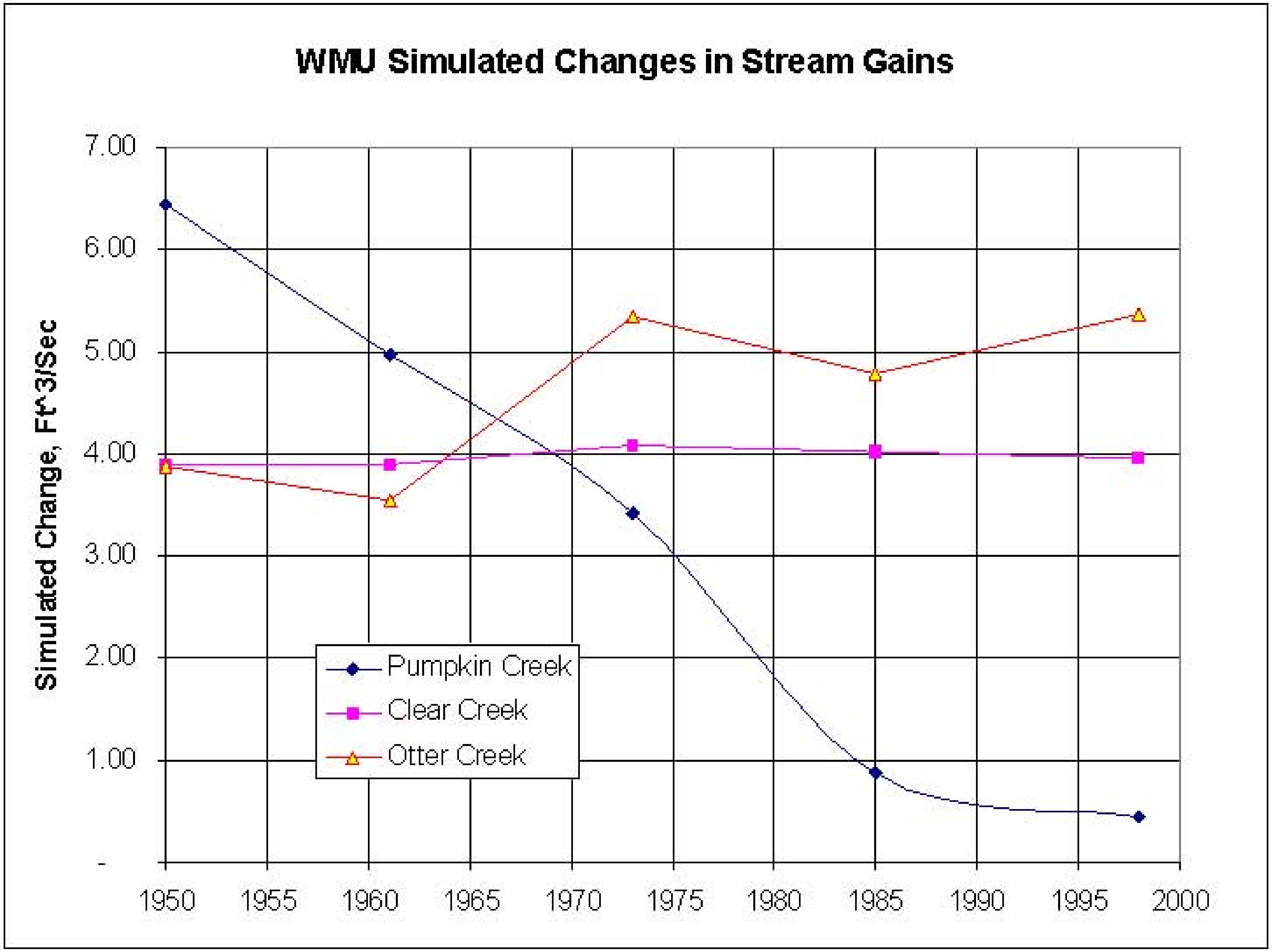
Eagle Resources
Advocacy → Sound Science → Innovation → Solutions



Eagle Resources
Advocacy → Sound Science → Innovation → Solutions

Western Model Unit Changes in Simulated Stream Gains - 2		
Date	Project Number	Approved:
8/21/05	13009.1	E.G.Lappala

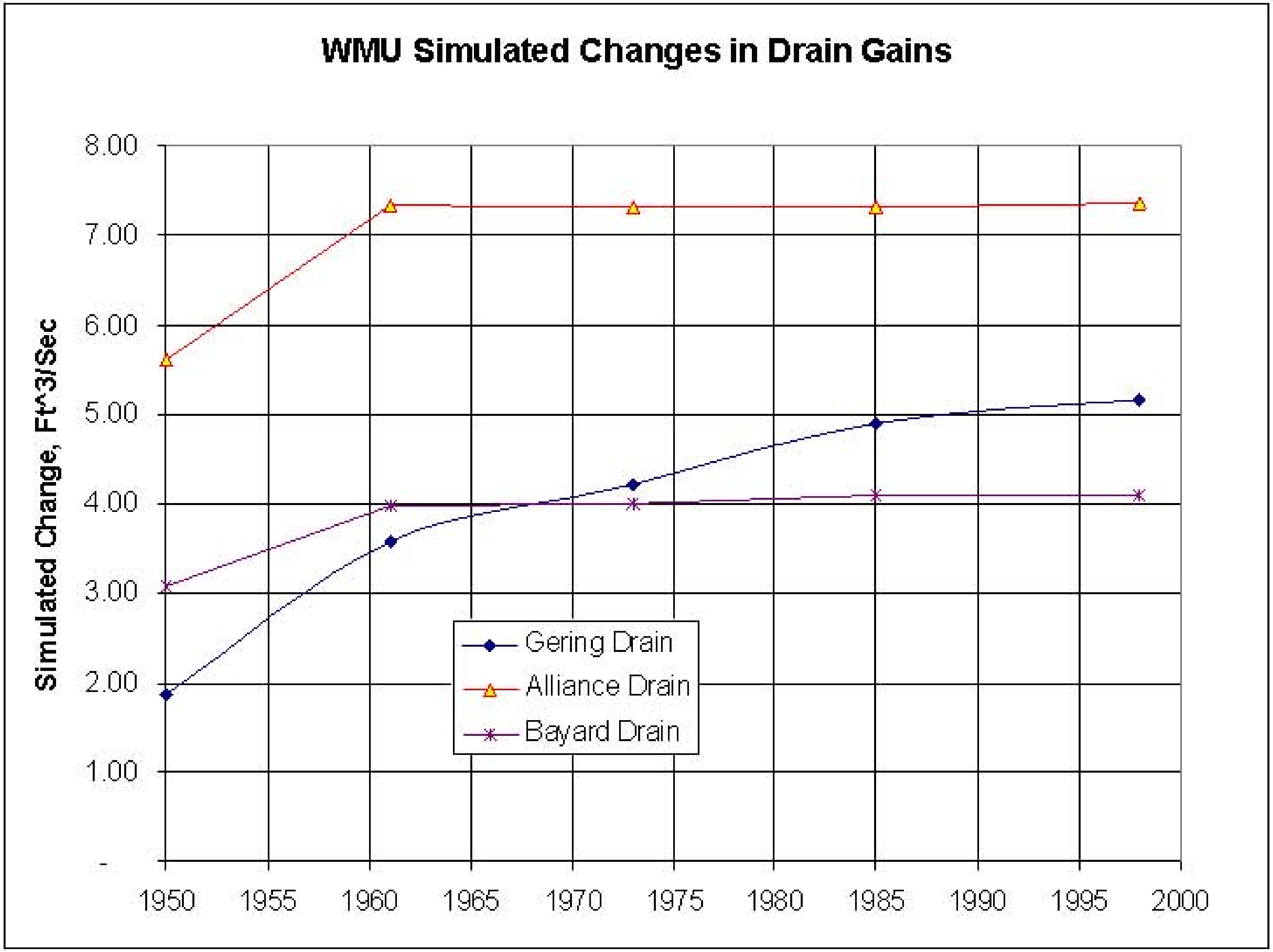
Figure 29



Western Model Unit
Changes in Simulated Stream Gains - 3

Date	Project Number	Approved:
8/21/05	13009.1	E.G.Lappala

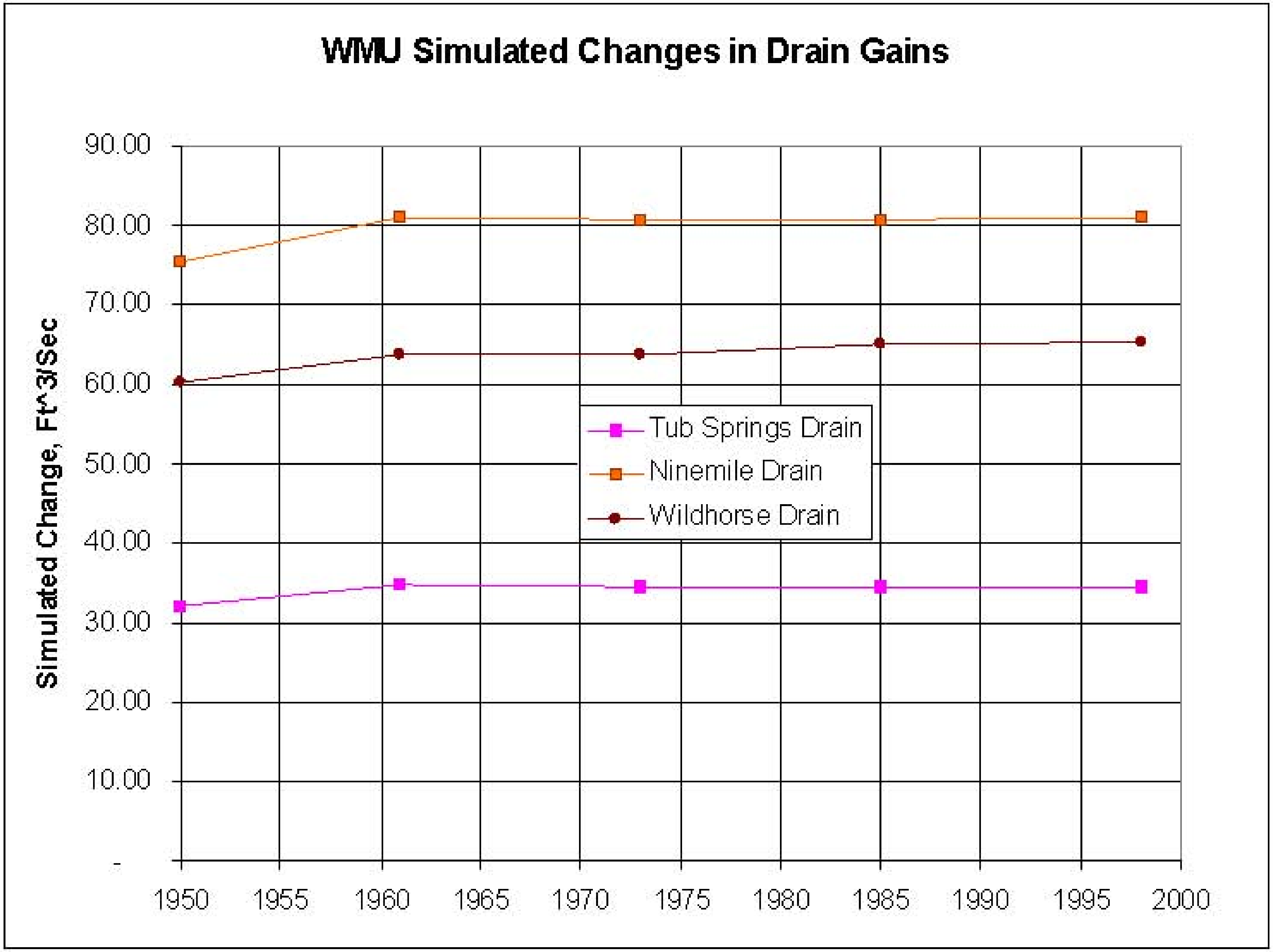
Figure 30



Eagle Resources
Advocacy → Sound Science → Innovation → Solutions

Western Model Unit Changes in Simulated Discharge to Drains - 1		
Date	Project Number	Approved:
8/21/05	13009.1	E.G.Lappala

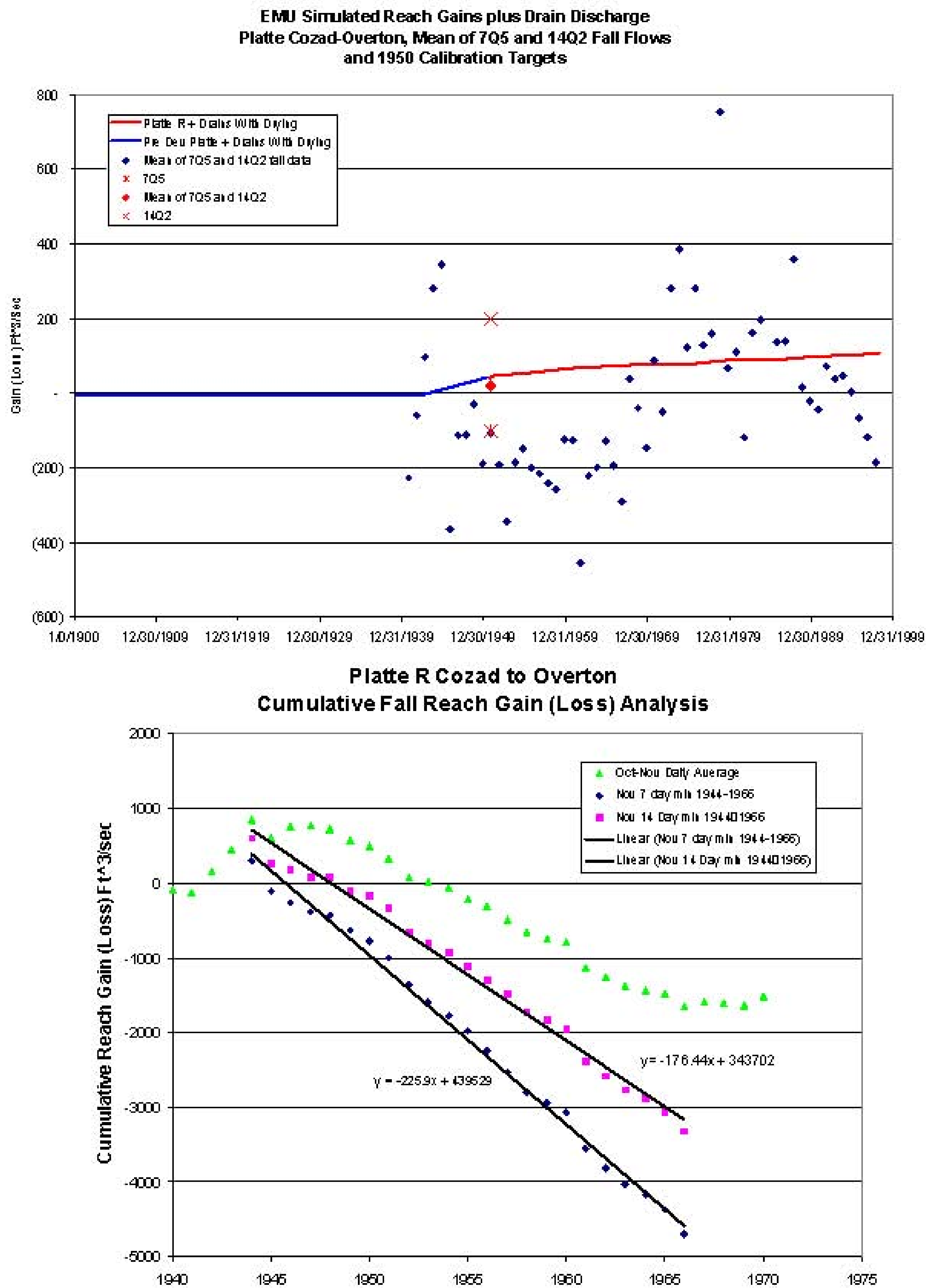
Figure 31



Eagle Resources
Advocacy → Sound Science → Innovation → Solutions

Western Model Unit Changes in Simulated Discharge to Drains 2		
Date	Project Number	Approved:
8/21/05	13009.1	E.G.Lappala

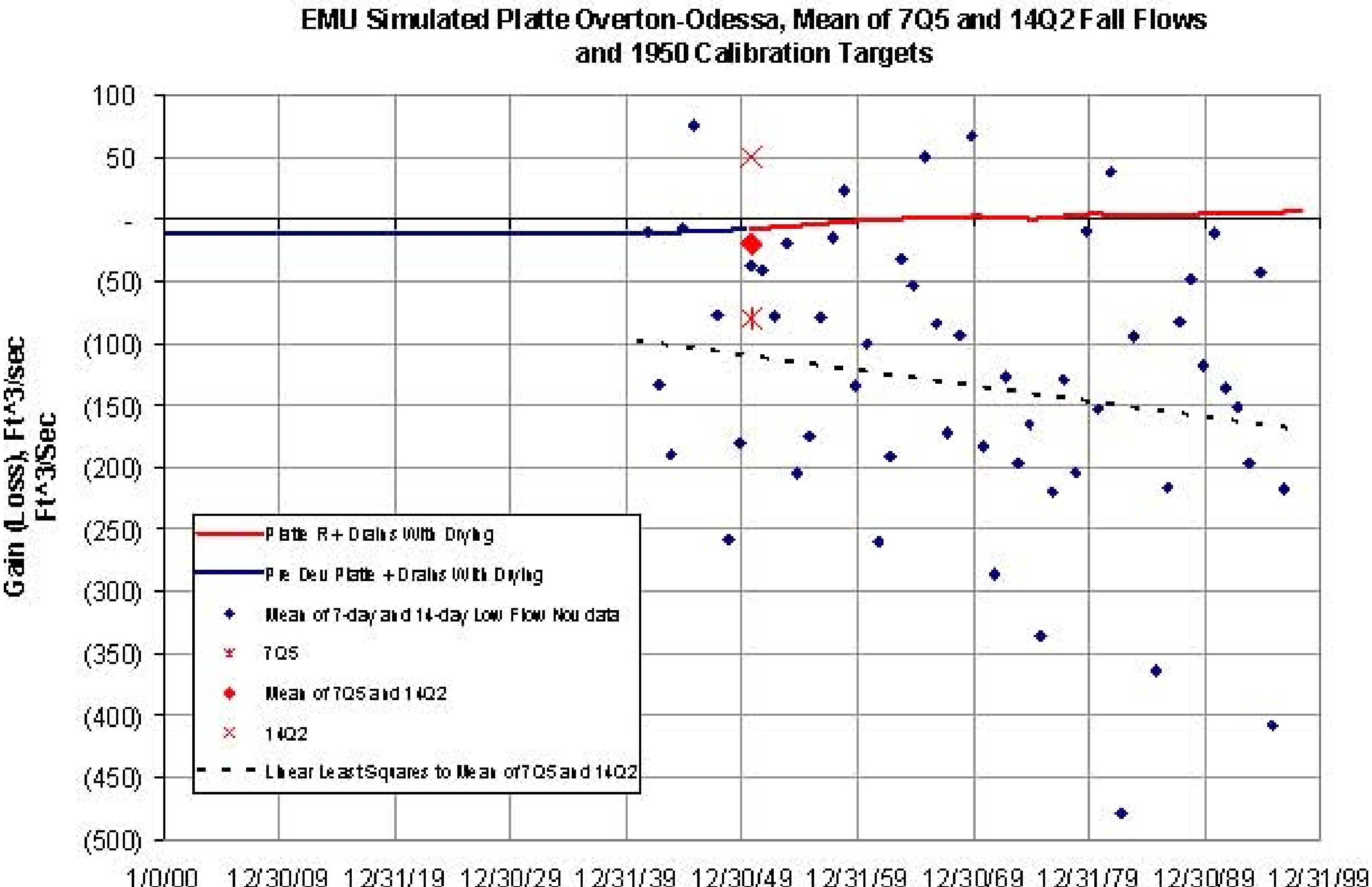
Figure 32

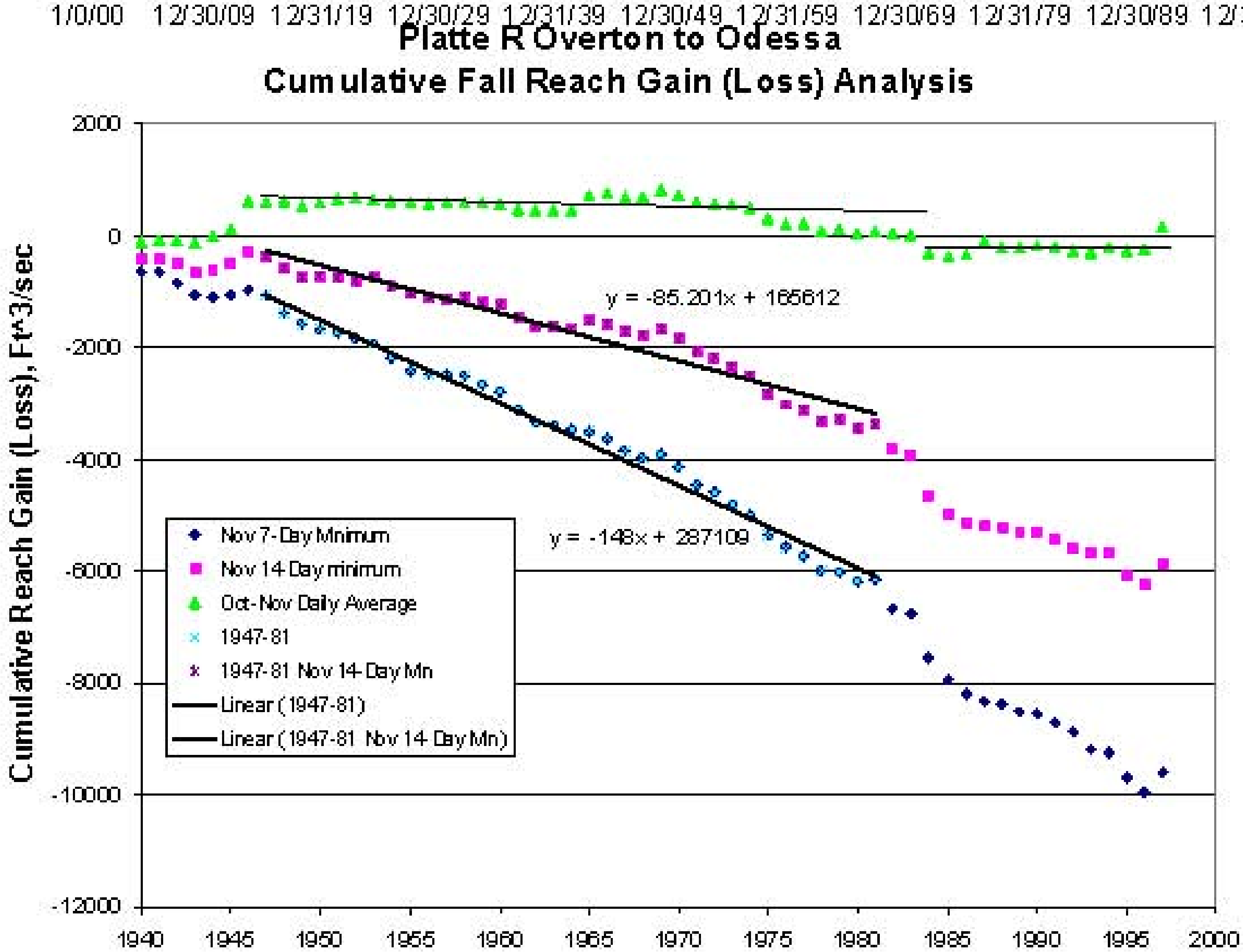


Eastern Model Unit Modeled Reach Gains, Annual Fall Low Flows and Single Mass Curves of Annual Fall Low Flows: Platte River from Cozad to Overton (Data after 1969 provided by COHYST does not account for power returns)		
Date	Project Number	Approved:
8/22/05	13009.1	E.G.Lappala

Figure 33

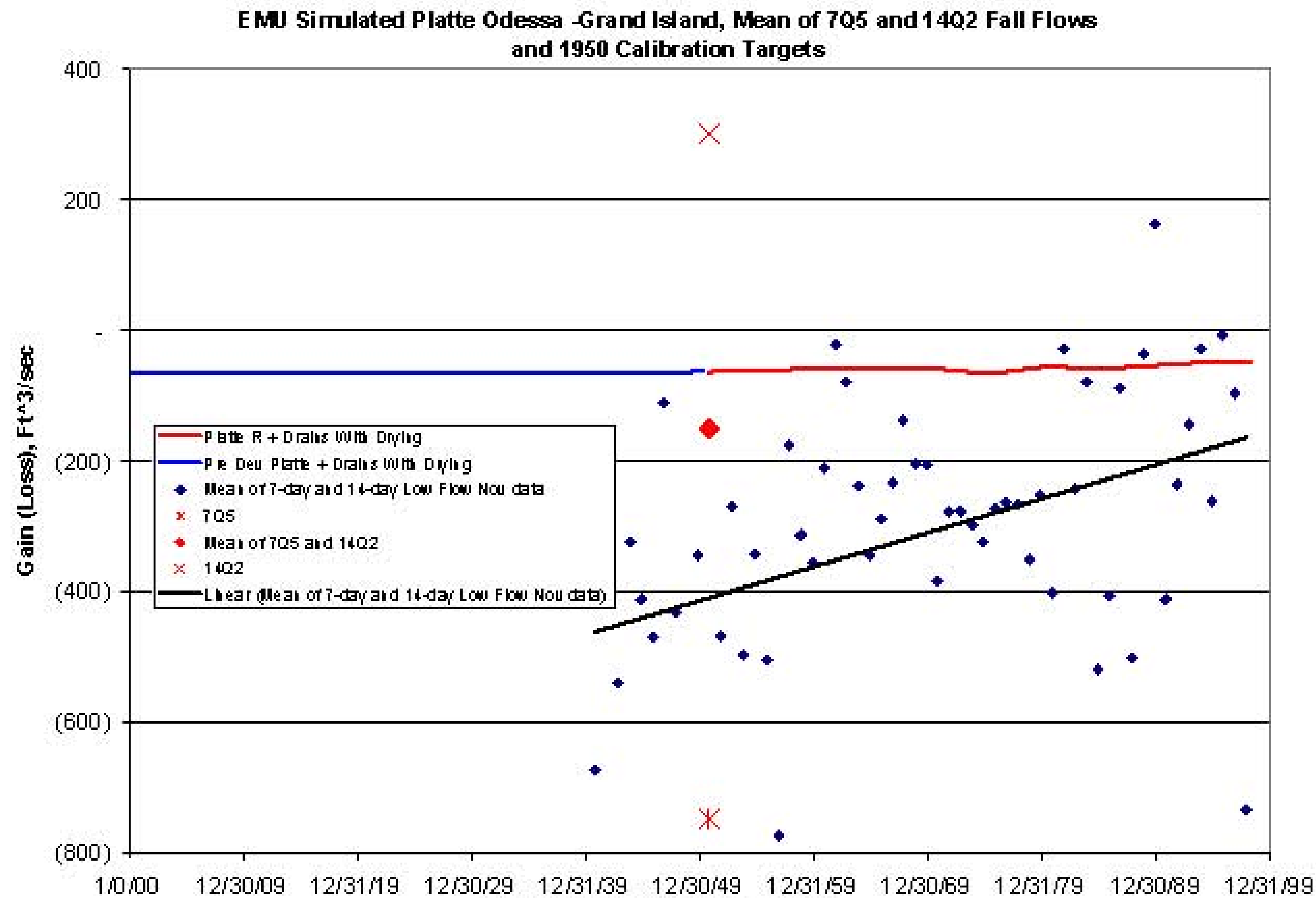
Eagle Resources
Advocacy + Sound Science + Innovation + Solutions

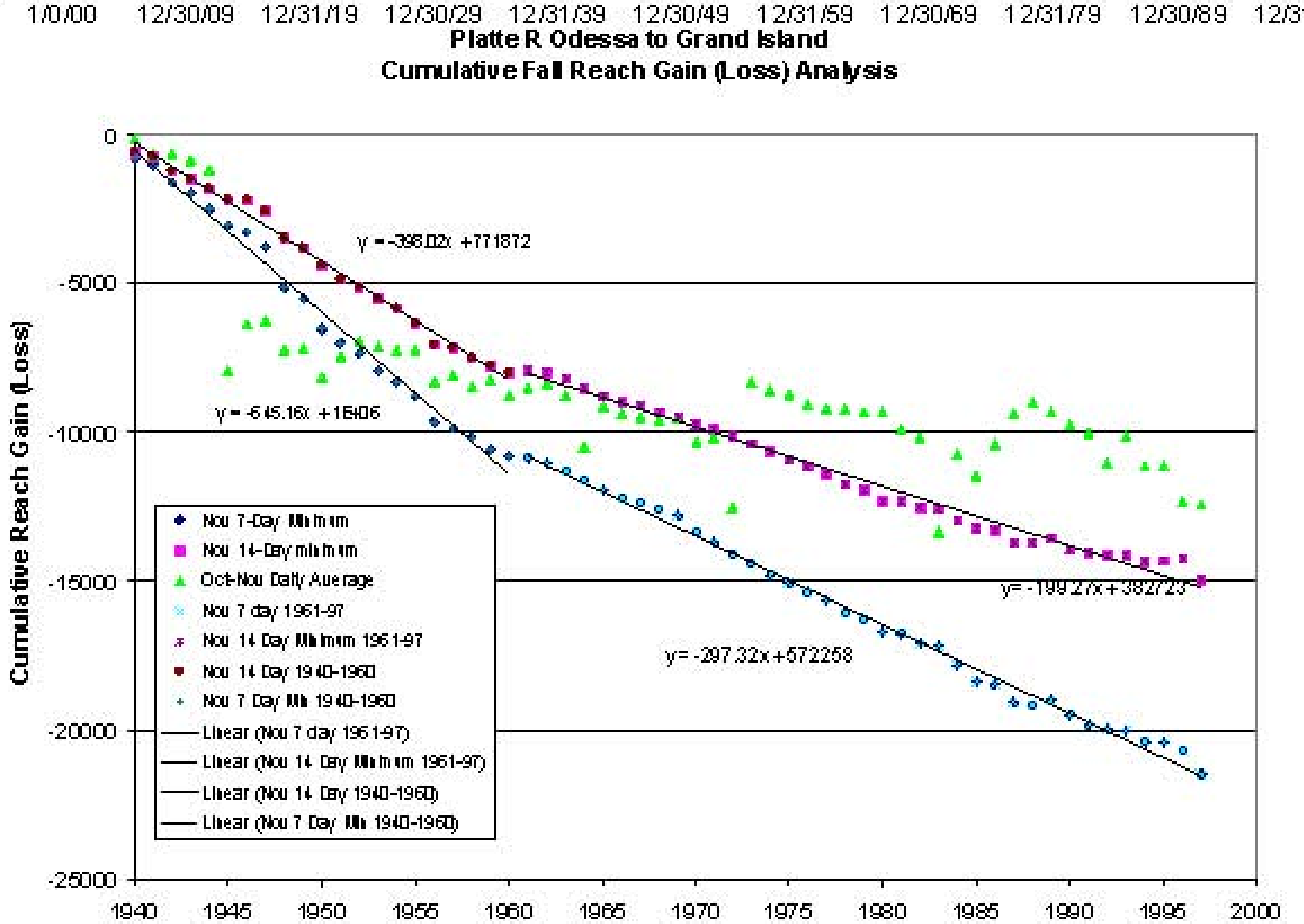




Eagle Resources
Advocacy → Sound Science → Innovation → Solutions

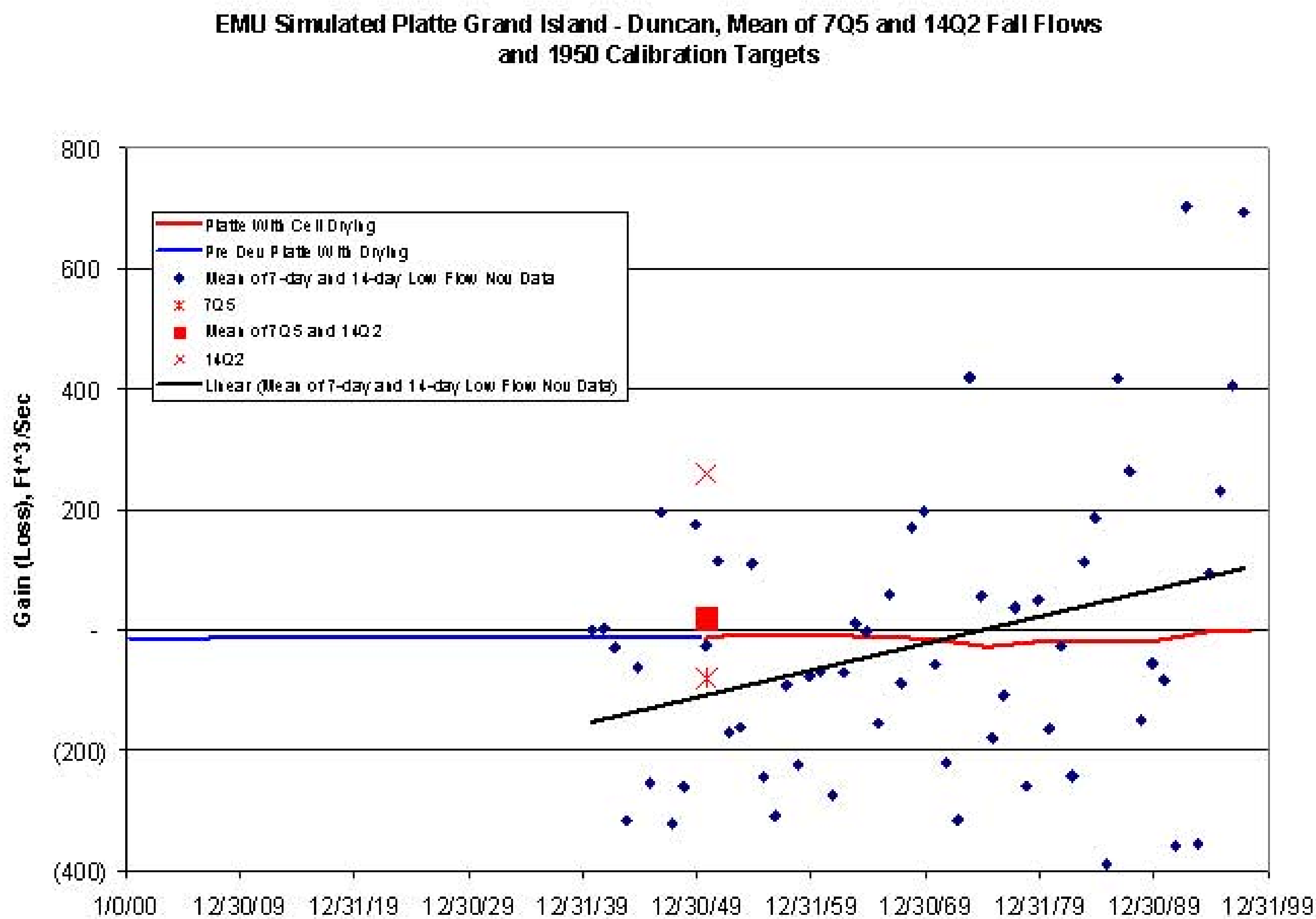
Eastern Model Unit Modeled Reach Gains, Annual Fall Low Flows and Single Mass Curves of Annual Fall Low Flows: Platte River from Overton to Odessa			**Figure 34**
Date	Project Number	Approved:	
8/22/05	13009.1	E.G.Lappala	

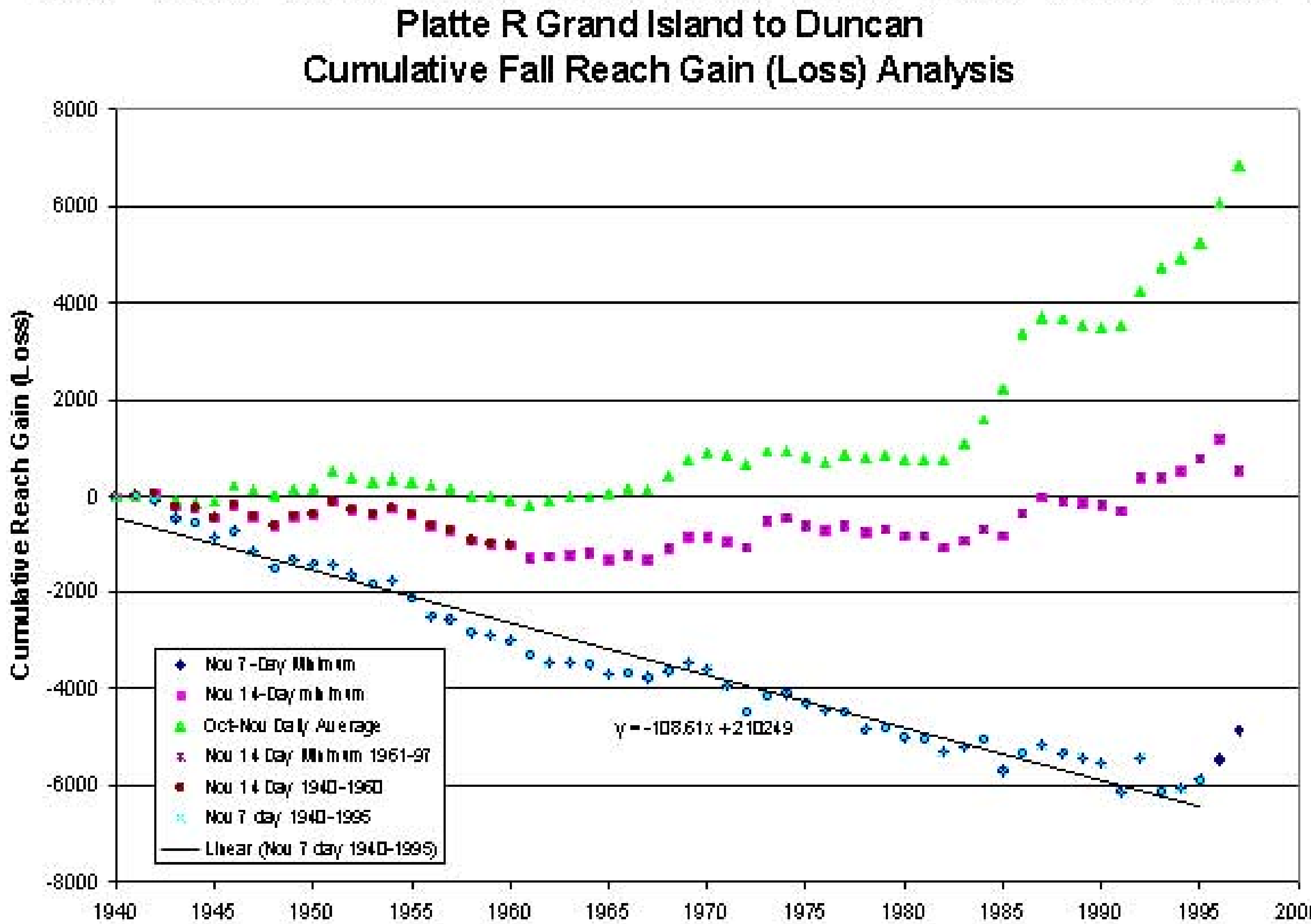




Eastern Model Unit Modeled Reach Gains, Annual Fall Low Flows and Single Mass Curves of Annual Fall Low Flows: Platte River from Cozad to Overton		
Date	Project Number	Approved:
8/22/05	13009.1	E.G.Lappala

Figure 35



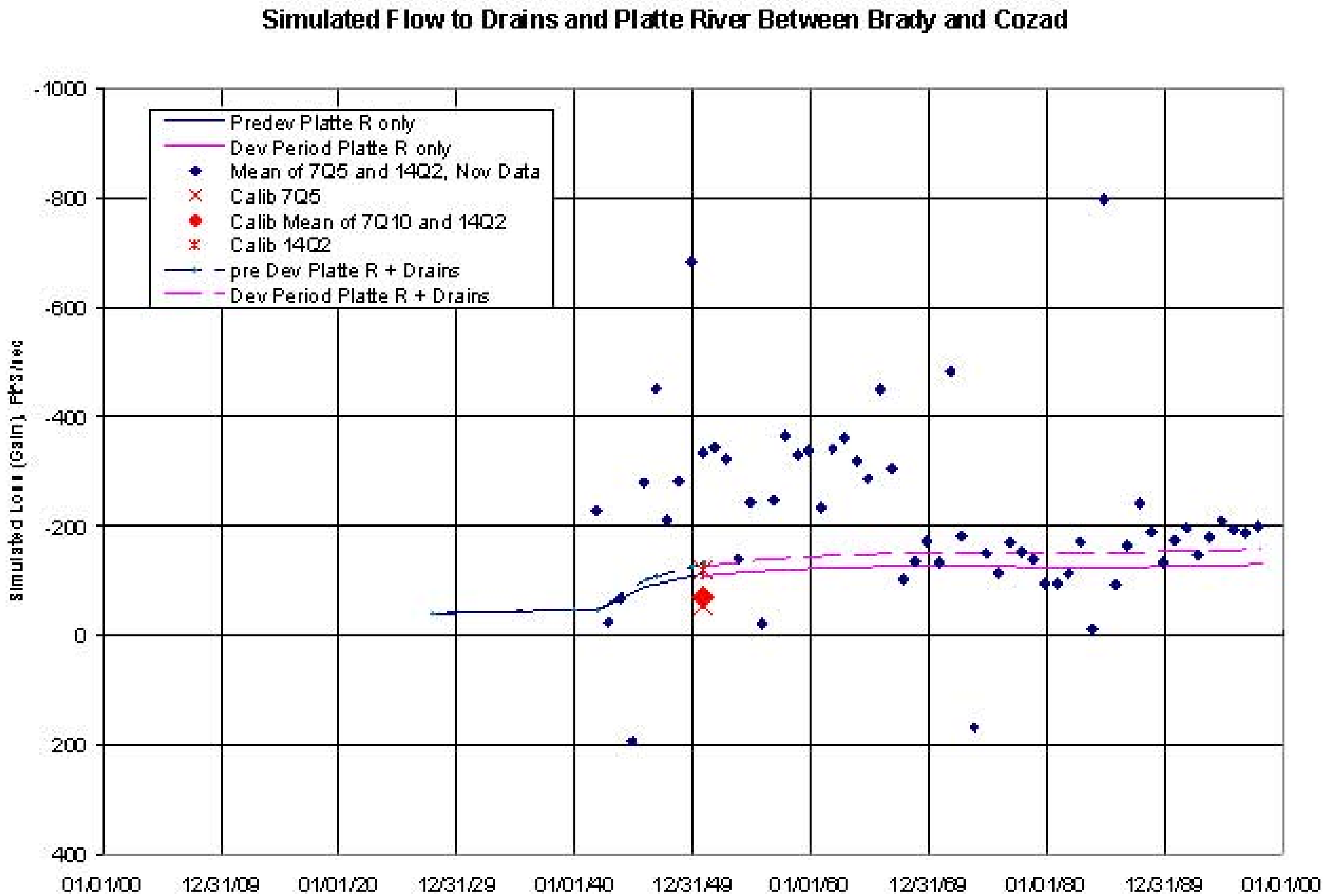


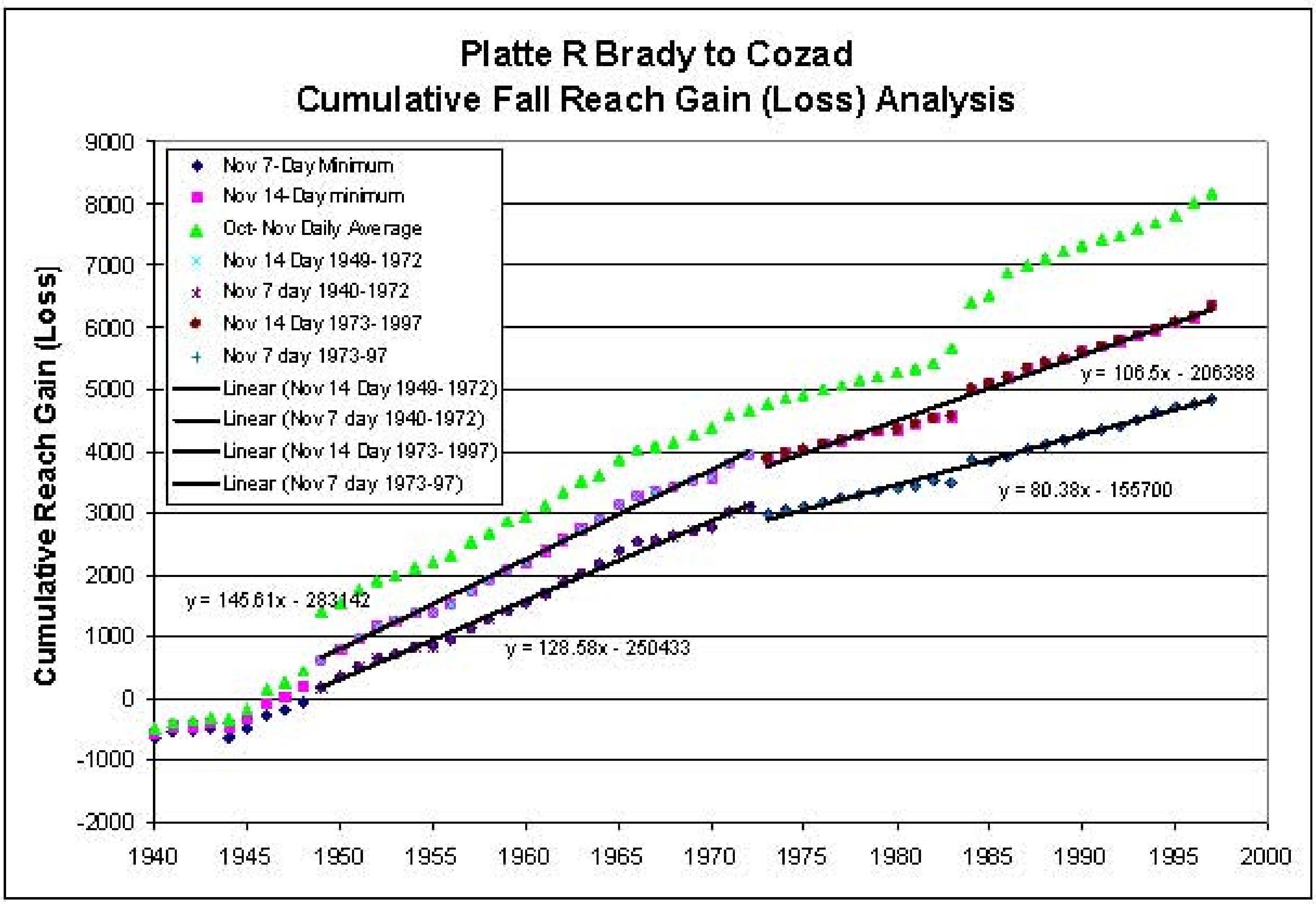
Eastern Model Unit Modeled Reach Gains, Annual Fall Low Flows
and Single Mass Curves of Annual Fall Low Flows:
Platte River from Odessa to Grand Island

Figure 36

Date	Project Number	Approved:
8/22/05	13009.1	E.G.Lappala

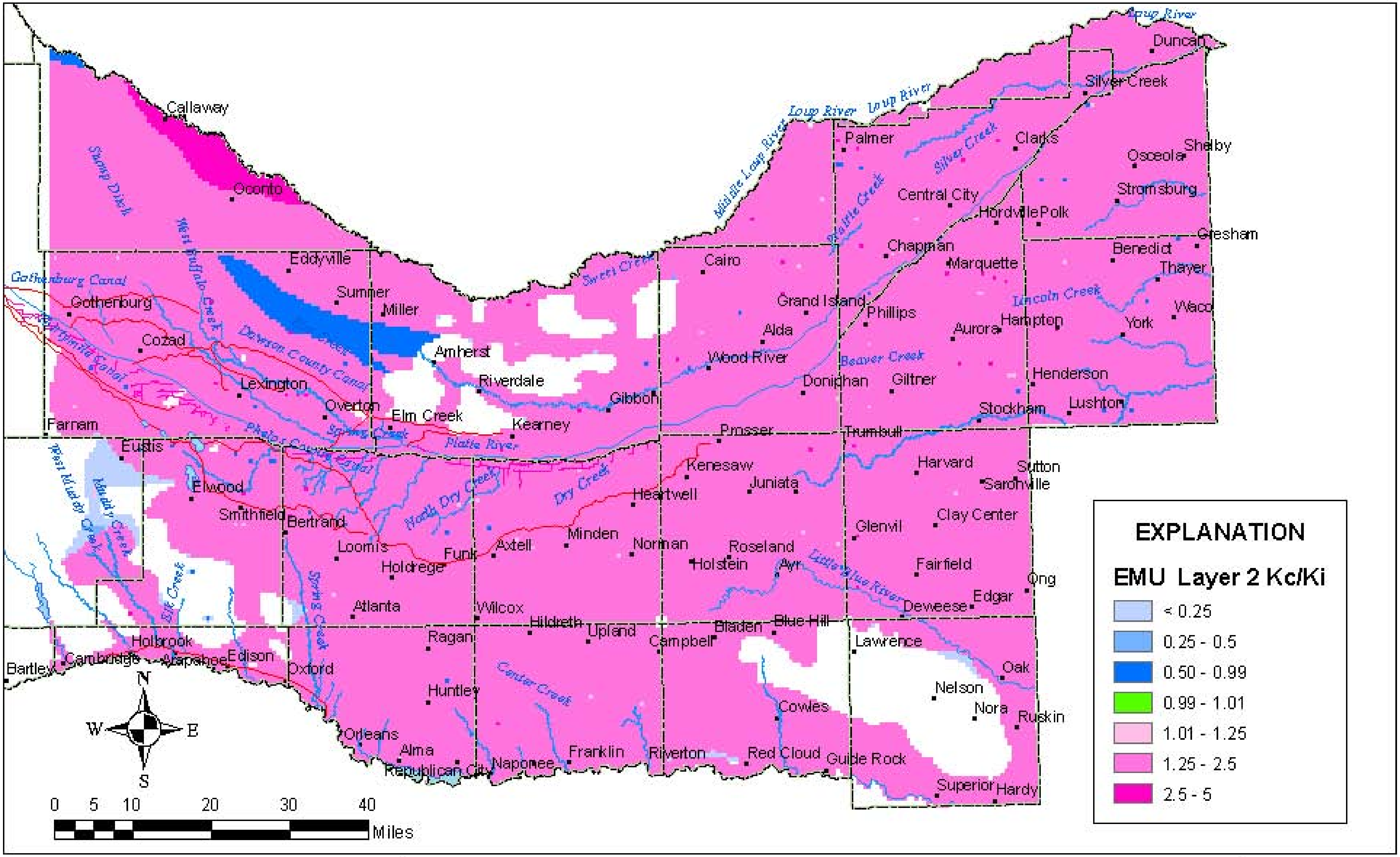
Eagle Resources
Advocacy → Sound Science → Innovation → Solutions





Eagle Resources
Advocacy – Sound Science – Innovation – Solutions

Central Model Unit Modeled Reach Gains, Annual Fall Low Flows and Single Mass Curves of Annual Fall Low Flows: Platte River from Cozad to Brady			Figure 37
Date	Project Number	Approved:	
8/22/05	13009.1	E.G.Lappala	

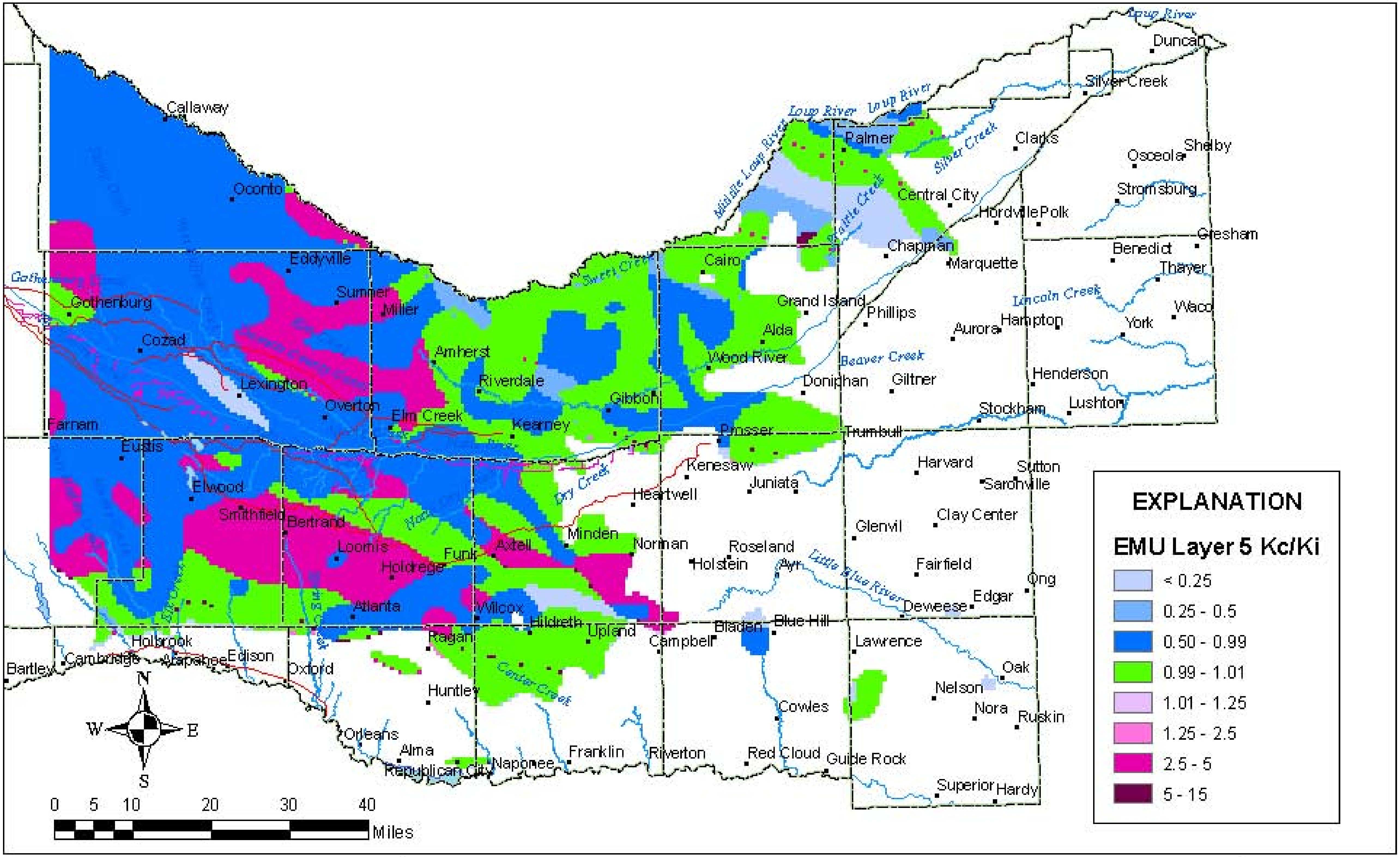


Eastern Model Unit Model Layer 2, Hydrostratigraphic Unit 2
Ratio of Calibrated Hydraulic Conductivity to Initial Hydraulic Conductivity

Date	Project Number	Approved:
8/20/05	13009.1	E.G.Lappala

Eagle Resources
Advocacy → Sound Science → Innovation → Solutions

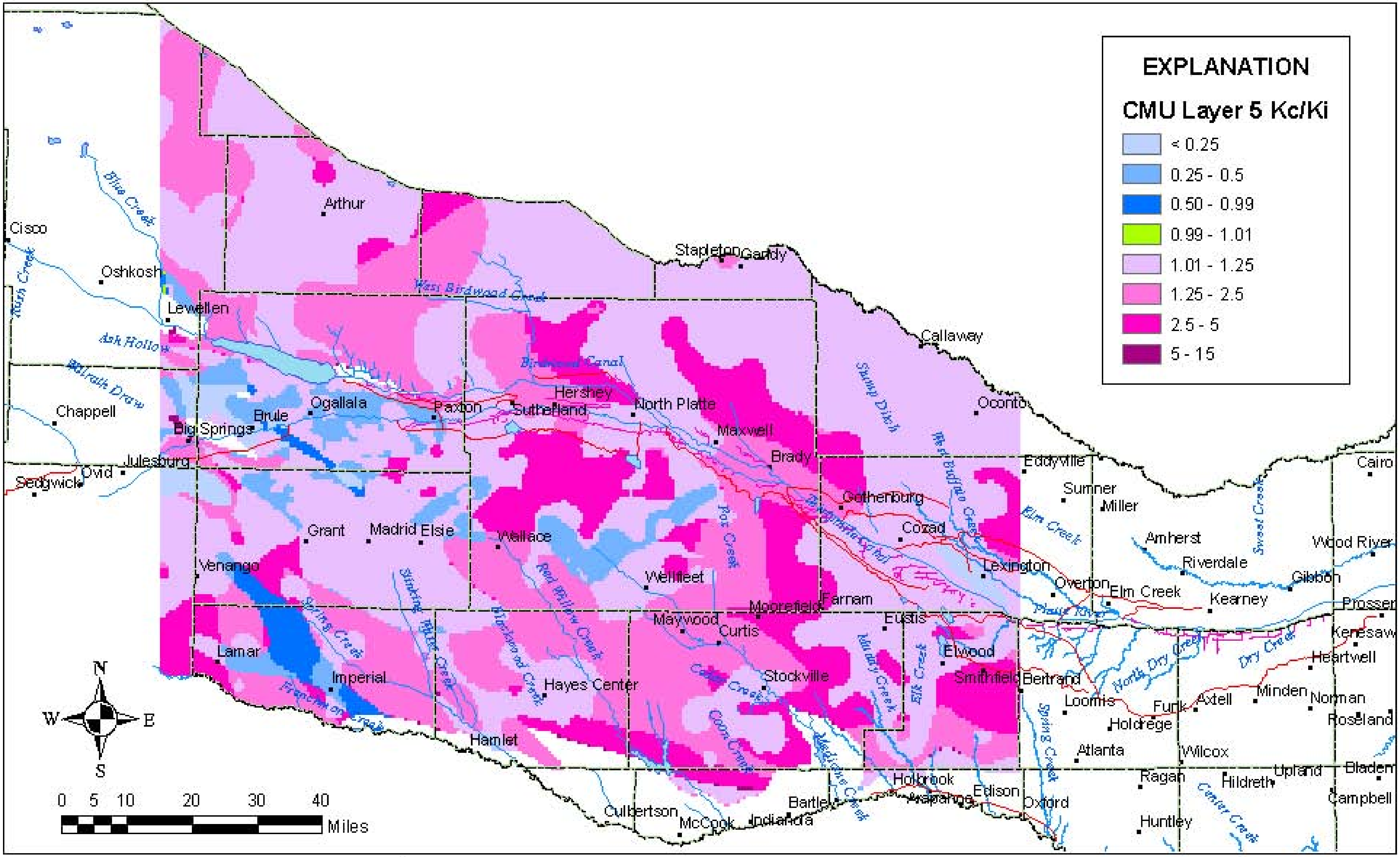
Figure 38



Eagle Resources
Advocacy → Sound Science → Innovation → Solutions

Eastern Model Unit Model Layer 5, Hydrostratigraphic Unit 6 Ratio of Calibrated Hydraulic Conductivity to Initial Hydraulic Conductivity		
Date	Project Number	Approved:
8/20/05	13009.1	E.G.Lappala

Figure 39

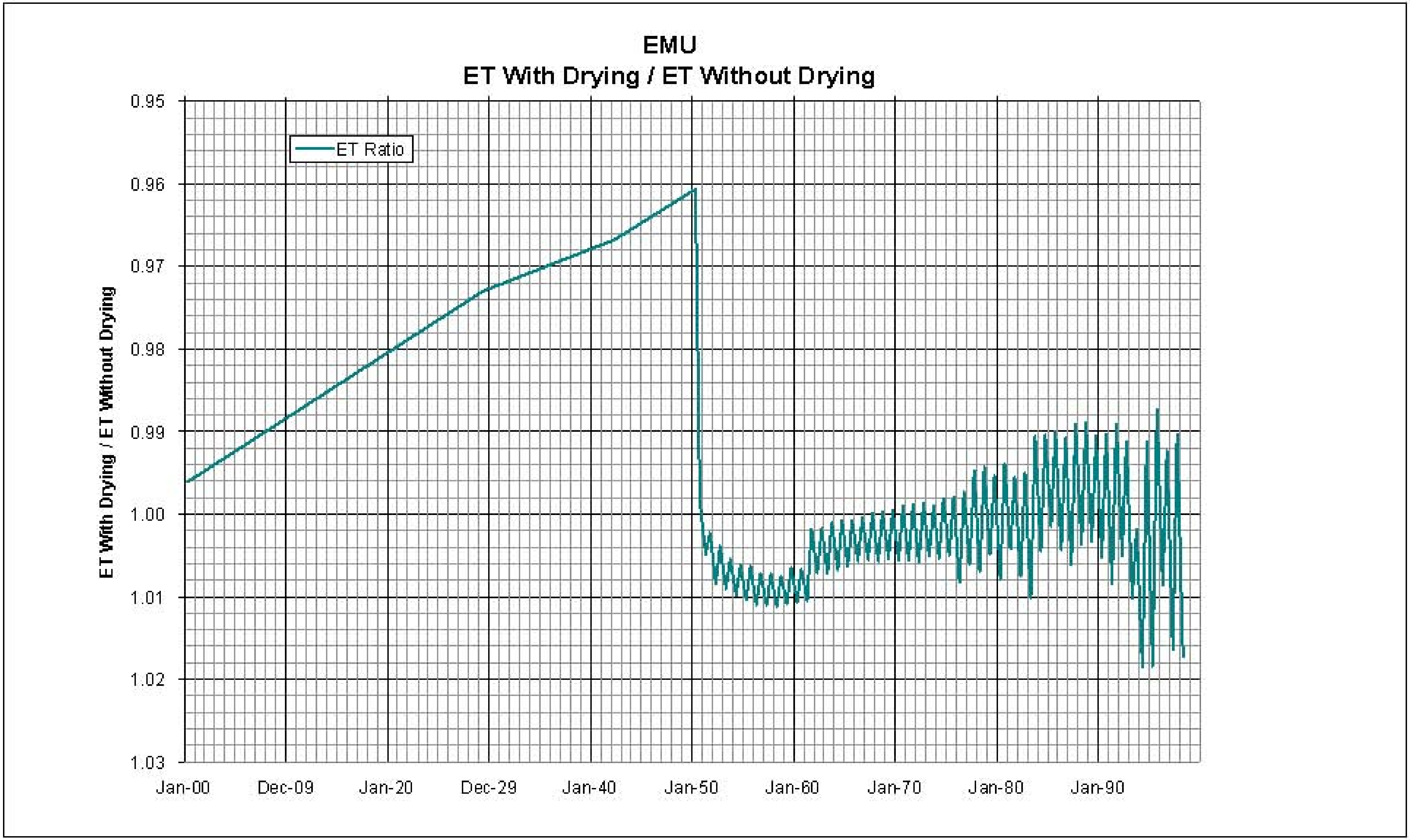


Central Model Unit Model Layer 5, Hydrostratigraphic Unit 6
Ratio of Calibrated Hydraulic Conductivity to Initial Hydraulic Conductivity

Date	Project Number	Approved:
8/20/05	13009.1	E.G.Lappala

Figure 40

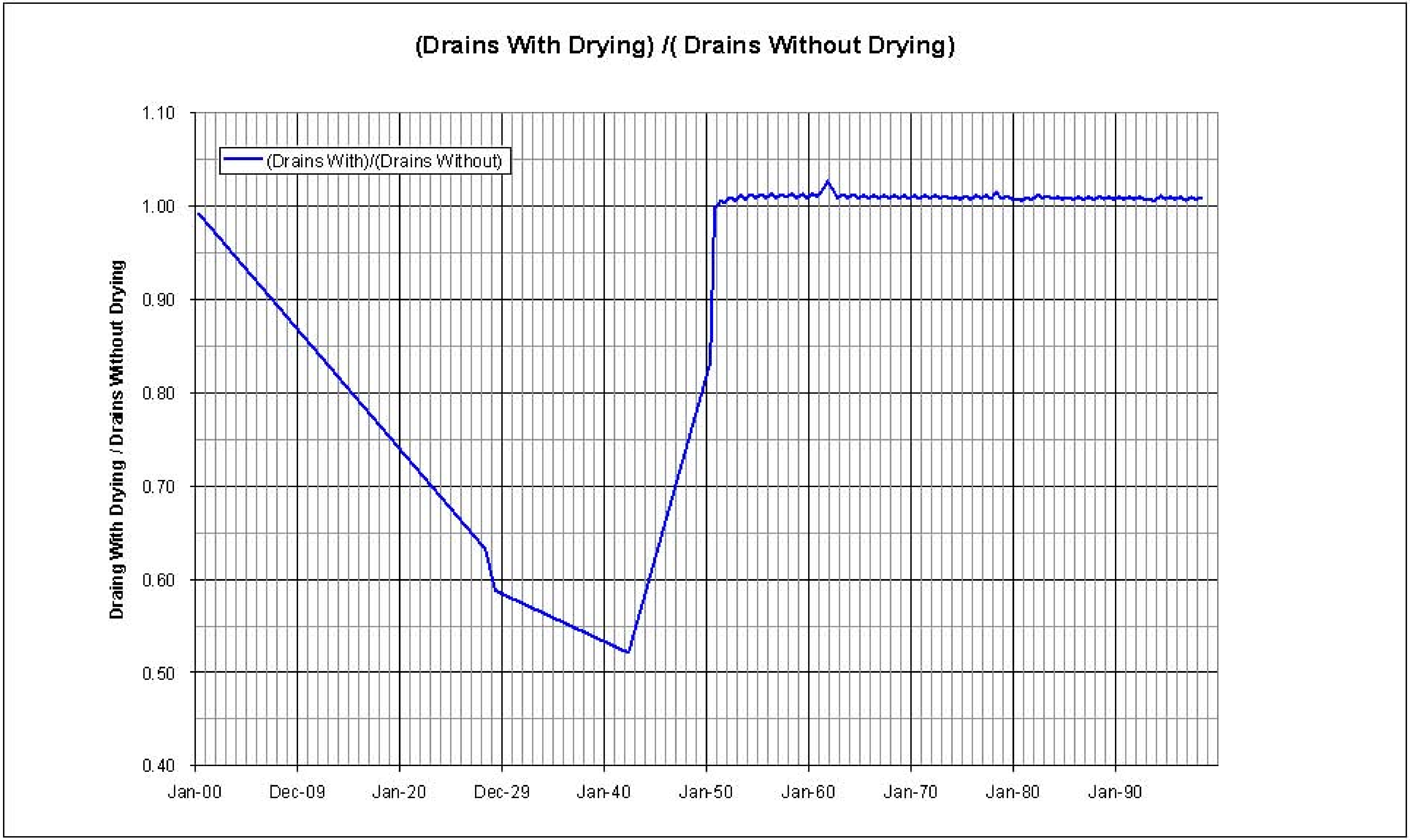
Eagle Resources
Advocacy → Sound Science → Innovation → Solutions



Eagle Resources
Advocacy → Sound Science → Innovation → Solutions

Eastern Model Unit Computed Groundwater Discharge to ET 1895-1998 Ratio of ET with to ET Without Correct Cell Drying Model Datasets hmMSTR1-3 and hmMLdev1-5		
Date	Project Number	Approved:
8/21/05	13009.1	E.G.Lappala

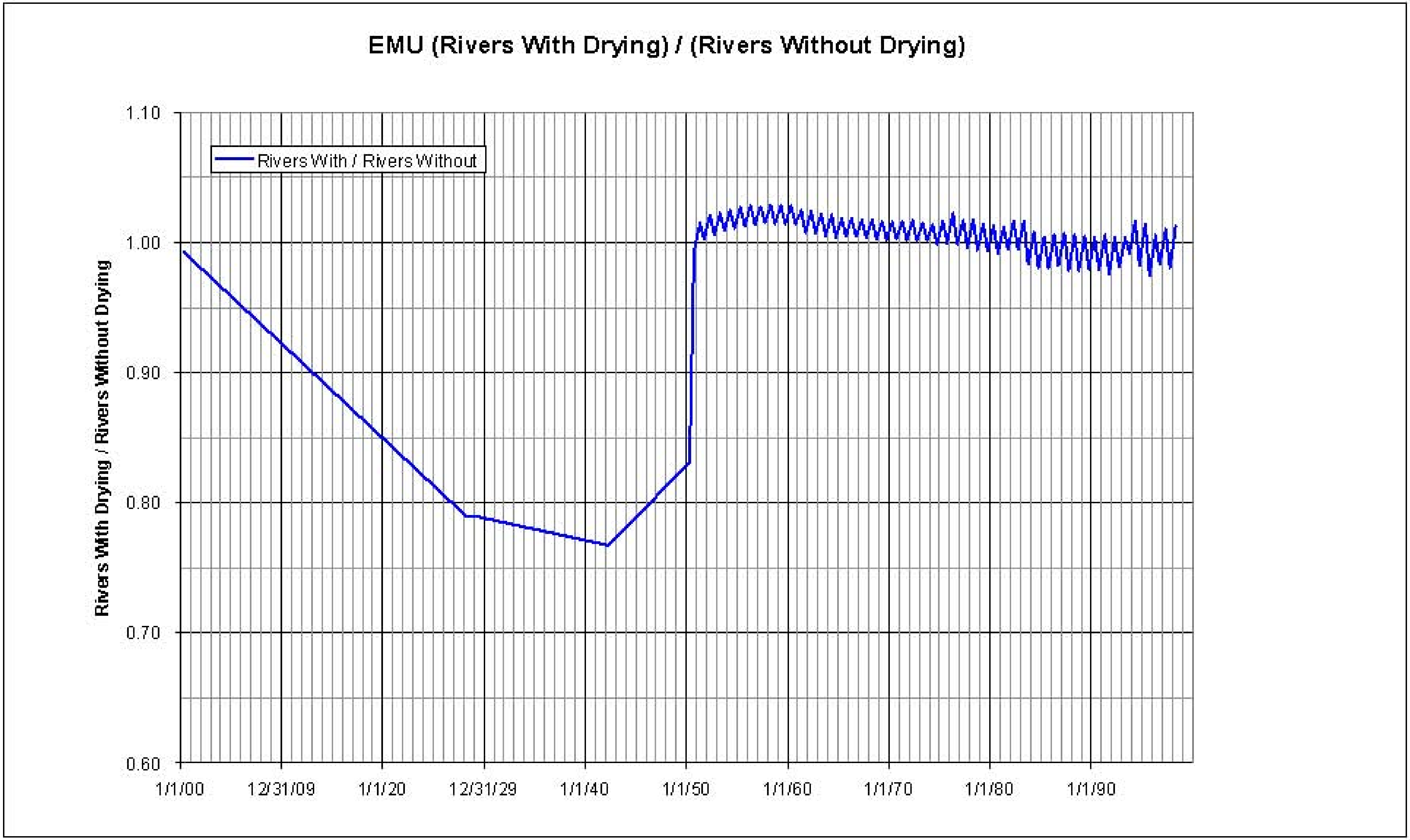
Figure 41



Eagle Resources
Advocacy → Sound Science → Innovation → Solutions

Eastern Model Unit Computed Groundwater Discharge to Drains 1895-1998 Ratio of Drains With to Without Correct Cell Drying Model Datasets hmMSTR1-3 and hmMLdev1-5		
Date	Project Number	Approved:
8/21/05	13009.1	E.G.Lappala

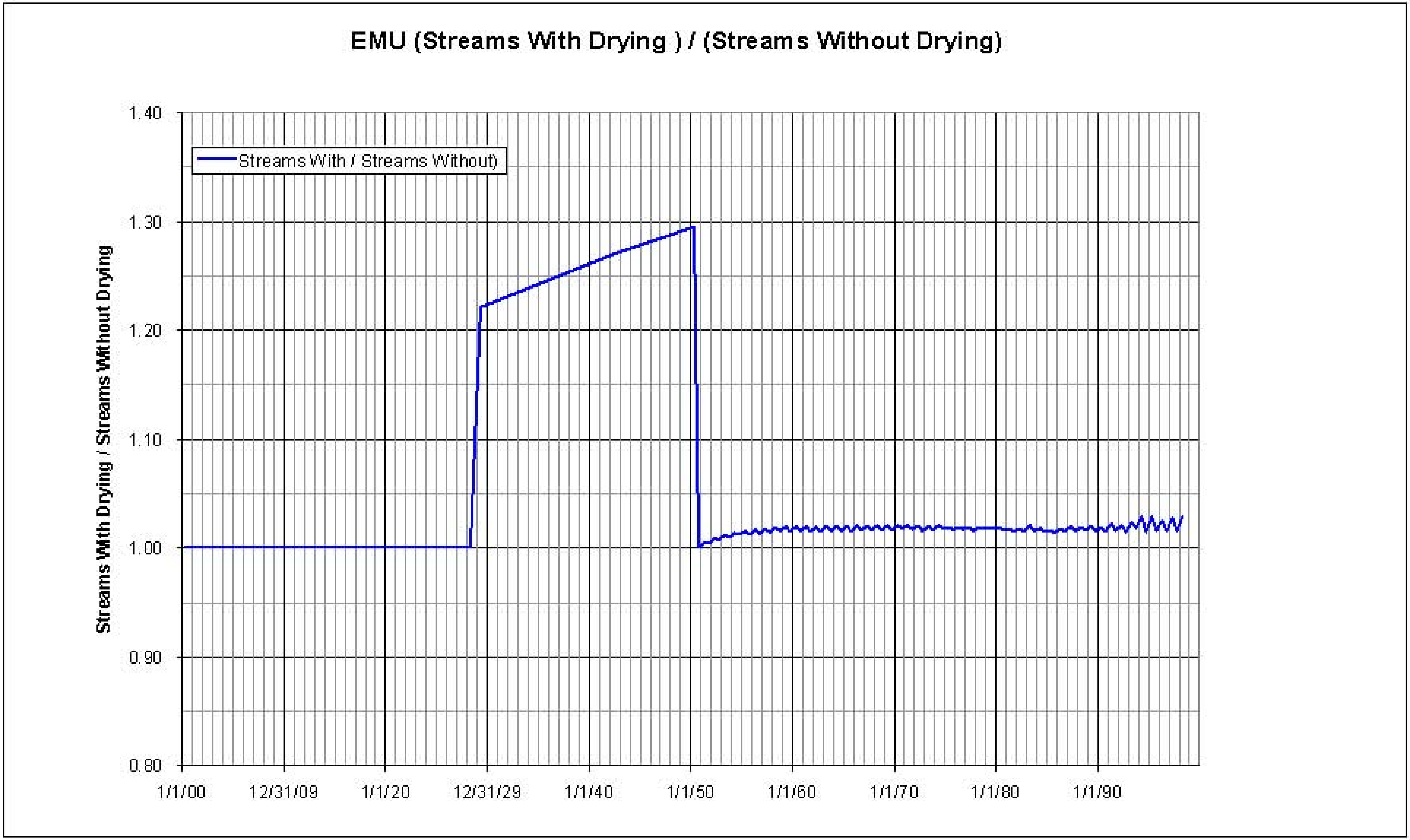
Figure 42



Eagle Resources
Advocacy → Sound Science → Innovation → Solutions

Eastern Model Unit Computed Groundwater Discharge to Rivers 1895-1998 Ratio of Rivers With to Without Correct Cell Drying Model Datasets hmMSTR1-3 and hmMLdev1-5		
Date	Project Number	Approved:
8/21/05	13009.1	E.G.Lappala

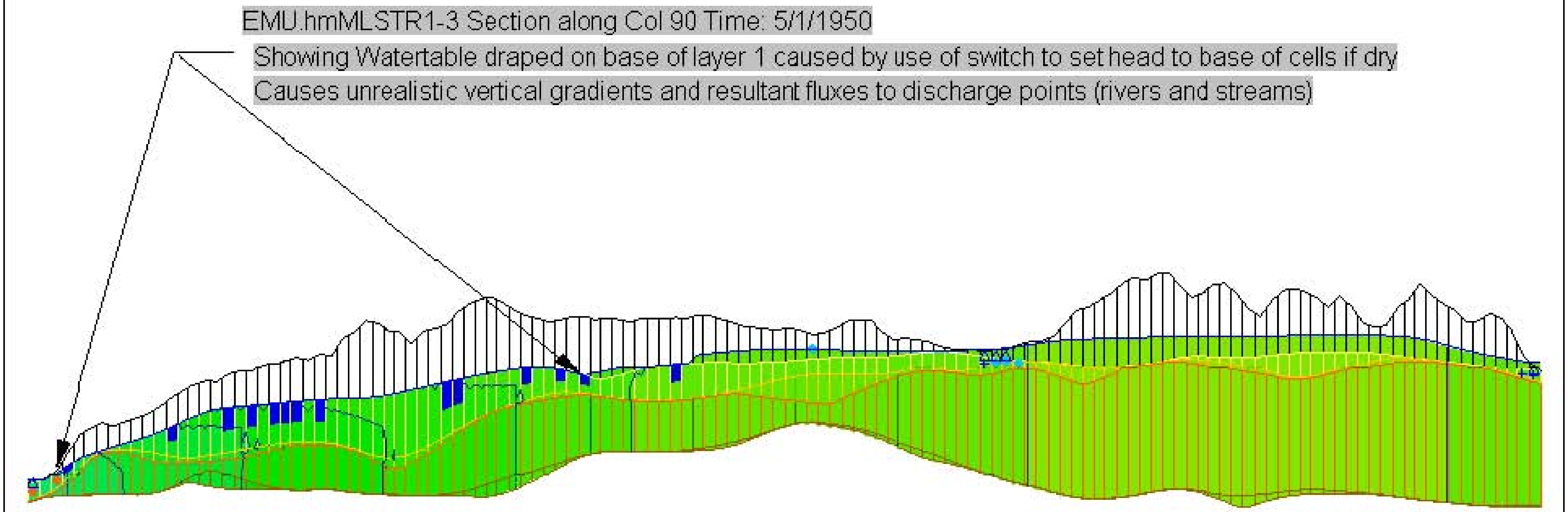
Figure 43



Eagle Resources
Advocacy → Sound Science → Innovation → Solutions

Eastern Model Unit Computed Groundwater Discharge to Streams 1895-1998 Ratio of Streams With to Without Correct Cell Drying Model Datasets hmMSTR1-3 and hmMLdev1-5		
Date	Project Number	Approved:
8/21/05	13009.1	E.G.Lappala

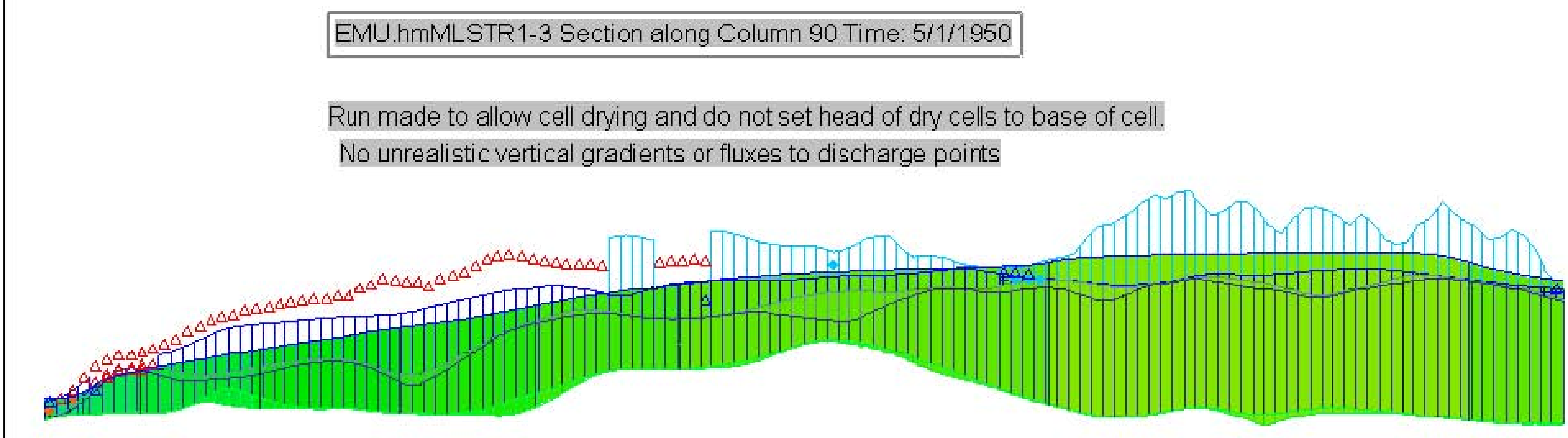
Figure 44



Eagle Resources
Advocacy → Sound Science → Innovation → Solutions

Eastern Model Unit North-South Section through Columnl 90 Showing Watertable Draped on Base of Layer 1 Model Dataset hmMLSTR1-3		
Date	Project Number	Approved:
8/21/05	13009.1	E.G.Lappala

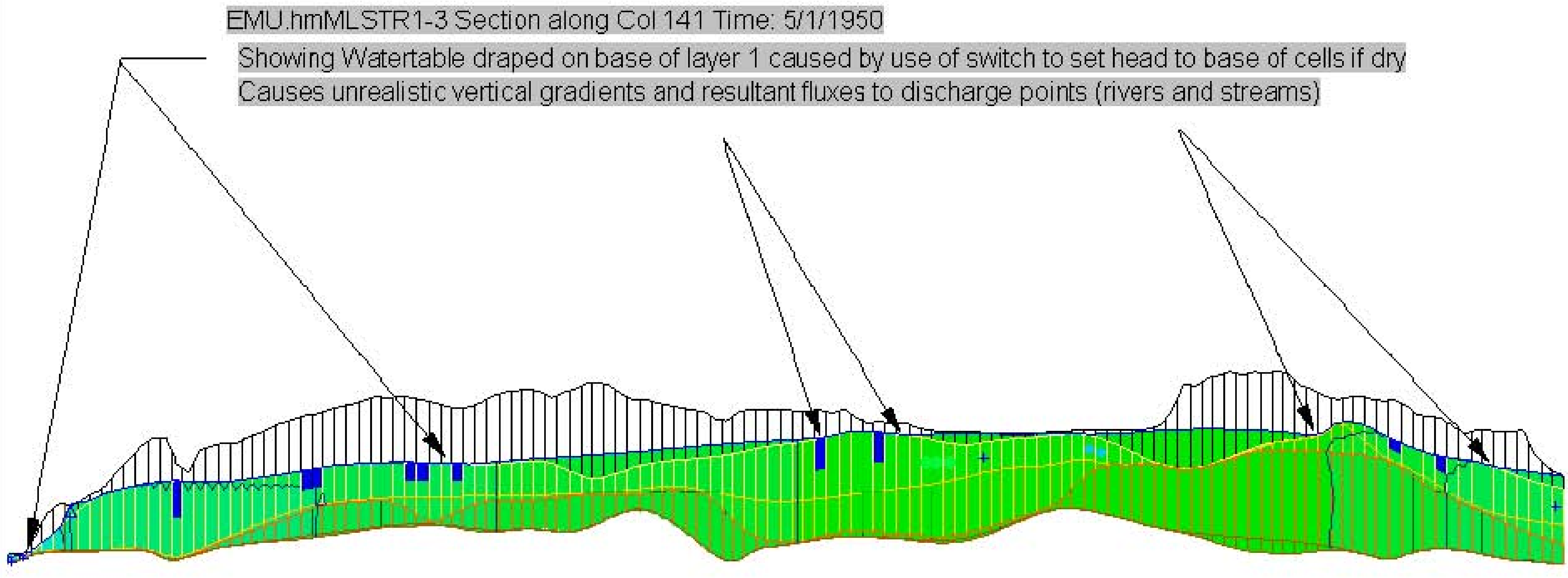
Figure 45



Eagle Resources
Advocacy → Sound Science → Innovation → Solutions

Eastern Model Unit North-South Section through Column 90 Showing Watertable Correctly Allowed to Fall Below Base of Layer 1. Model Dataset hmMLSTR1-3		
Date	Project Number	Approved:
8/21/05	13009.1	E.G.Lappala

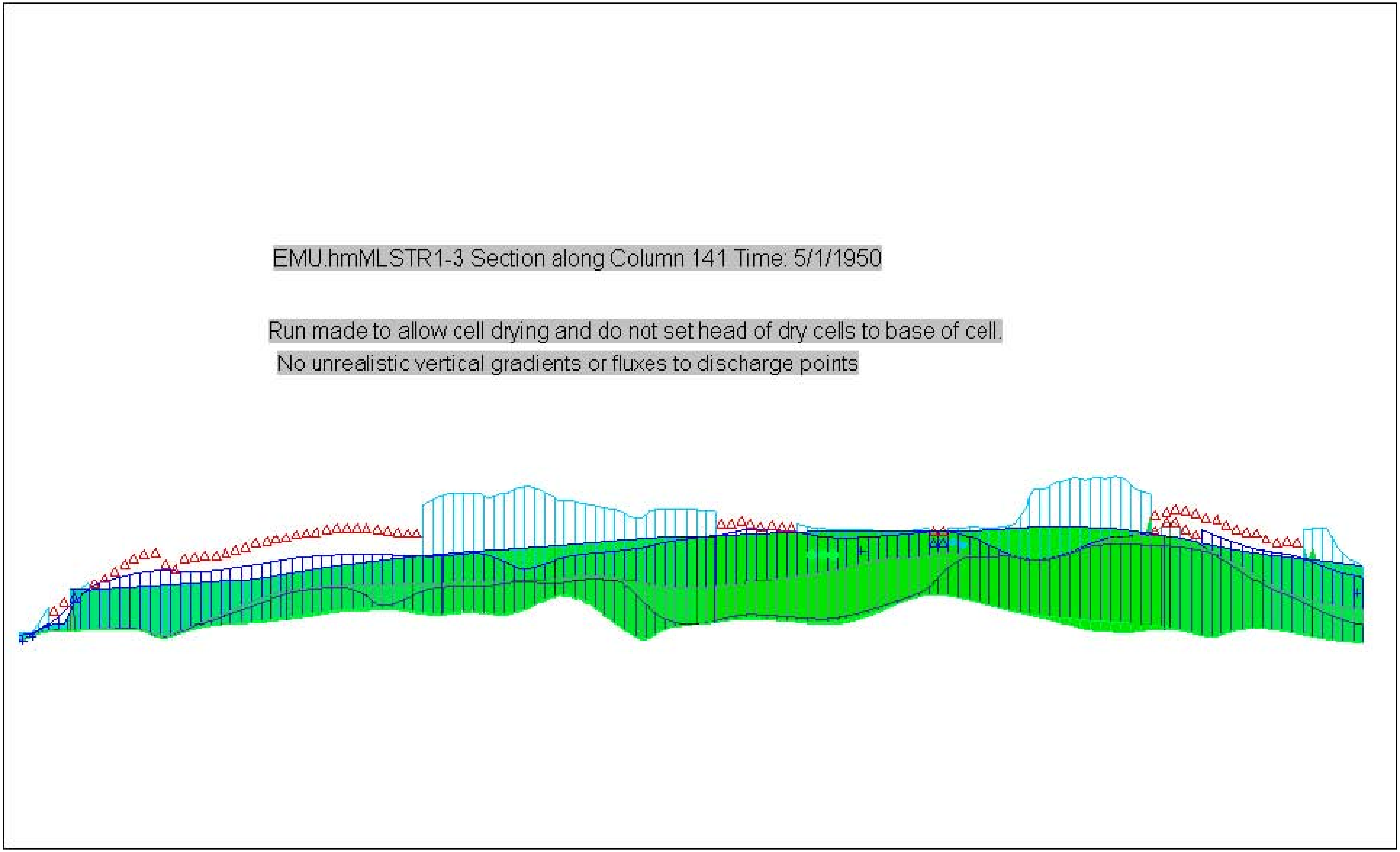
Figure 46



Eagle Resources
Advocacy → Sound Science → Innovation → Solutions

Eastern Model Unit North-South Section through Column 141 Showing Watertable Draped on Base of Layer 1 Model Dataset hmMLSTR1-3		
Date	Project Number	Approved:
8/21/05	13009.1	E.G.Lappala

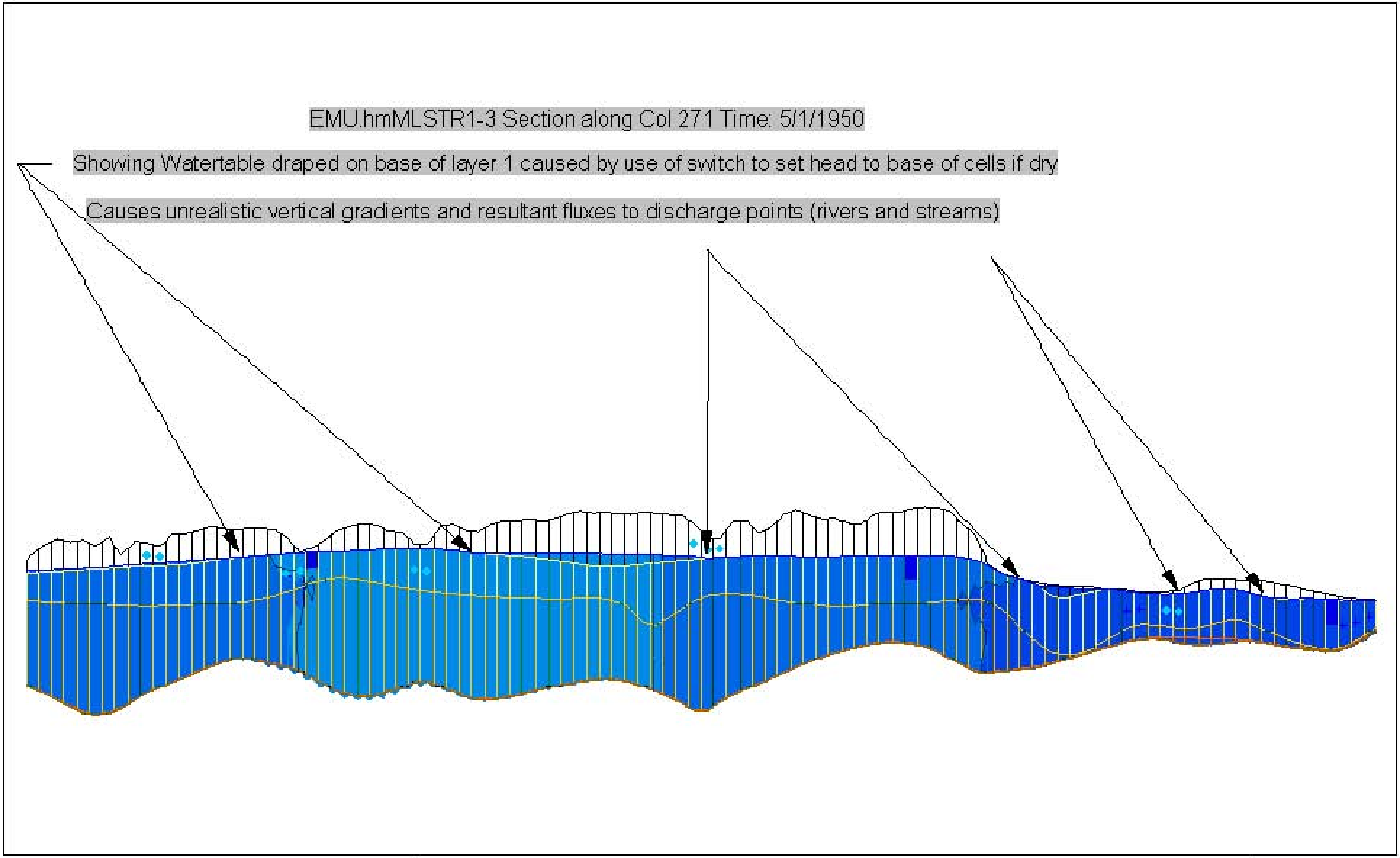
Figure 47



Eagle Resources
Advocacy → Sound Science → Innovation → Solutions

Eastern Model Unit North-South Section Through Column 141 Showing Watertable Correctly Allowed to Fall Below Base of Layer 1. Model Dataset hmMLSTR1-3		
Date	Project Number	Approved:
8/21/05	13009.1	E.G.Lappala

Figure 48



Eagle Resources
Advocacy → Sound Science → Innovation → Solutions

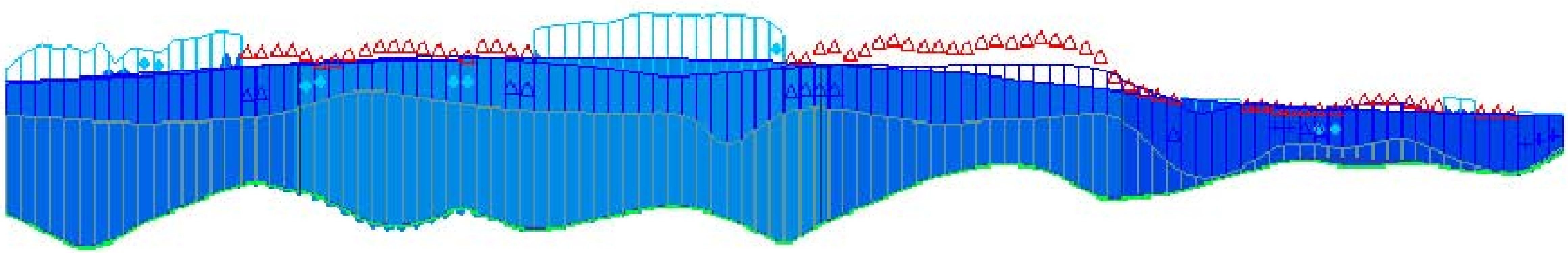
Eastern Model Unit North-South Section through Column 271 Showing Watertable Draped on Base of Layer 1 Model Dataset hmMLSTR1-3		
Date	Project Number	Approved:
8/21/05	13009.1	E.G.Lappala

Figure 49

EMU.hmMLSTR1-3 Section along Column 90 Time: 5/1/1950

Run made to allow cell drying and do not set head of dry cells to base of cell.

No unrealistic vertical gradients or fluxes to discharge points

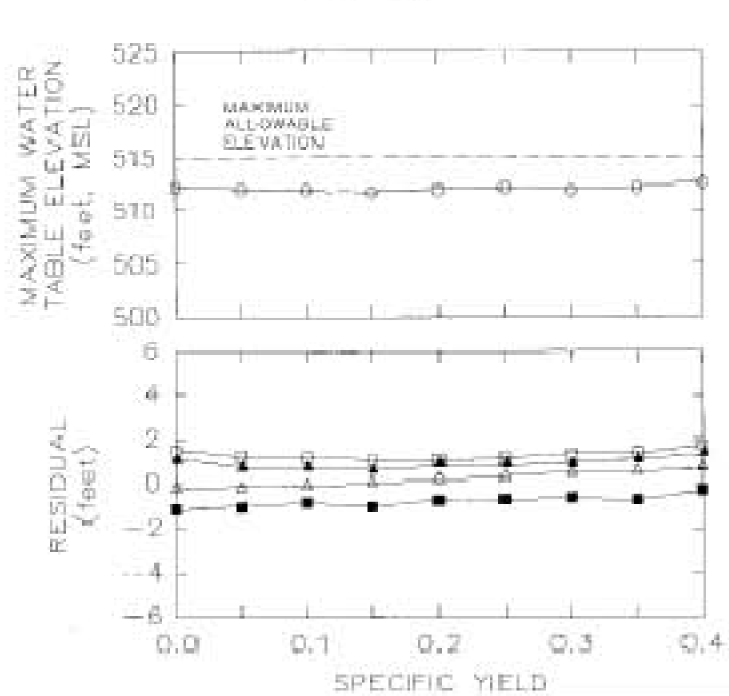


Eagle Resources
Advocacy → Sound Science → Innovation → Solutions

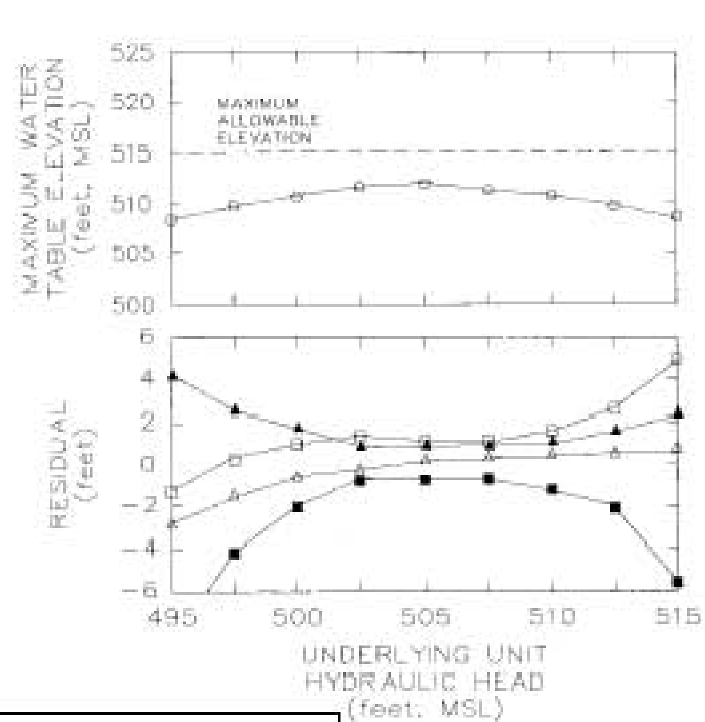
Eastern Model Unit North-South Section through Column 271 Showing Watertable Correctly Allowed to Fall Below Base of Layer 1. Model Dataset hmMLSTR1-3		
Date	Project Number	Approved:
8/21/05	13009.1	E.G.Lappala

Figure 50

TYPE I

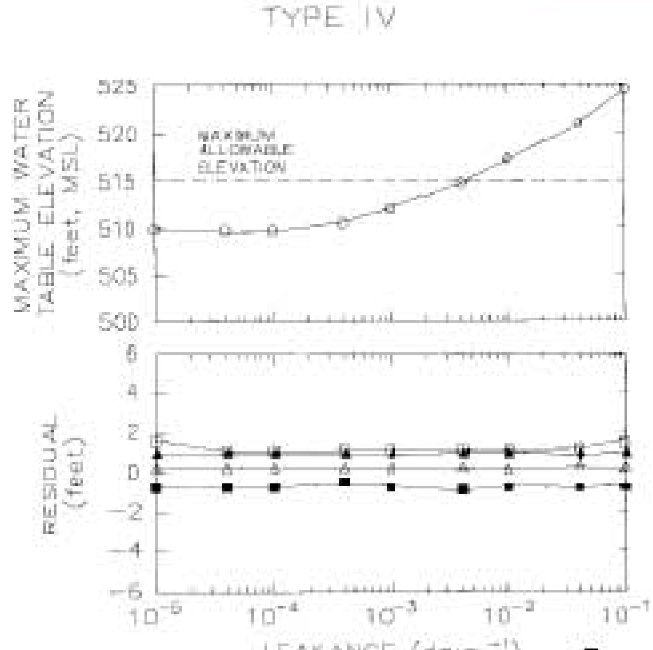


TYPE II

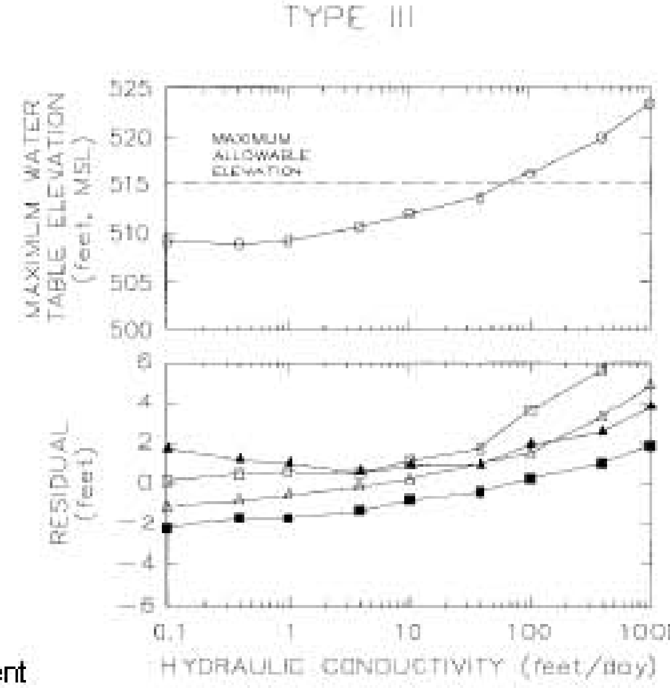


		CHANGE IN CALIBRATION RESIDUALS	
		Insignificant	Significant
CHANGE IN CONCLUSIONS	Insignificant	TYPE I Conclusions remain the Same independent of input values	TYPE II Conclusions remain the Same independent of input values
	Significant	TYPE IV Can invalidate model results because over the range of that parameter used for calibration, conclusions change. Requires methods to reduce range of parameter values	TYPE III Conclusions change in response to input values but calibration eliminates unrealistic values

TYPE IV



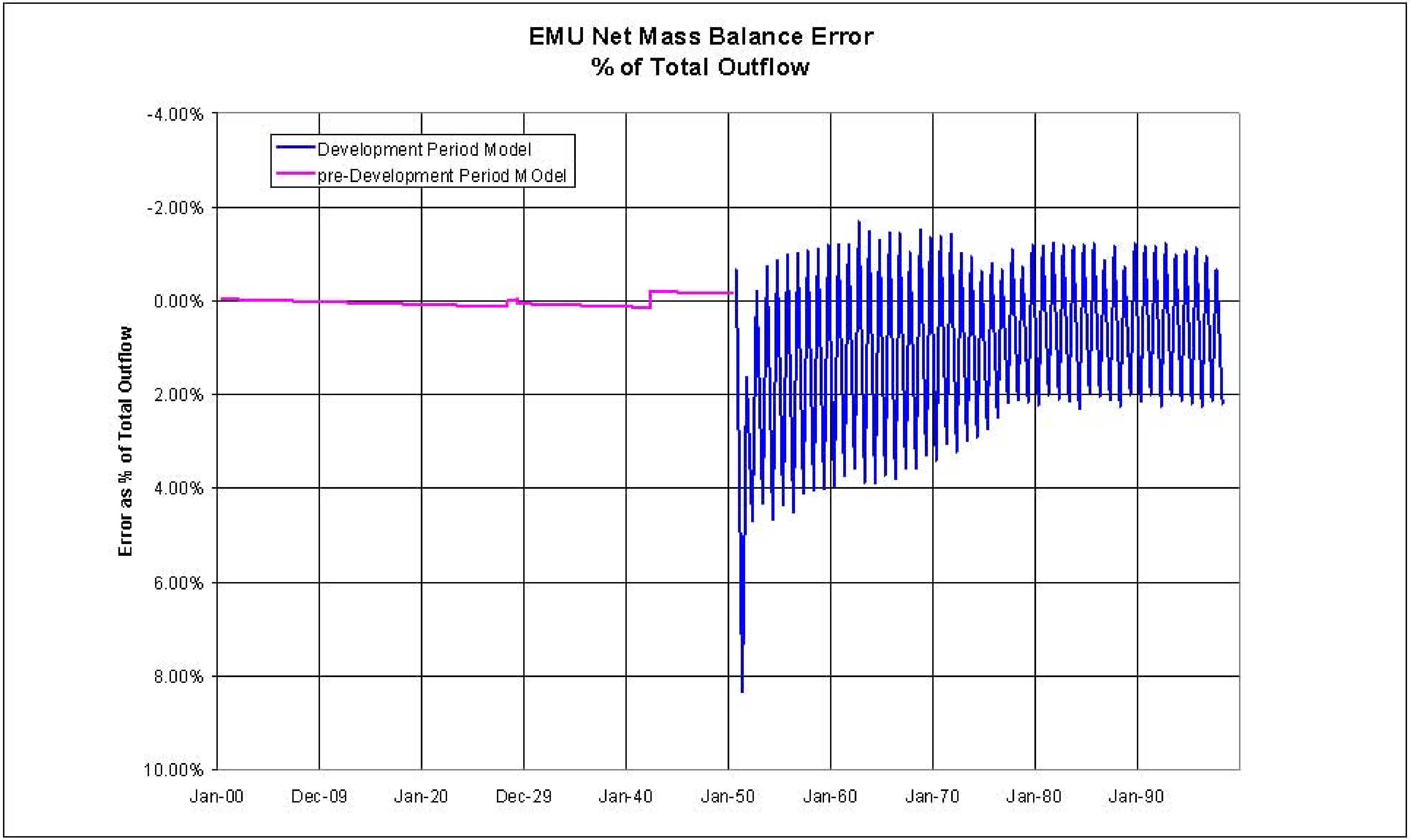
TYPE III



Eagle Resources
Advocacy → Sound Science → Innovation → Solutions

Four Categories of Calibrated Model Error ASTM Standard D 6511-94: Standard Guide for Conducting a Sensitivity Analysis for a Ground-Water Flow Model Application		
Date	Project Number	Approved:
8/22/05	13009.1	E.G.Lappala

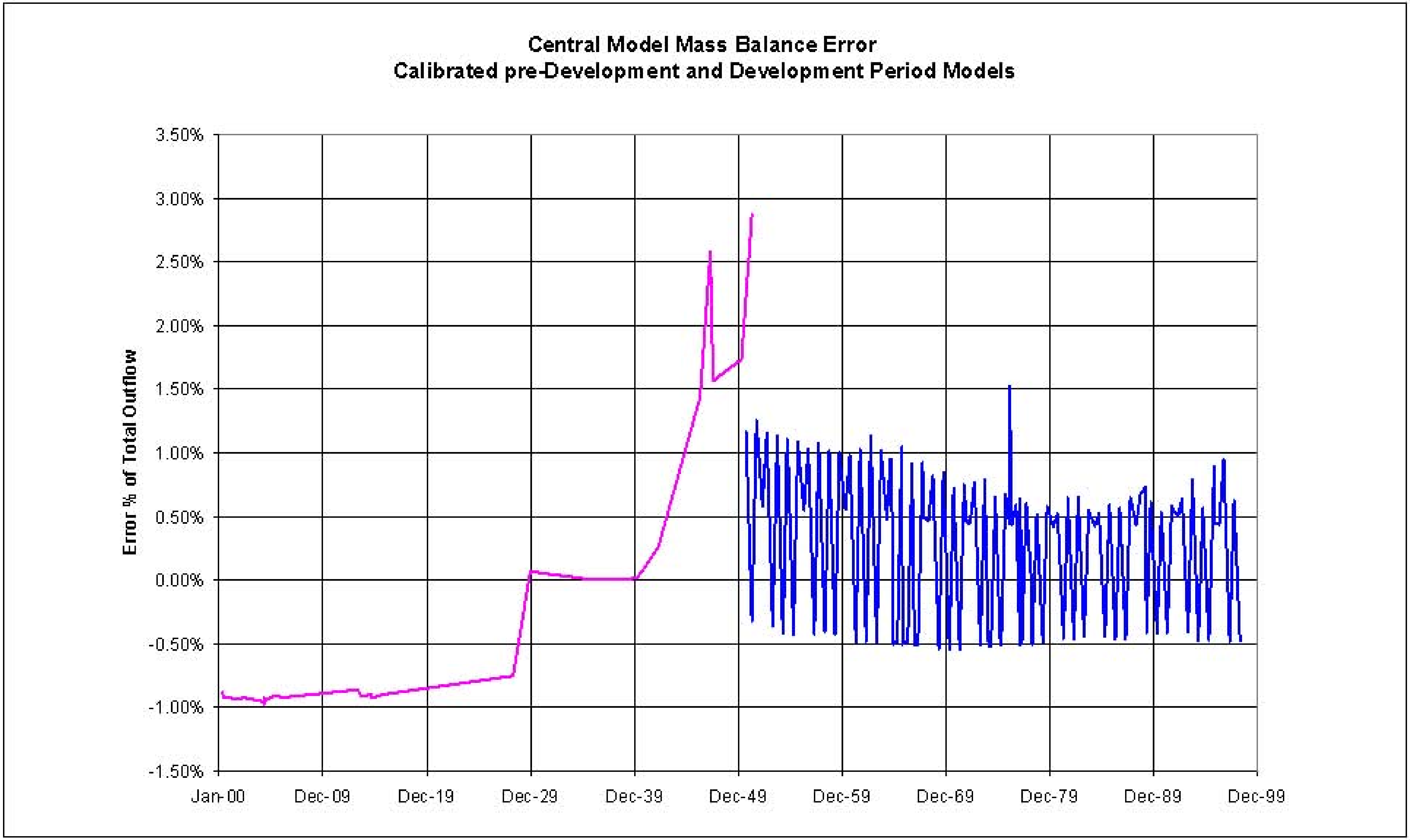
Figure 51



Eagle Resources
Advocacy → Sound Science → Innovation → Solutions

Eastern Model Unit Mass Balance Error as a Percentage of Total Simulated Outflow 1895-1998 Model Datasets hmMLSTR1-3 and hmMLdev1-5		
Date	Project Number	Approved:
8/21/05	13009.1	E.G.Lappala

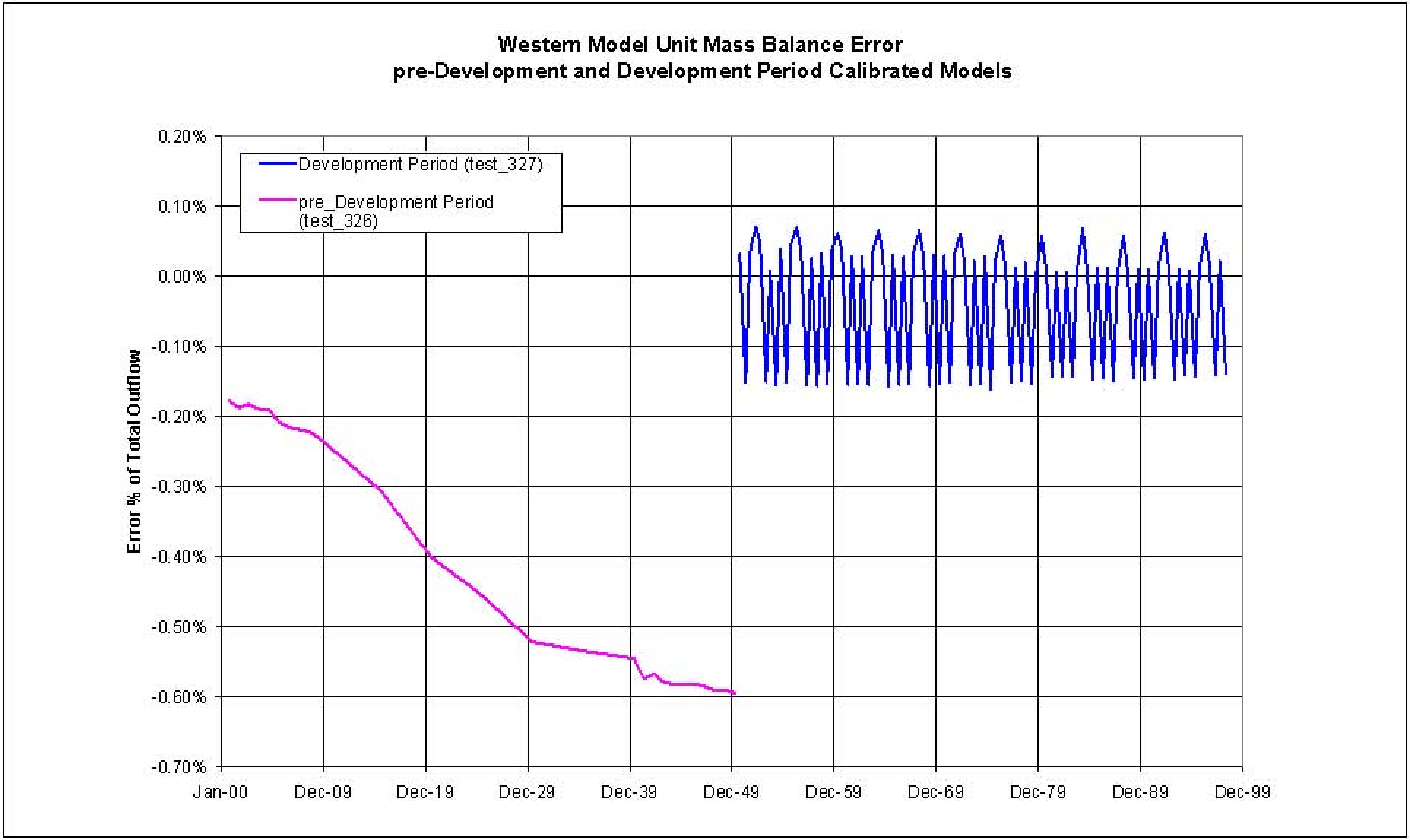
Figure 52



Eagle Resources
Advocacy → Sound Science → Innovation → Solutions

Central Model Unit Mass Balance Error as a Percentage of Total Simulated Outflow 1895-1998 Model Datasets CMUhm_PSTT_sim and and CMUhm_DevPeriod_sim		
Date	Project Number	Approved:
8/21/05	13009.1	E.G.Lappala

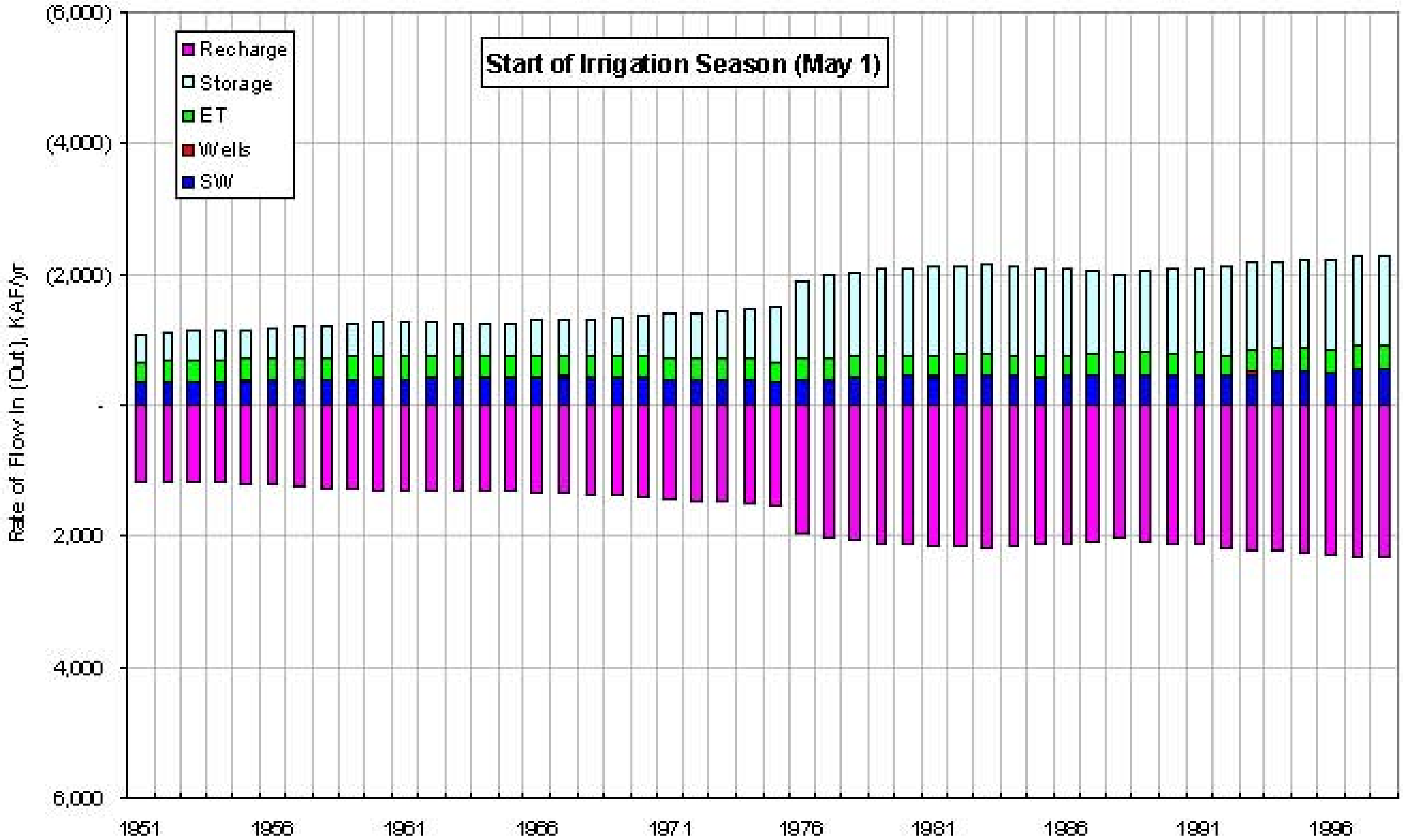
Figure 53

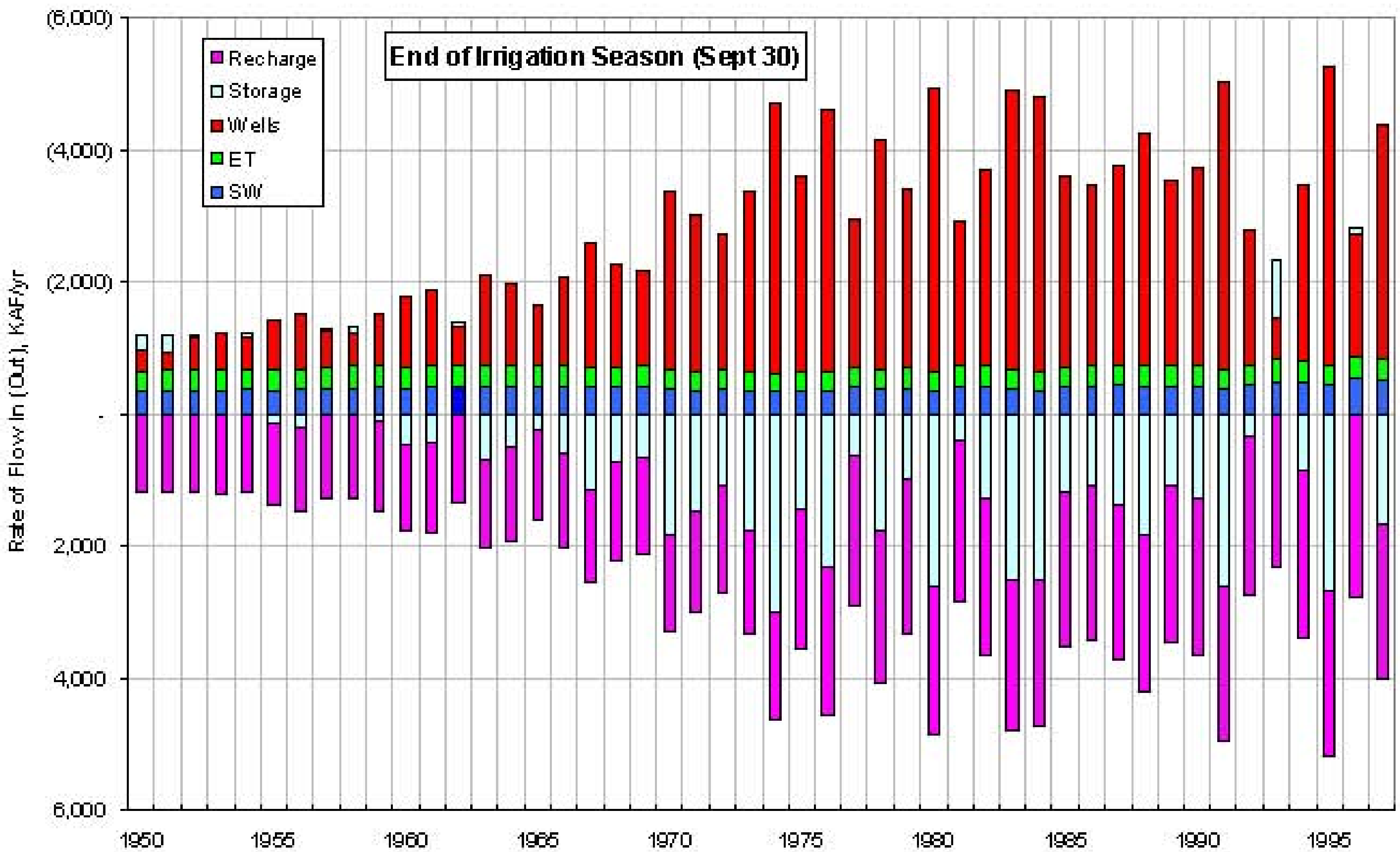


Eagle Resources
Advocacy → Sound Science → Innovation → Solutions

Western Model Unit Mass Balance Error as a Percentage of Total Simulated Outflow 1895-1998 Model Datasets test_326 and test_328		
Date	Project Number	Approved:
8/21/05	13009.1	E.G.Lappala

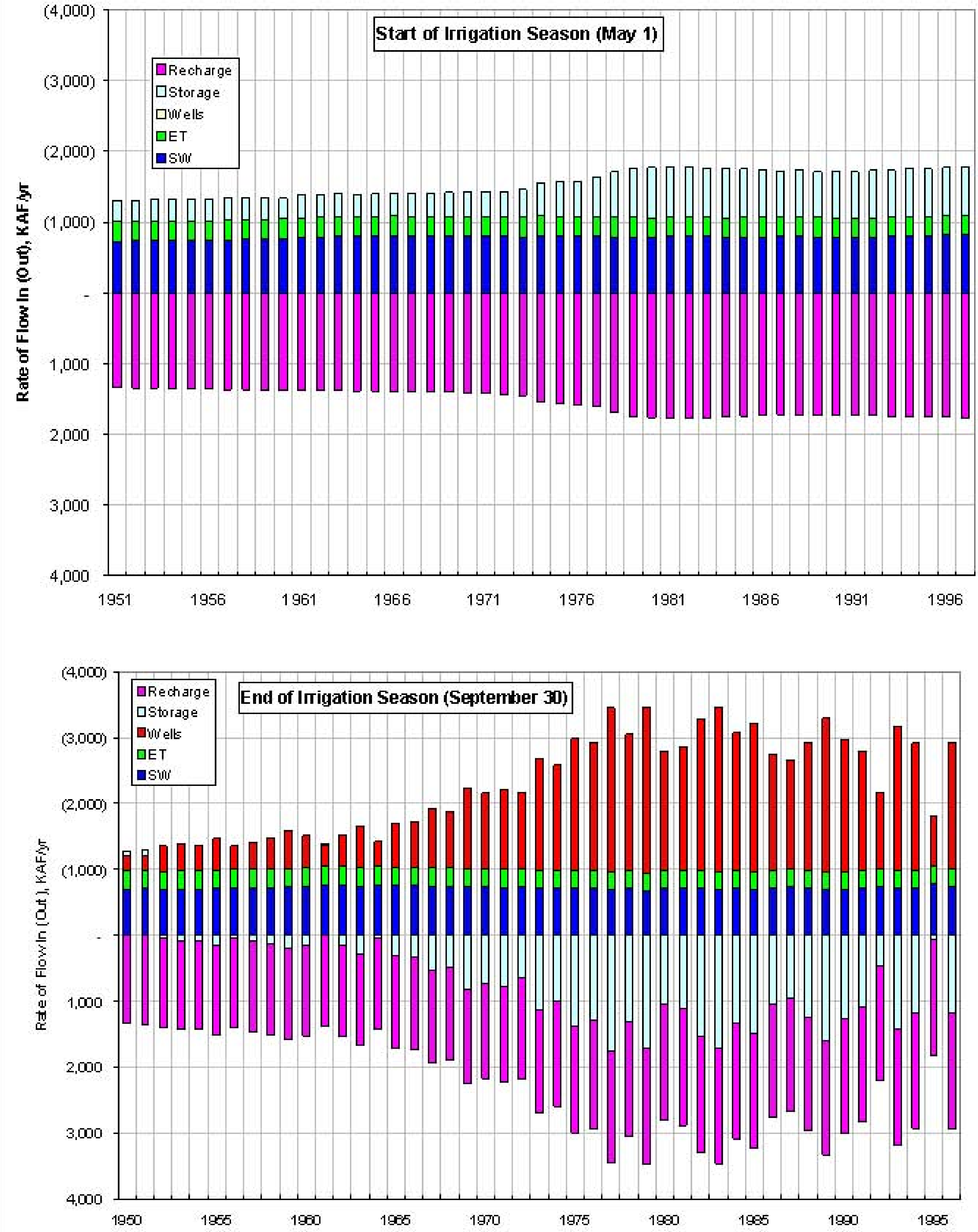
Figure 54



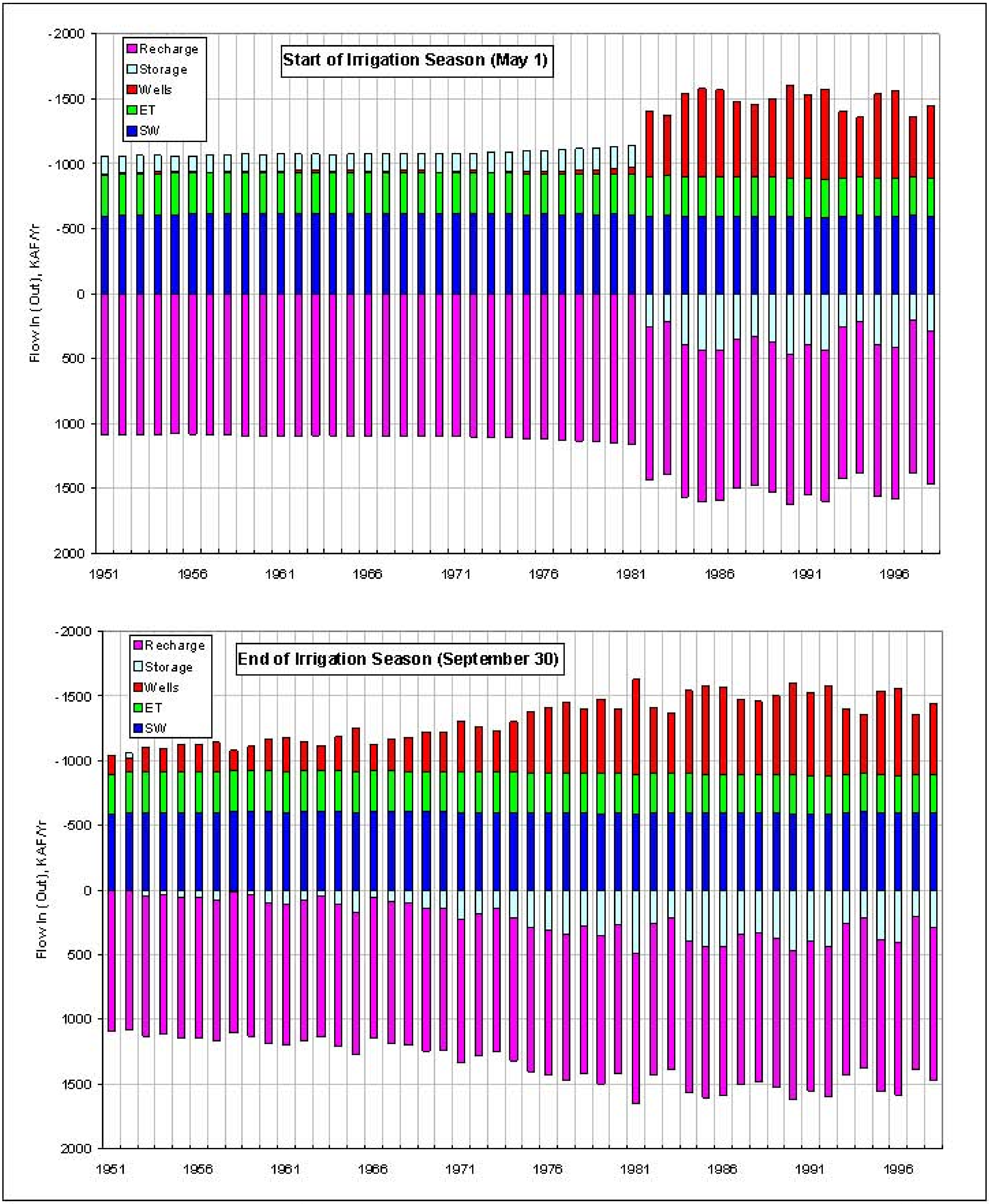


Eagle Resources
Advocacy → Sound Science → Innovation → Solutions

Eastern Model Unit Mass Balance Components at Start of Irrigation Season (May 1) and End of Irrigation Season (September 30)			Figure 55
Date	Project Number	Approved:	
8/22/05	13009.1	E.G.Lappala	



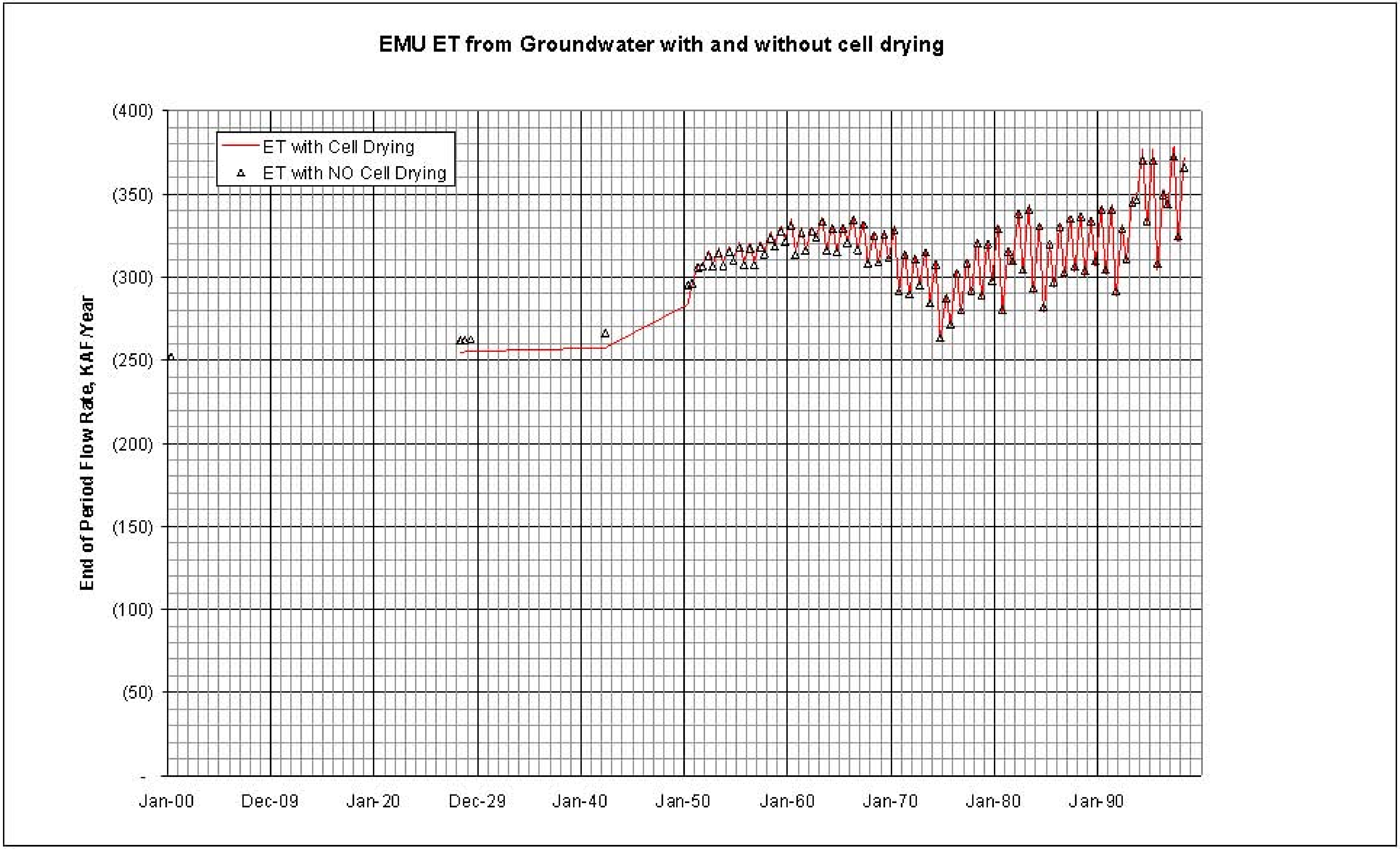
Central Model Unit Mass Balance Components at Start of Irrigation Season (May 1) and End of Irrigation Season (September 30)			**Figure 56**
Date	Project Number	Approved:	
8/22/05	13009.1	E.G.Lappala	



Eagle Resources
Advocacy → Sound Science → Innovation → Solutions

WesternModel Unit Mass Balance Components at Start of Irrigation Season (May 1) and End of Irrigation Season (September 30)		
Date	Project Number	Approved:
8/22/05	13009.1	E.G.Lappala

Figure 57



Eagle Resources
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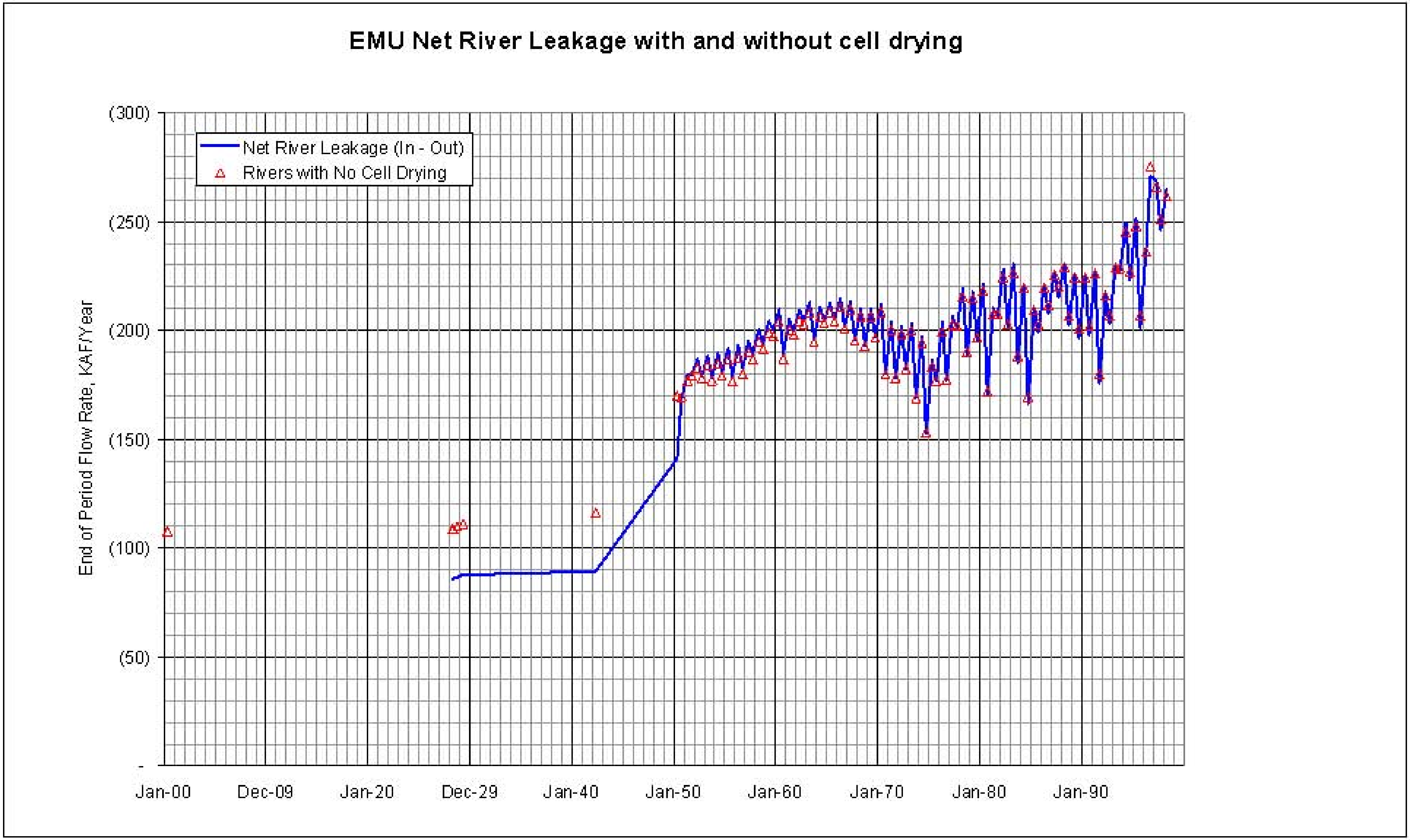
Eastern Model Unit Computed ET from Groundwater 1895-1998 Model Datasets hmMSTR1-3 and hmMLdev1-5		
Date	Project Number	Approved:
8/21/05	13009.1	E.G.Lappala

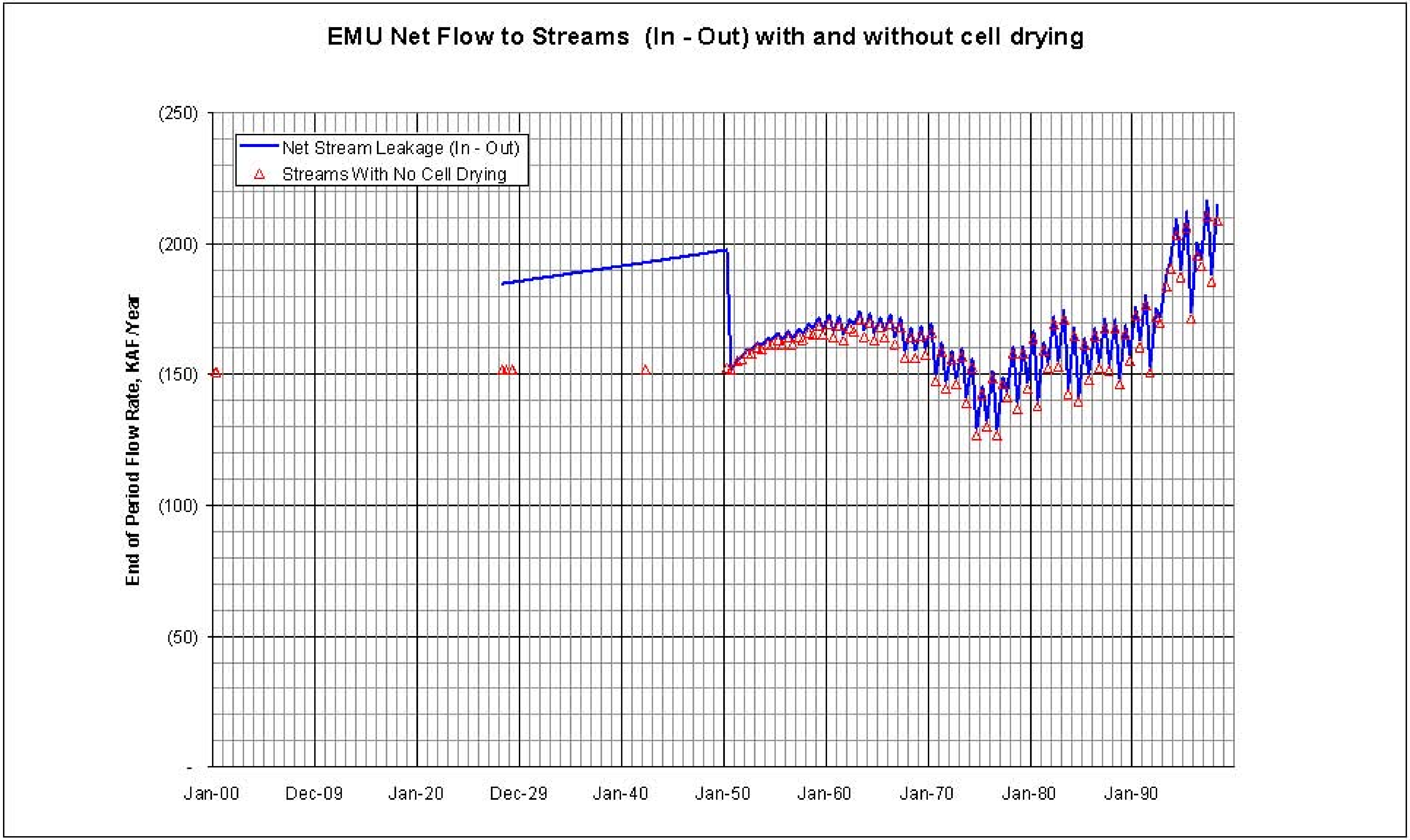
Figure 58



Eastern Model Unit Computed Net Groundwater Flow to Rivers 1895-1998 Model Datasets hmMSTR1-3 and hmMLdev1-5		
Date	Project Number	Approved:
8/21/05	13009.1	E.G.Lappala

Figure 59

Eagle Resources
Advocacy → Sound Science → Innovation → Solutions



Eagle Resources
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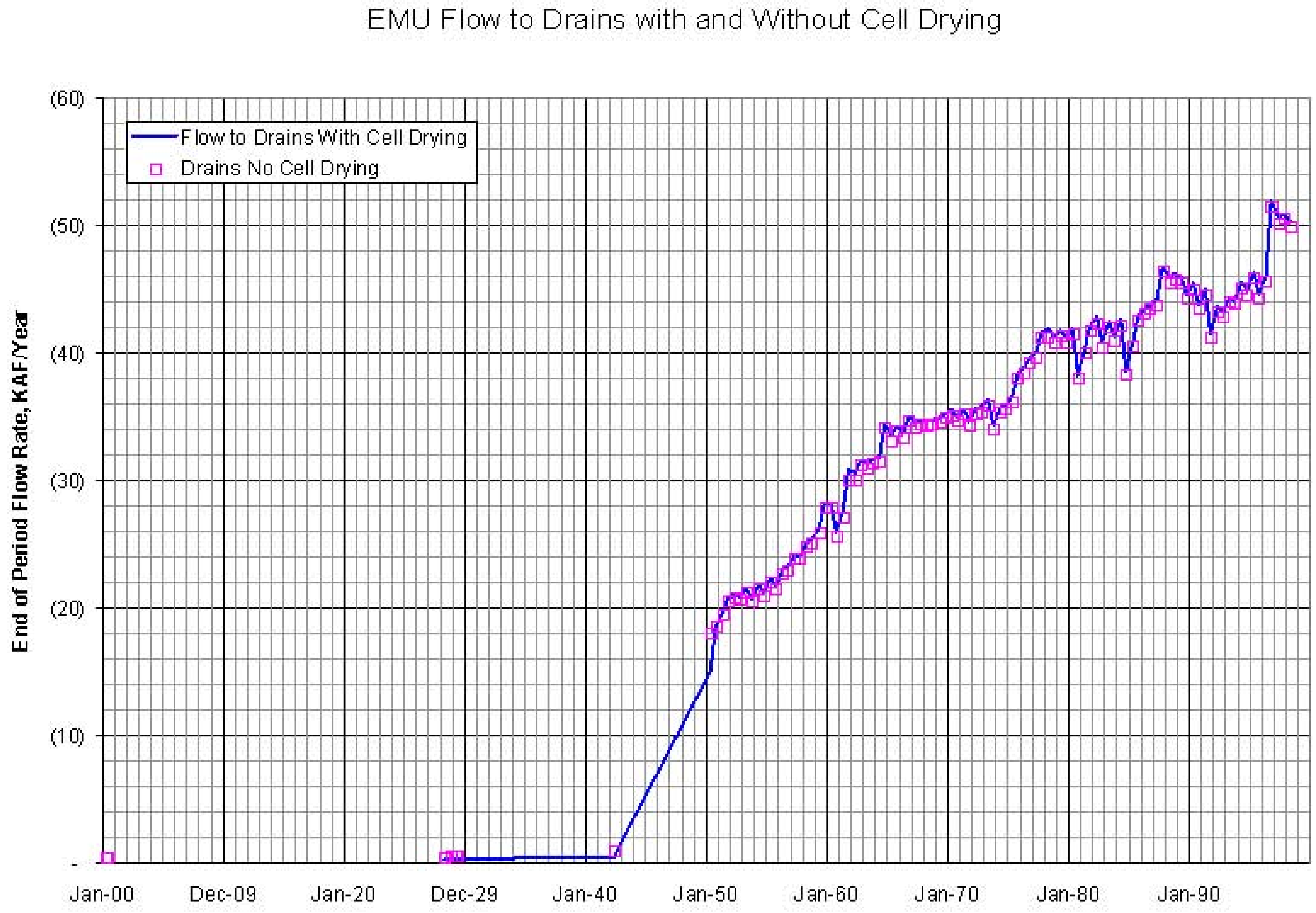
Eastern Model Unit Computed Net Groundwater Flow to Streams1895-1998 Model Datasets hmMSTR1-3 and hmMLdev1-5		
Date	Project Number	Approved:
8/21/05	13009.1	E.G.Lappala

Figure
60



Eastern Model Unit Computed Groundwater Discharge to Drains 1895-1998
Model Datasets hmMSTR1-3 and hmMLdev1-5

Date	Project Number	Approved:
8/21/05	13009.1	E.G.Lappala

Figure 61

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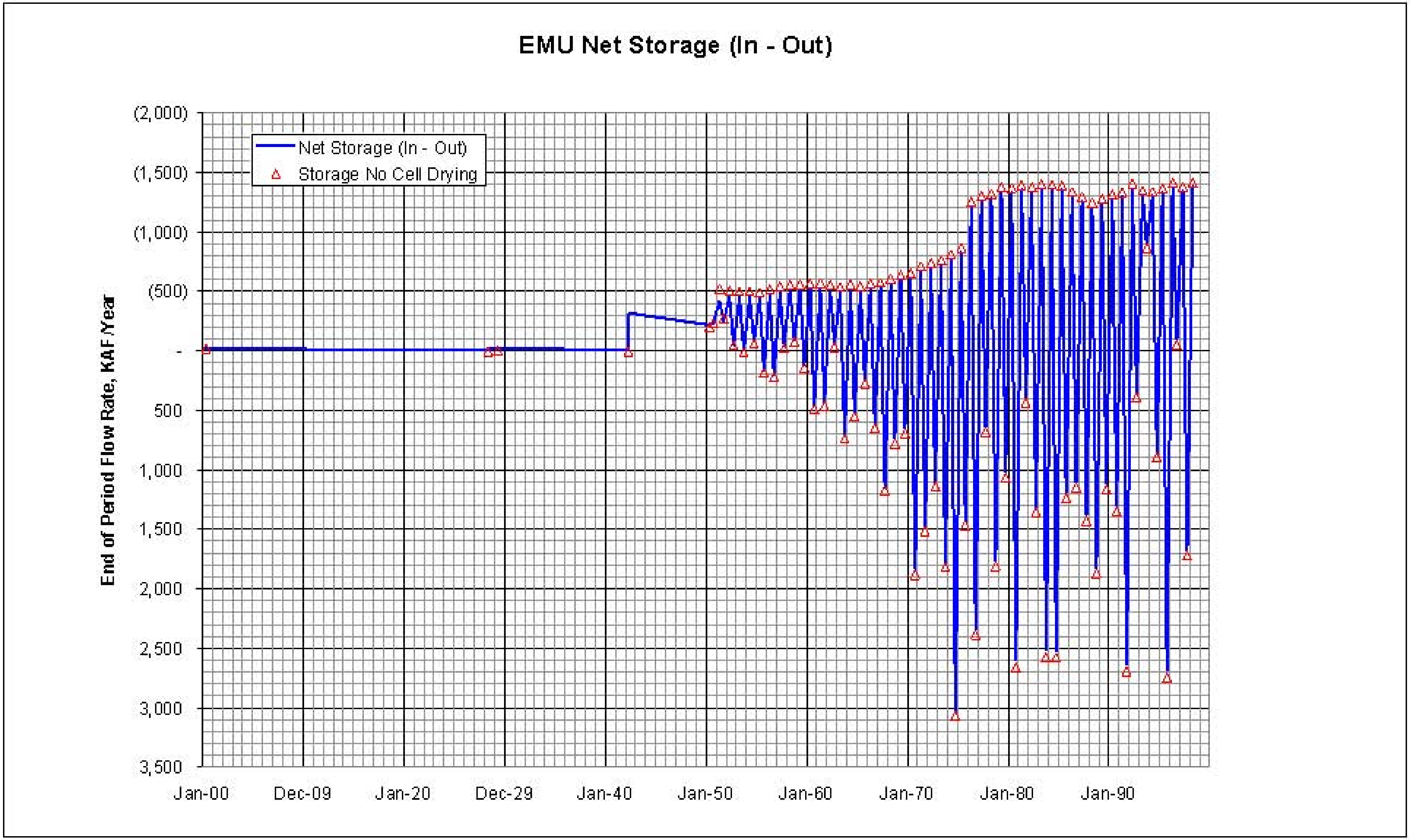

Eagle Resources
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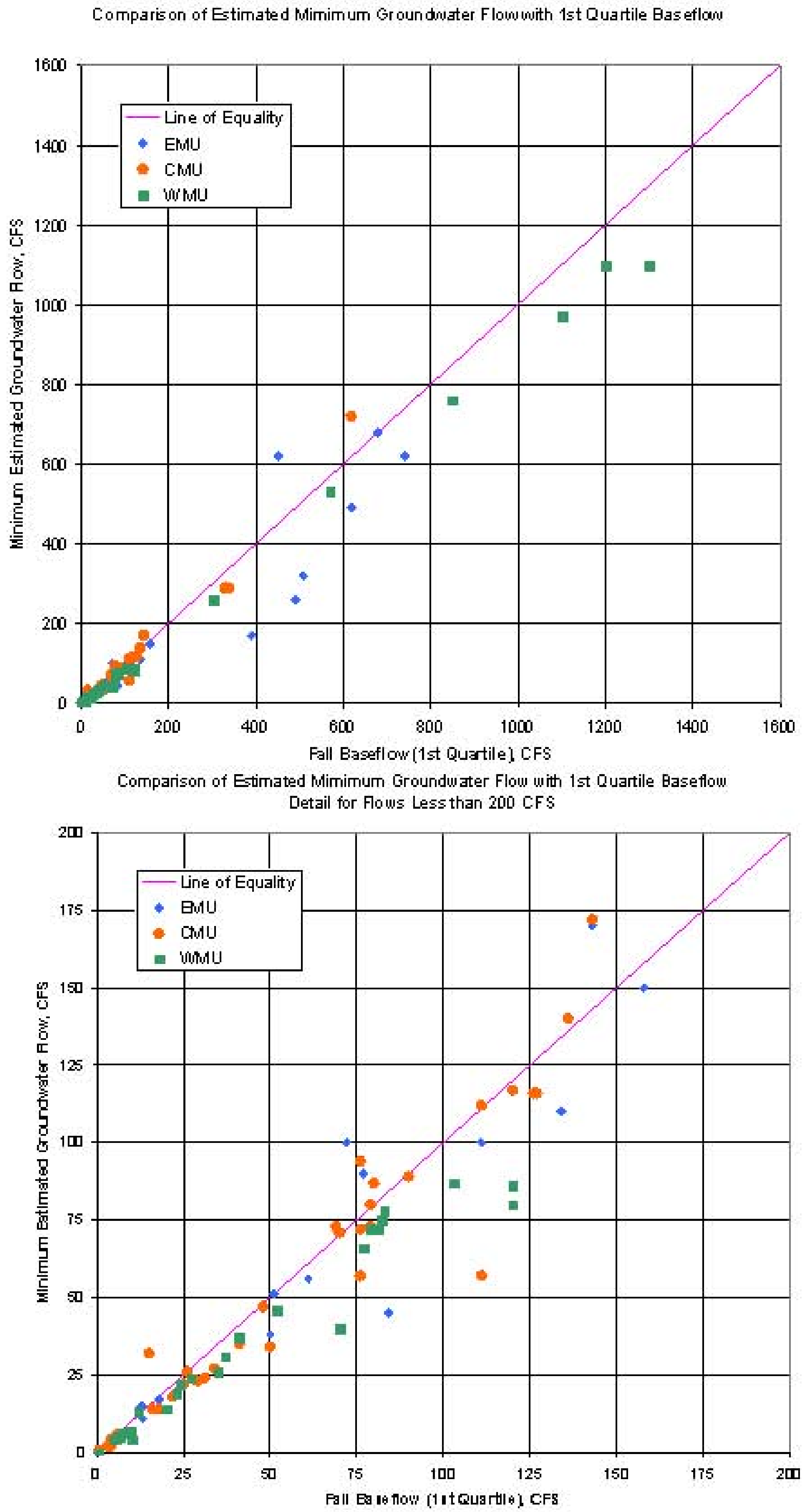
Eastern Model Unit Computed Net Flow to Groundwater Storage 1895-1998 Model Datasets hmMSTR1-3 and hmMLdev1-5		
Date	Project Number	Approved:
8/21/05	13009.1	E.G.Lappala

Figure 62



Comparison of Fall Baseflow as Estimated by the 1st-Quartile Flows from BFI Analysis with Minimum COHYST Estimated Groundwater Discharge Using 7Q5 Flows.		
Date	Project Number	Approved:
10/8/2005	13009.1	E.G.Lappala

Figure 63

Eagle Resources
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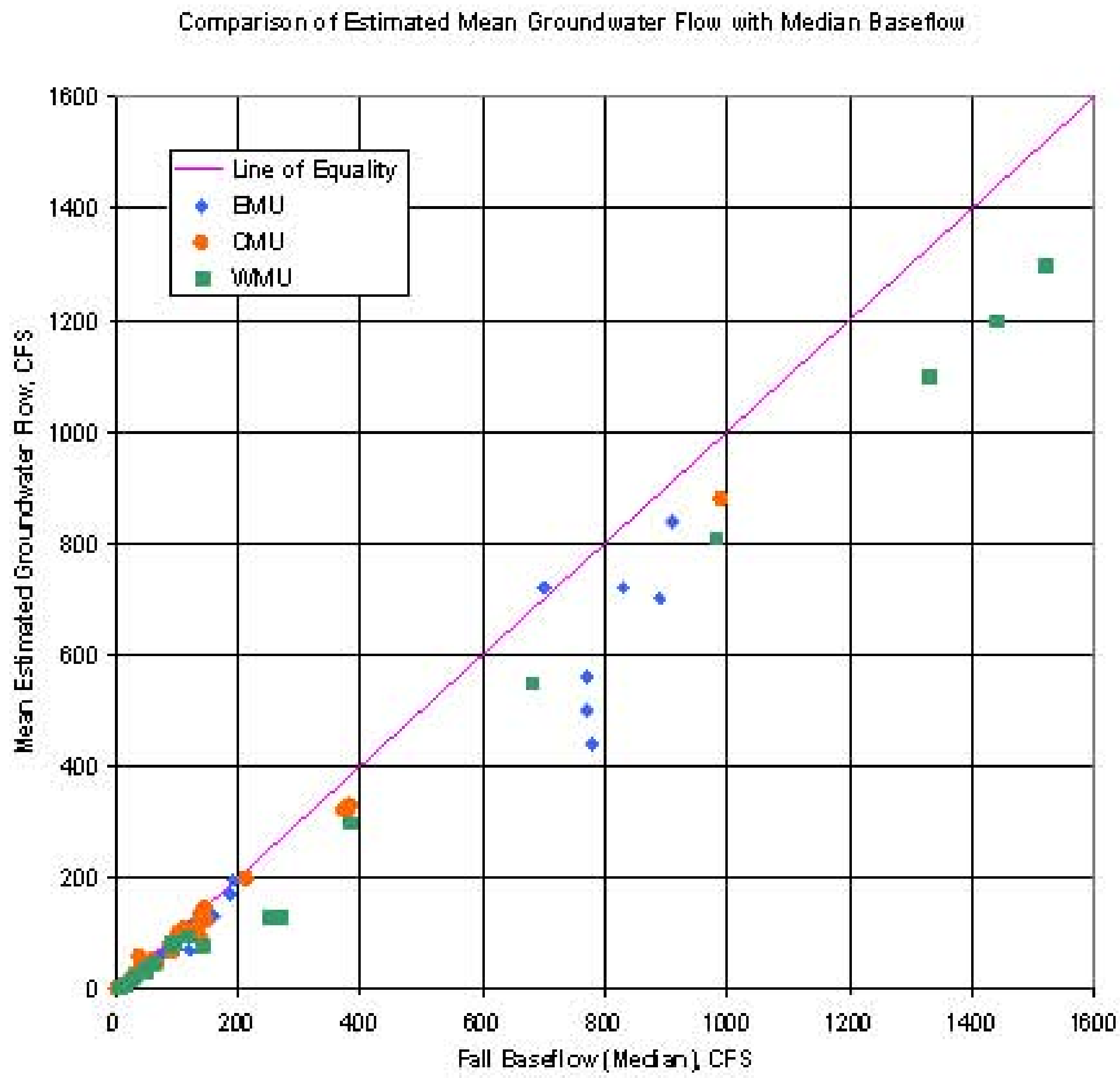

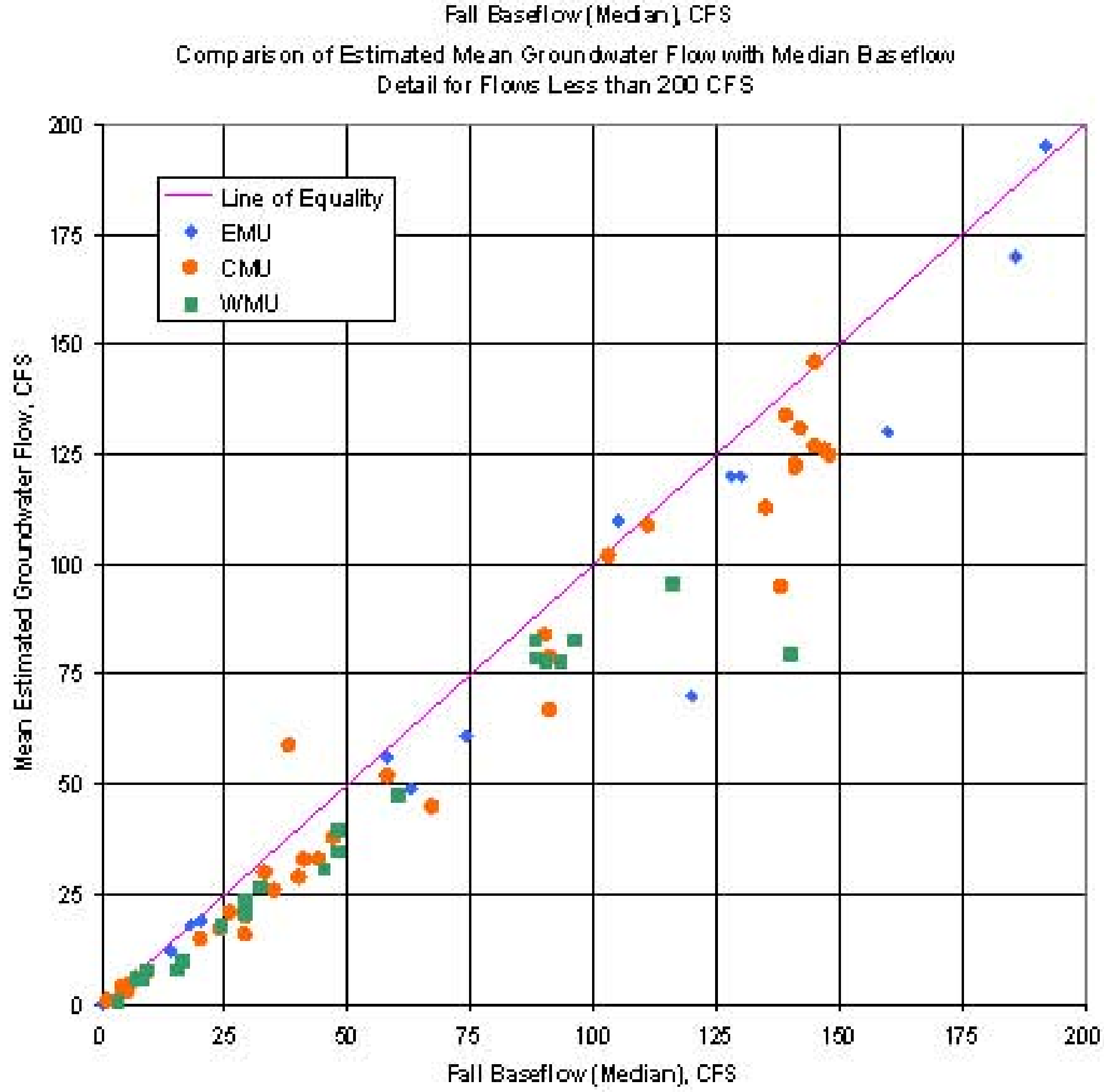

Comparison of Fall Baseflow as Estimated by the Median Flows from BFI Analysis with Mean COHYST Estimated Groundwater Discharge (Mean of 7Q5 and 14Q2 Flows)

Date	Project Number	Approved:
10/6/2005	13009.1	E.G.Lappala

Figure 64

Eagle Resources
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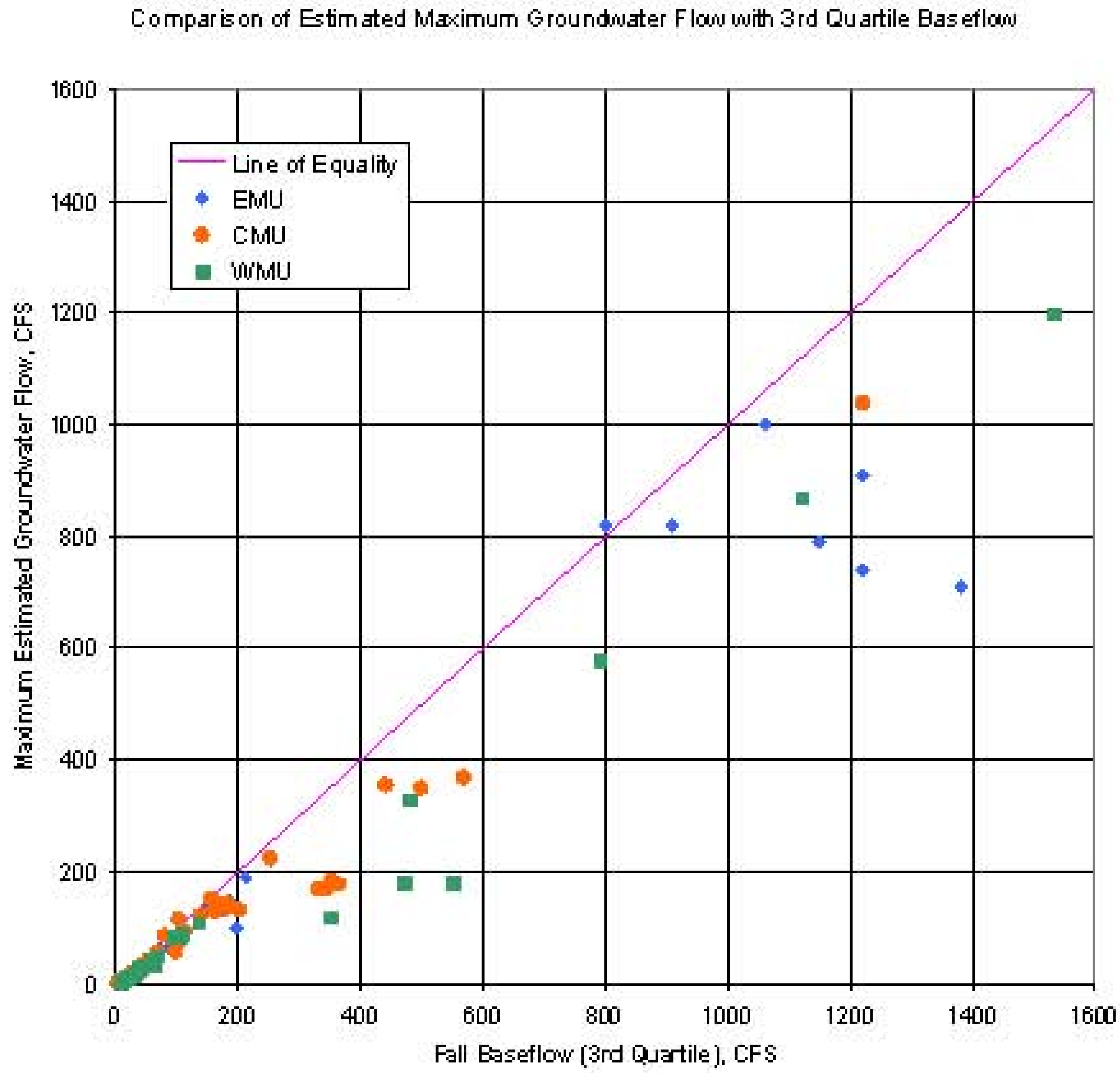

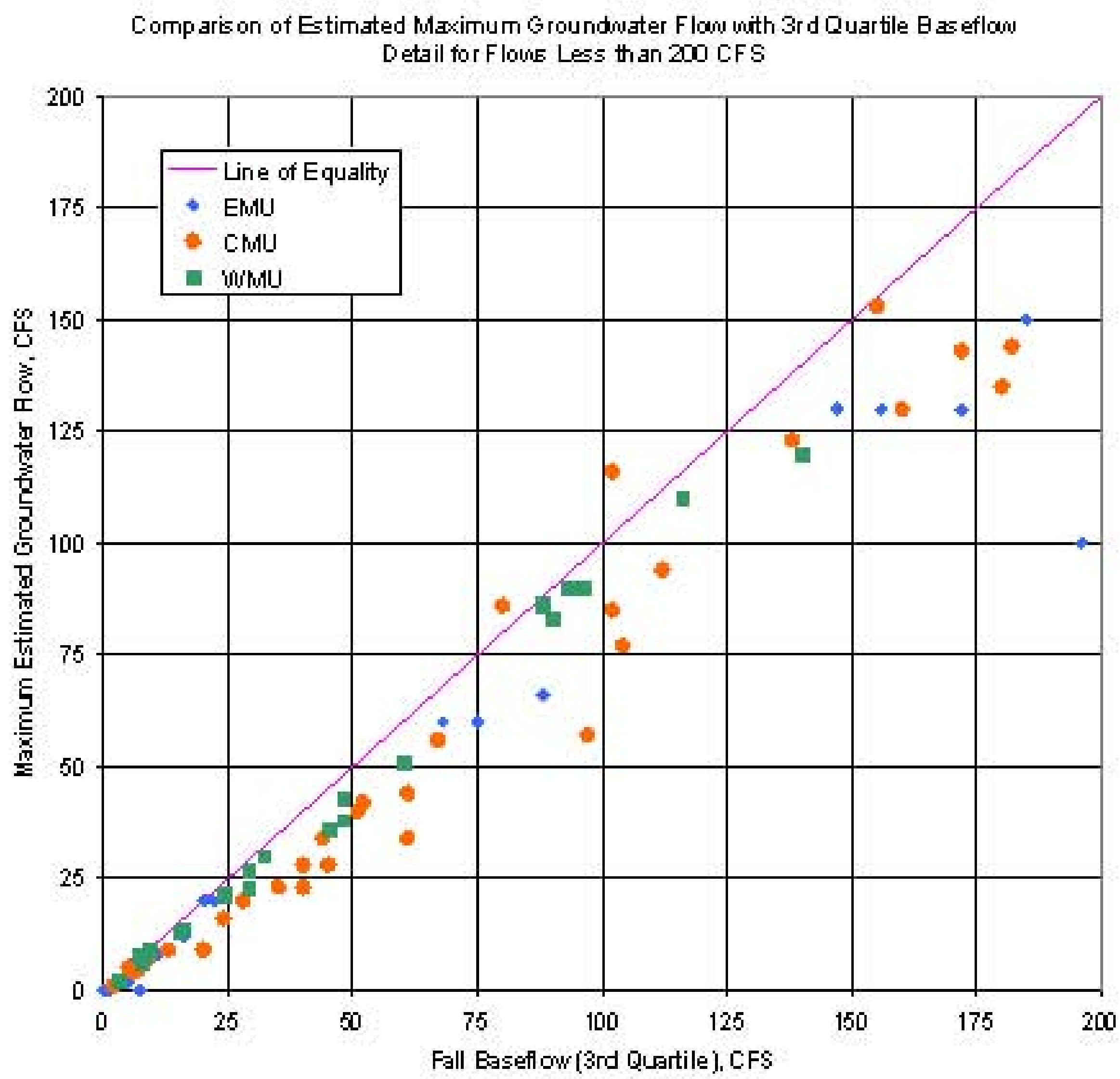

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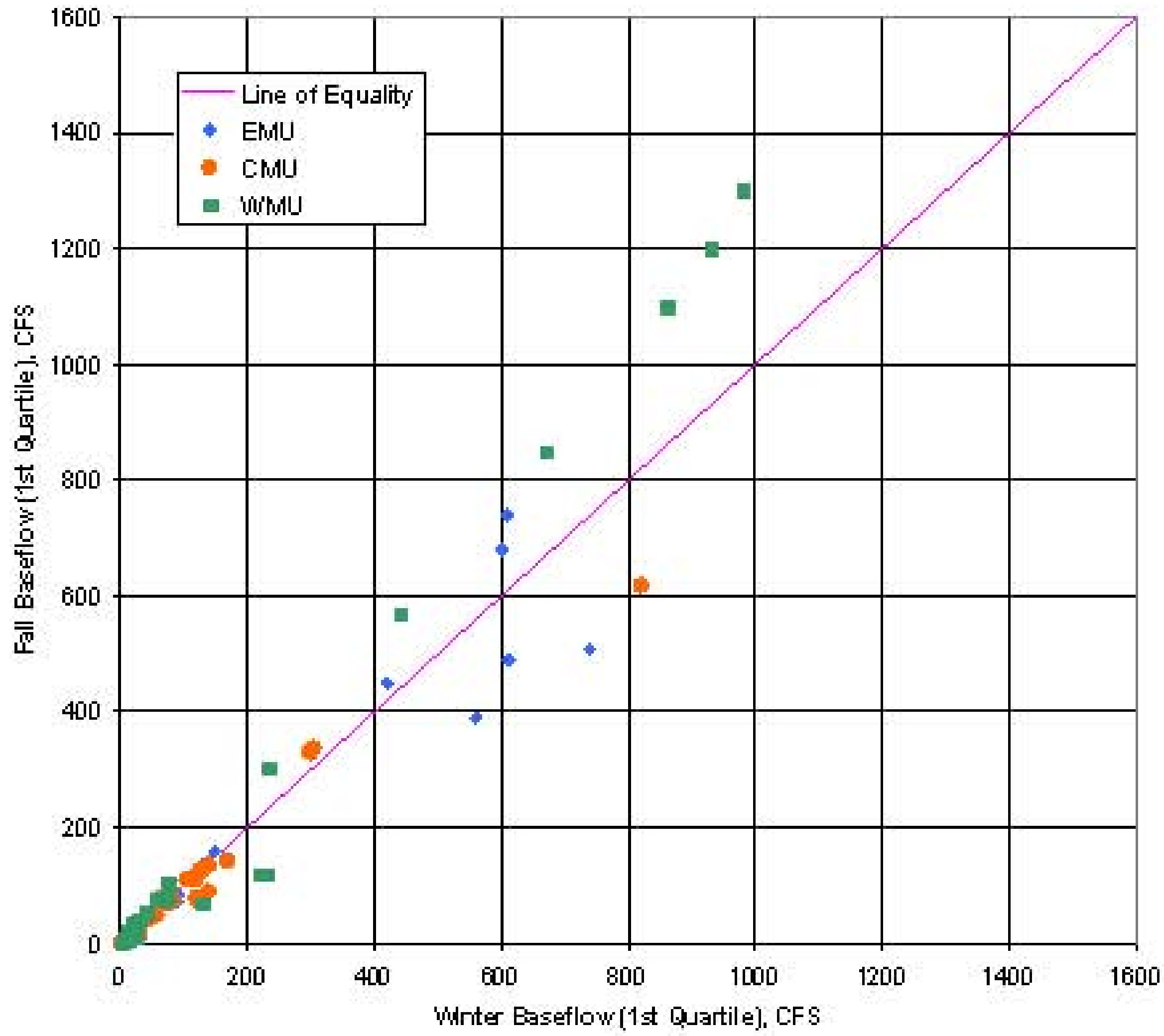
Comparison of Fall Baseflow as Estimated by the 3rd-Quartile Flows from BFI Analysis with Maximum COHYST Estimated Groundwater Discharge Using 14Q2 Flows.

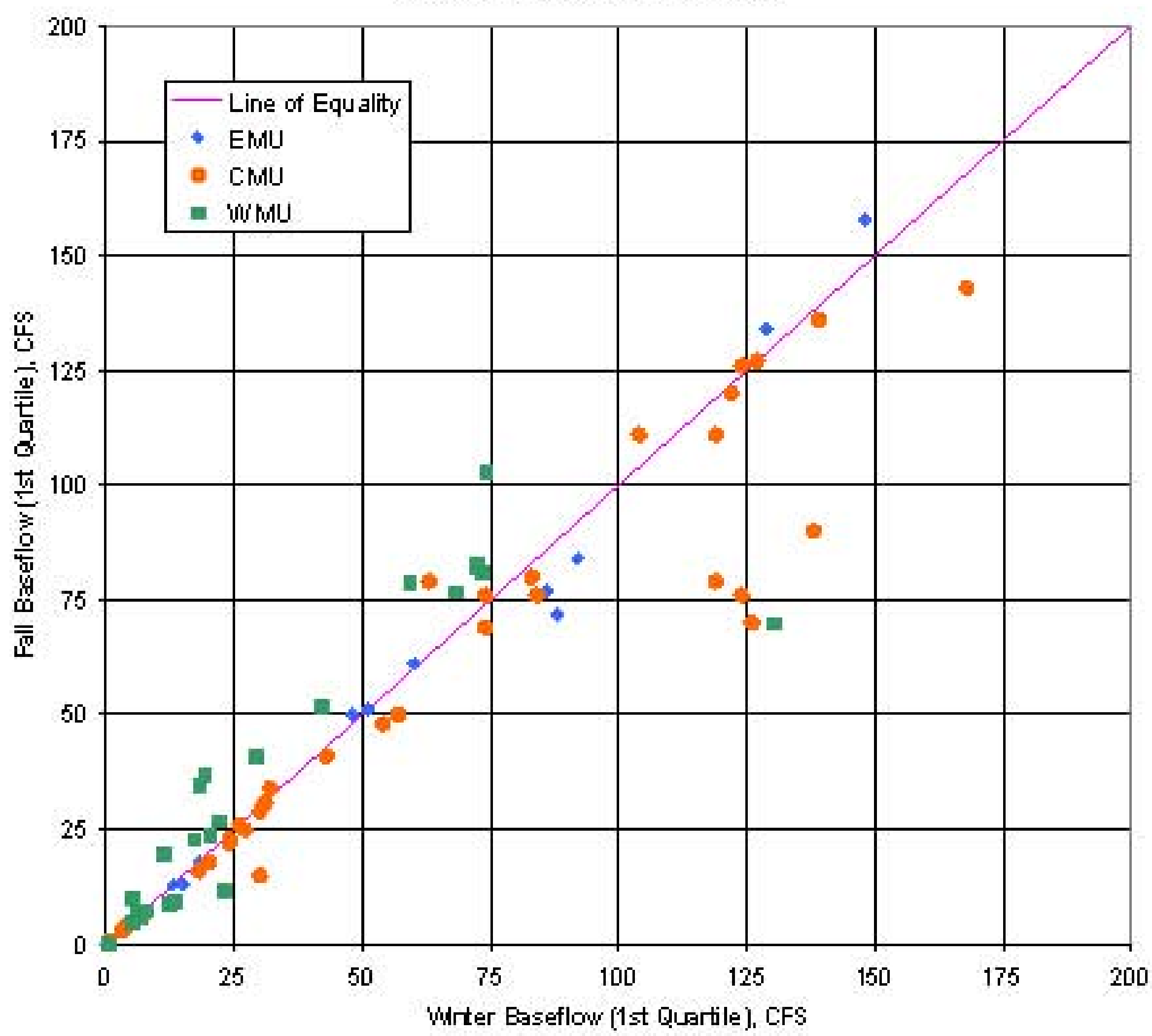
Date	Project Number	Approved:
10/8/2005	13009.1	E.G.Lappala

Figure 65

Comparison of Fall (Oct-Nov) with Winter (Oct-Mar) Baseflow Estimates from BFI



Comparison of Fall (Oct-Nov) with Winter (Oct-Mar) Baseflow Estimates from BFI
Detail for Flows Less than 200 CFS



Comparison of Fall (Oct-Nov) to Winter (Oct-Mar) Baseflow as Estimated by the 1st-Quartile Flows from BFI.

Figure 66

Date	Project Number	Approved:
10/8/2005	13009.1	E.G.Lappala

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Attachments

List of Attachments

Attachment A.—List of Reviewed Model and Supporting Data Files.

Attachment B.—Summary Table of Completeness and Adequacy Review, Eastern Model Unit

Attachment C.—Summary Table of Completeness and Adequacy Review, Central Model Unit

Attachment D.—Summary Table of Completeness and Adequacy Review, Western Model Unit

Attachment E.—Specific Review Comments: Eastern Model Unit Report

Attachment F.—Specific Review Comments: Central Model Unit Report

Attachment G.—Specific Review Comments: Western Model Unit Report

Attachment H. — Review of Reports on Estimated Groundwater Discharge of Streams in the Western, Central, and Eastern Model Units

Attachment I.—Processes and Problems with Using Alternative Approaches to Running MODFLOW

Attachment J.—Specific Review Comments, Specific Review Comments: Hydrostratigraphic Units and Aquifer Characterization Report

Attachment K. —Specific Review Comments: Final CropSim Update and Scenario Report and CropSim Documentation

Attachment L. — Specific Review Comments Unpublished Reports by Rich Kern, NDNR on Development of Recharge and Net Pumpage Datasets

Attachment M. — Specific Review Comments: Planning and Strategy Documents

Attachment N. — Specific Review Comments: The 40-Year, 28-Percent Stream Depletion Lines

Attachment O. — Response to Comments on Draft Peer Review Report provided by Richard R. Luckey, Steven J. Peterson, and Clint Case

Attachment A.—List of Reviewed Model and Supporting Data Files

List of Reviewed Model Data Files and Supporting Data.

Model Unit	Condition	Dataset name root	Can Open and Read COHYST Solution with GMS		Can Open and Run with GMS	
			Y/N	Comment	Y/N	Comment
EMU	Calibrated Pre-development period 1895-1950 as received	hmMLSTR1-3	Y		Y	
	Calibrated Pre-development period 1895-1950 corrected to allow layer drying	hmMLSTR1-3_Aloow_Drying	N/A		Y	Turned off option to set heads to base of dry cells
	Pre-development Sensitivity to 120% of Kh	STRKh120	Y		N/A	Did not attempt to run
	Development period 1950-1998 as received	hmMLdev1-5	Y		Y	
	Development period 1950-1998 corrected to allow layer drying	EGL_hmMLdev1-5_cell_drying	N/A		Y	Turned off option to set heads to base of dry cells
	Development period Sensitivity to 120% of recharge	devdlrech120	Y		N/A	Did not attempt to run
CMU	5000-year Pre-Settlement Transient Simulation	CMUhm_5Kyr_predev_sim	Y		Y	Did not attempt to complete run
	Pre Groundwater Development Period Simulation	CMUhm_PSTT_sim	Y		Y	
	Development Period Simulation	CMUhm_DevPeriod_sim	Y		Y	
	Dev Period Sensitivity decrease canal seepage 20%	hm_canalseep_20pct_dec_Sens	Y		N/A	Did not attempt to run
	Dev Period Sensitivity decrease dryland recharge 20%	hm_drylandrch_20pct_dec_Sens	Y		N/A	Did not attempt to run
	Dev Period Sensitivity decrease irrigated recharge 20%	hm_irrigatedlandrch_20pct_dec_Sens	Y		N/A	Did not attempt to run
	Dev Period Sensitivity decrease net pumpage 20%	hm_pumpage_20pct_dec_Sens	Y		N/A	Did not attempt to run
	Dev Period Sensitivity decrease specific yield 20%	hm_Sy_20pct_dec_Sens	Y		N/A	Did not attempt to run
	Pre Groundwater Development Period Sensitivity decrease canal seepage 20%	hm_PSTT_CanSeep_20pct_dec_Sens	Y		N/A	Did not attempt to run
	Pre Groundwater Development Period Sensitivity decrease recharge 20%	hm_PSTT_Rch_20pct_dec_Sens	Y		N/A	Did not attempt to run
	Pre Groundwater Development Period Sensitivity decrease Kh 20%	PSTThm_Kh_20pct_dec.out	Y		N/A	Did not attempt to run
	Pre Groundwater Development Period Sensitivity decrease Kh/Kv 20%	PSTThm_KhKvratio_20pct_dec_Sens	Y		N/A	Did not attempt to run
	Pre Groundwater Development Period Sensitivity decrease Sy 20%	PSTThm_Sy_20pct_dec_Sens	Y		N/A	Did not attempt to run
WMU	Calibrated pre-groundwater development period simulation	Test_326	Y		Y	
	Calibrated 1950-98 period simulation with CropSim 90% Uniform ET, 90% pumpage	Test_327	Y		Y	
	Calibrated 1950-98 period simulation with NebGuide 90%	Test_328	Y		Y	
	Sensivity analysis of pre-groundwater development period, last simulation only	Test_326_sensivity	Y		N/A	Did not attempt to run
	Sessivity analysis of 1950-98 period. Last simualtion only	Test_327_sensivity	Y		N/A	Did not attempt to run

Attachment B.—Summary Table of Completeness and Adequacy Review, Eastern Model Unit

Attachment B.-- Easterm Model Unit Completeness Review Checklist

Developed from ASTM D5718, D5490, D5611, D5979, and D5981 and Professional Experience

Project Element			Included in Report	Comment/ Adequacy Summary
Introduction	Objectives	Objectives	X	To follow modeling Strategy (However reasons for changing from original strategy not all documented)
		Purpose & Goals of Study	X	General COHYST purpose
		Applicability of Model as Part of Study	X	Under Modeling Strategy Section
		What types of predictions are to be done	X?	General discussion only Should be more specific up front
	Model Function	How will model be used to satisfy Objectives	X?	General discussion only Should be more specific up front
	Model Area Setting	Study Area Definition	X	Discussion and Map (Figure 1)
		Regional Topography	X	General topography discussed but no altitude range is included
		Geology	X	Geologic and Hydrostratigraphic Units Section
		Hydrology and Hydrogeology	X	Description of Eastern Model Unit Section: Climate (Precipitation and Lake Evap), Streamflow, Wetlands, ET, Watertable slope. Reference to Hydrostratigraphic units and HU report
		Land Use	X	
		Regional Map	X	Figure 1
		Previous Studies	X	No discussion of gaps or needed improvements in previous studies
	Study Time Domain	Applicable periods used	X	
	Who performed modeling	Individuals and responsibilities	No	No list of principal authors or modelers, or agencies. Should have included a section on this as significant work on recharge and pumpage was done by others (Neb DNR, Rich Kern)
Conceptual Model		Boundaries and General Description	X	Statement on p 18 justifying boundary selection is not clear. Arbitrary selection of project boundaries at political boundaries instead of hydrologic boundaries. Why not use Republican River for all of Southern Boundary except Harlan Co Reservoir? WMU was extended into CO and WO, and CMU was extended into CO. *** No discussion of upper and lower model boundary definition.***
	Aquifer system	Geologic	X	p 23, fig 9, Fig 8
		Hydrogeologic	X	

Attachment B.-- Easterm Model Unit Completeness Review Checklist (cont.)

Project Element				Included in Report	Comment/ Adequacy Summary
Conceptual Model (cont.)	Hydrologic Boundaries	Locations		X	Fig 7
		Flux (type 2)		X	Western, Eastern, SE Boundaries and portion of southern boundary in Nuckolls Co See comment on zero Flux along portion of West Fork of Big Blue R.
		Gradient GHB, (type 3)		No	Not used. See comments on preferred use of GHB to handle model overlap areas. Note CMU and WMU used GHB for Reservoirs
		Head (type 1)		X	Used for Harlan Co Reservoir. Note CMU and WMU used GHB for Reservoirs.
		Horizontal Flow (Wall) Barrier		X	Used for bedrock high in southern Franklin and Webster Counties
		Rivers	General Discussion	X	See comments about more appropriate use of Stream BC for all Rivers to allow Platte River to go dry during anticipated future simulation scenarios. Stream aquifer interaction discussion needs to state which parameters control the interaction rather than the general statement on top of p 20.
			Riverbed elevation	No	Not Discussed in Conceptual Model Section see Numerical Model Section
			River Stage	No	Not Discussed in Conceptual Model Section see Numerical Model Section
			Riverbed conductance	No	Not Discussed in Conceptual Model Section see Numerical Model Section
		Streams	General Discussion	X	See comments about more appropriate use of Stream BC for all Rivers to allow Platte River to go dry during anticipated future simulation scenarios. Stream aquifer interaction discussion needs to state which parameters control the interaction rather than the general statement on top of p 20.
			Streambed elevation	No	Not Discussed in Conceptual Model Section see Numerical Model Section
			Stream Stage	No	Not Discussed in Conceptual Model Section see Numerical Model Section
			Streambed conductance	No	Not Discussed in Conceptual Model Section see Numerical Model Section
		Drains	General Discussion	No	Inadequate discussion of the operation of drains. i.e. flow when the watertable rises to the specified elevation of the drain, no flow when watertable is below drain elevation
			Drain elevation	No	Not Discussed in Conceptual Model Section see Numerical Model Section
			Drain Conductance	No	Not Discussed in Conceptual Model Section see Numerical Model Section

Attachment B.-- Easterm Model Unit Completeness Review Checklist (cont.)

Project Element			Included in Report	Comment/ Adequacy Summary
Conceptual Model (cont.)	Hydraulic Properties	Layer Selection and Thicknesses	X	p 23. However, six hydrostratigraphic units were used, and 5 layers were used, with Hus 3 & 4 being lumped into one layer.
		Hydraulic Conductivity	X	No discussion or rationale as to why a single value of Kh was used for layers 1 and 5. No discussion regarding anisotropy. COHYST Test hole database, but methodology using grain size correlation not discussed or referenced. No support for values of vertical to horizontal anisotropy used.
		Confined, Unconfined, or Convertible	No	Not discussed in text for any layer
		Specific Storage	No	Not discussed at all however the model datasets show that a value of the Primary Storage Coefficient that is approximately equal to the layer thickness x the compressibility of water was used. Text says Initial constant value of 0.20 for all layers modified by calibration. Values for layer 1 in predevelopment data set are all set to 0.16 for layer 1 and spatially vary for all other layers. Not clear which values were used for the pre-development calibration
		Specific Yield	No	Mentioned in Executive Summary and in numerical model construction section, but basis for selection is not described not in conceptual model section. Text says Initial constant value of 0.20 for all layers modified by calibration. Values for layer 1 in predevelopment data set are all set to 0.16 for layer 1 and spatially vary for all other layers. Not clear which values were used for the pre-development calibration
		Porosity	No	Not discussed - not needed unless particle tracking is used
	Time Domain	Steady State	No	Not Discussed in Conceptual Model Section see Numerical Model Section
		Series of Steady States	No	Not Discussed in Conceptual Model Section see Numerical Model Section
		Transient	No	Not Discussed in Conceptual Model Section see Numerical Model Section

Attachment B.-- Easterm Model Unit Completeness Review Checklist (cont.)

Project Element				Included in Report	Comment/ Adequacy Summary
Conceptual Model (concluded)	Sources and Sinks	Wells/Pumpage		No	Not Discussed in Conceptual Model Section see Numerical Model Section
		Recharge		No	Canals are mentioned, but not the mechanism used to simulate them or the rationale for their elevations. No discussion of areally distributed recharge or the basis for determining it is included in the conceptual model section
		ET from GW		X	p 20 However, the ET surface used is not discussed in the conceptual model section, it is not discussed until the model calibration section. Check of the model datasets (see figure) shows that in 33% of cells where et was simulated that the et surface was greater than the mean land surface in cells where ET could have occurred
	Water Budget	Conceptual/semi quantitative		No	Not included in conceptual model
Computer Code Description	Code Selection	Code description		X	
		Selection Criteria		X	No criteria given regarding ease of future use, use by others, etc
	Assumptions	Justify based upon study objectives		X	P 23
	Limitations	Impacts on study objectives		No	GMS with properly formulated conceptual model is probably the best and easiest tool to assess changes in gw/sw interaction, However not discussed in report
	Solution Techniques			No	Not discussed in report. Model datasets show that all models used the Strongly Implicit Method, SIP
Model Construction	Model Domain	Map on topography		No	Not topographic map or topographic region map included
		Model grid size and layer selection		X	Grid selection and layers described in Numerical Model Section.
		Preprocessing	Methods	X	GMS Selected and used, although full conceptual model datasets not provided for review
			Codes used	X	GMS
	Time Domain	Steady State		X	Model strategy called for pre-Development period to be steady state, this apparently was abandoned and conditions in 1895 were simulated using a quasi steady state approach. Convergence problems caused by thin layers required by the GMS approach mandated this
		Series of Steady States		No	not used because of thin, highly permeable, continuous layers constructed in GMS
		Transient		X	Pre-Settlement, pre-Development, and development periods were transient

Attachment B.-- Easterm Model Unit Completeness Review Checklist (cont.)

Project Element				Included in Report	Comment/ Adequacy Summary
Model Construction (cont)	Hydraulic Properties	Hydraulic Conductivity		X	Uniform values assigned to each layer. Why was lateral variation within each layer not used based upon test hole logs?
		Specific Storage		No	In model datasets at 1e05, not discussed in reports value is low for silts and clays
		Specific Yield		X	One uniform value for all layers. Not clear why different values not assigned to each layer or laterally within each layer in accordance with the HU Report
		Porosity		No	Not included - no particle tracking used
	Sources and Sinks	Wells/Pumpage		X	Net Irr. Requirement pumpage computed by CROPSIM. Assignment of pumpage to only one layer, real world wells often interconnect Pleistocene and Ogallala deposits.
		Recharge		X	Recharge from precipitation was a model calibration parameter. Why was CROPSIM or similar method not used for rangeland recharge, using assumption that pre-1950 climate was similar to post 1950 period when climatic data was available?. Recharge from surface water irr. and canal leakage computed with help of canal records.
		ET from GW		No	Not discussed in Numerical Model Construction section
	Hydrologic Boundaries	Locations		X	Figure 7
		Flux (type 2)		X	Used at arbitrary political boundaries.
		Gradient GHB, (type 3)		X	Harlan Co Res on Republican R, although Fig 7 calls this BC a fixed head boundary. No discussion as to why GHB not used for arbitrary model boundaries, including those where models overlap.
		Head (type 1)		X	Fig 7 states that Harlan Co Res was Fixed Head BC, but model dataset shows that it is a general head BC
		Rivers	Riverbed elevation	X	Digital Elevation used for nodes on rivers and streams, GMS linear interpolation between nodes. No discussion re accuracy or resolution of DEM used.
			River Stage	No	No discussion in report regarding values used. Used stage = 2 ft above bed elevation based upon examination of model datasets, Note WMU used bed + 1 ft for stage, and CMU used bed + 2 ft for stage.
			Riverbed conductance	X	Initial values assigned based on size and character of stream and consideration of bed conductance studies. Values changed during calibration

Attachment B.-- Easterm Model Unit Completeness Review Checklist (cont.)

Project Element				Included in Report	Comment/ Adequacy Summary
Model Construction (concluded)	Hydrologic Boundaries (concluded)	Streams	Streambed elevation	X	Digital Elevation used for nodes on rivers and streams, GMS linear interpolation between nodes. No discussion re accuracy or resolution of DEM used.
			Stream Stage	No	No discussion in report regarding values used. Used stage = 2 ft above bed elevation based upon examination of model datasets, Note WMU used bed + 1 ft for stage, and CMU used bed + 2 ft for stage.
			Streambed conductance	X	Initial values assigned based on size and character of stream and consideration of bed conductance studies. Values changed during calibration
		Drains	Drain elevation	X	Digital Elevation used for nodes on rivers and streams, GMS linear interpolation between nodes. No discussion re accuracy or resolution of DEM used.
			Drain Conductance	No	No discussion in report regarding values used
	Numerical Parameters	Method used		No	Not discussed in report. Model datasets show SIP used.
		Parameters for Numerical Method		No	Not discussed in report. Model datasets show 8 SIP iteration parameters initially computed at start of simulation and an acceleration parameter of 0.95
		Closure Criteria		No	Not discussed in report. Note that closure criteria option in GMS set head in dry cells to base of cell - thus draping watertable on base of layer that contained initial head. Nodel datasets show head convergence criteria of 0.005 ft.
Calibration	Calibration Targets and Goals	Targets	Selection	X	Selection of head for pre-Development and head change for Development period
			Justification re project goals	No	No discussion of selection of model calibration targets relative to model goals
			Justification re project limits	No	No discussion of model limitations resulting from selection of calibration targets
		Goals	Selection	No	No discussion re what constituted the goal of model calibration for this project. I.E. no numerical metrics of acceptable calibration discussed
			Justification re project goals	No	No discussion of selection of model calibration goals relative to project goals
			Justification re project limits	No	No discussion of model limitations resulting from selection of calibration goals

Attachment B.-- Easterm Model Unit Completeness Review Checklist (cont.)

Project Element				Included in Report	Comment/ Adequacy Summary
Calibration (cont)	Selection of Calibration Targets	Distinct Hydrologic Condition Grouping	heads	No	No grouping of calibration targets by distinct Hus
			flows	X	Streams and River reach gains from baseflow estimate report for EMU
		Presentation of Target Data	maps	No	Not included in report,
			tables	X?	Head and water level change data not included in report, separate spreadsheets provided on request. Stream and river reach gains summarized for 1950 only in report, no analysis included to assess temporal changes
		Data Support for Targets	heads	No	Not included in report, separate spreadsheets provided
			flows	No	Summary tables showing only one point in time included, no analysis to assess temporal changes
	Selection of Calibration Parameters	Method Used	Sensitivity analyses to initial values	No	Not reported to have been used
			Ad Hoc Reasoning	X	Apparent method used to select calibration parameters. Note that claim of uniqueness in calibrated hydraulic conductivity and recharge for pre-development is not supported because streambed/riverbed conductance was also used as a calibration parameter. Not clear from report if ET parameters were changed during calibration.
		Summary of Calibration Parameters Selected		No	No table summarizing parameters and selection criteria
	History Matching	Methods Used	Manual	?	No documentation as to the calibration method(s) used
			Automatic	?	No documentation as to the calibration method(s) used
			Mixed	?	No documentation as to the calibration method(s) used
		Computed vs. Target Residuals Computed	Heads	X	Discussion of heads and head changes discussed, but no scatter charts included.
			Flows	No	No residuals computed, only simulated reach gain in 1950 compared to being "within range" of values estimated in the baseflow estimation reports. No assessment of changes during the calibration period for flows. Basis for flow target ranges uses arbitrary statistics, and does not account for observed temporal changes to some reach gains and losses

Attachment B.-- Easterm Model Unit Completeness Review Checklist (cont.)

Project Element				Included in Report	Comment/ Adequacy Summary
Calibration (concluded)	Residual Statistics	Max and Min	Heads	No	Not included as a reported statistic
			Flows	No	Not included as a reported statistic
		First Order: Means	Heads	X	Tables 4 and 10
			Flows	No	No residual reported for flows
		First Order: Absolute Means	Heads	X	Tables 4 and 10
			Flows	No	No residual reported for flows
		Second Order: Standard Deviation/RMS	Heads	X	Tables 4 and 10
			Flows	No	No residual reported for flows
		Second Order: Standard Error of Estimate	Heads	No	Statistic not computed or reported
			Flows	No	Statistic not computed or reported
		Second Order RMS normalized to observed max - min	Heads	No	Statistic not computed or reported
			Flows	No	Statistic not computed or reported
	Residual Correlation	Listing	Heads	No	No table of residuals
			Flows	?	No residuals computed, but Table 6 shows computed 1950 reach gains compared to base flow estimates using period of record 7Q5 and 14Q2 flows
		Scattergram observed vs. computed	Heads	No	Not included in report, data to do so provided in separate spreadsheets
			Flows	No	No measured vs. observed means or other stats plotted
		Spatial Correlation (Maps)	Heads	X	Maps comparing simulated and observed or otherwise estimated heads included in Figures 17 and 18. Comparison of simulated and observed or otherwise estimated head changes shown in Figures 20, 21, & 22.
			Flows	No	No maps showing comparison of observed and simulated reach gains
		Temporal Correlation (Transient Analyses)	Heads	No	No analysis of the correlation of residuals over the 4 transient calibration periods
			Flows	No	No temporal calibration to flows
	Resultant Calibrated Model Parameters	Comparison to Initial Estimates	Range	No	No table, map, or discussion in text of changes to mean or range of values
			Means	No	No table, map, or discussion in text of changes to mean or range of values
		Justification of Changes from Calibration		No	No discussion of the justification of the changes that were made to any calibration parameters

Attachment B.-- Easterm Model Unit Completeness Review Checklist (cont.)

Project Element				In Report	Comment/ Adequacy Summary
Sensitivity Analyses	Sensitivity Analyses with Calibrated Model	Goals		No	No discussion of the goals of sensitivity analyses: I.E. to assess model uncertainty
		Procedures used		X	For parameters used the method is discussed in the text
		Justification of parameters and ranges used	parameters	No	Not all calibration parameters were used in sensitivity analyses
			ranges	No	Ranges selected were apparently arbitrary, and not based upon the amount of change during calibration or on other criteria to set reasonable ranges
		Justification of model output used for analyses		No	Analyses apparently did not consider the most important metric for which the models are to be used: changes to reach gains and losses of the Platte River. Only flow sensitivity analyses included were for small tributaries to the Republican River
		Method used	MF2k	No	MODFLOW 96 was used
			Ad hoc	X	From report, it appears an arbitrary ad-hoc method was used
			Mixed	?	
		Sensitivity Types Identified for each Parameter (Change in Conclusions vs. Change in Calibration	Type I	No	No Sensitivity Error Analyses included
			Type II	No	No Sensitivity Error Analyses included
			Type III	No	No Sensitivity Error Analyses included
			Type IV	No	No Sensitivity Error Analyses included
		Results Reported	Charts	X	Figures 24, 25, and 26
			Maps	No	No maps showing sensitivity by area included, therefore, no map showing relative model reliability was included
			Statistics Tables	No	No
Model Verification	Model Verification Simulation	Included?		No	Amount of historical data assembled for COHYST is adequate to use verification analyses, and it would have strengthened confidence in models
		Goals		No	
		Results	maps	No	
			tables	No	
		Residuals	maps	No	
			tables	No	
	Mass Balance Analysis	Model-wide Mass Balance and Water Budget	Tables	X	Tables 7 and 11
			Discussion of Components	X	No discussion of the differences in relative magnitude of mass balance components between pre-Development and Development Periods. No presentation or discussion of time changes of components over time.
			Compare to Conceptual Model	No	No water balance discussion included under Conceptual Model section of report.
			Precision	No	No discussion in report
		Zones or areas of Interest Mass Balances	Included	No	No zonal water balances for areas of interest included in report
			Discussion of Components	No	No zonal water balances for areas of interest included in report

Attachment B.-- Easterm Model Unit Completeness Review Checklist (concluded)

Project Element				Included in Report	Comment/ Adequacy Summary
Predictive Simulations		Included?		No	
		Description of Simulations	Relate to model objectives	No	No example scenarios were developed for application of predicative analyses
		Changes made to calibrated model	Necessary or done?	No	N/A
			Effect on calibration	No	N/A
		Metrics	Heads	No	N/A
			Flows	No	N/A
		Results	Relevance to COHYST objectives	No	No example scenarios were developed for application of predicative analyses
			maps	No	N/A
			tables	No	N/A
		Mass Balance	discussion of components	No	N/A
			Compare to Conceptual Model	No	N/A
			Relevance to COHYST objectives	No	N/A
Summary and Conclusions		Summary	discussion	X?	No section titled summary and conclusions included. However the Executive Summary provides this
		Conclusions Relative to Model Objectives	met or not	No	No discussion in summary section or Executive Summary
		Model uncertainty discussion	uncertainty summary	No	No summary discussion
			effects on conclusions	No	No summary discussion
		Recommended uses to meet COHYST objectives	discussion	X?	Very limited statement at end of Executive Summary that provides little guidance as to how this model meets or can be used to meet COHYST objectives
References			Included	X	
Model Archive	Data	Final Calibration	Input Data Sets	X	
			Output Data Sets	X	
		Verification Simulation	Input Data Sets	No	
			Output Data Sets	No	
		Sensitivity Analyses	Input Data Sets	Partial	Only selected datasets were provided for Peer Review
			Output Data Sets	Partial	Only selected datasets were provided for Peer Review
		Predictive Simulations	Input Data Sets	No	No predictive simulations included
			Output Data Sets	No	No predictive simulations included
	Computer Codes		Executables	X	MODFLOW and GMS
			Source	X	CROPSIM, Rich Kern Visual Basic Codes, MODFLOW is public domain, GMS is proprietary
			Documentation	No	Cropsim and Rich Kern Codes not published
	Modeling Procedures		Documentation	No	No modeling procedure document for future use provided

Attachment C.—Summary Table of Completeness and Adequacy Review, Central Model Unit

Attachment C.-- Central Model Unit Completeness Review Checklist

Developed from ASTM D5718, D5490, D5611, D5979, and D5981 and Professional Experience

Project Element			Included in Report	Comment/ Adequacy Summary
Introduction	Objectives	Objectives	X	To follow modeling Strategy (However reasons for changing from original strategy not all documented)
		Purpose & Goals of Study	X	General COHYST purpose
		Applicability of Model as Part of Study	X	Under Modeling Strategy Section
		What types of predictions are to be done	X?	General discussion only Should be more specific up front
	Model Function	How will model be used to satisfy Objectives	X?	General discussion only Should be more specific up front
	Model Area Setting	Study Area Definition	X	Discussion and Map (Figure 1)
		Regional Topography	X	General topography discussed but no altitude range is included
		Geology	X	Geologic and Hydrostratigraphic Units Section
		Hydrology and Hydrogeology	X	Description of Central Model Unit Section: Climate (Precipitation and Lake Evap), Streamflow, Wetlands, ET, Watertable slope. Reference to Hydrostratigraphic units and HU report
		Land Use	X	
		Regional Map	X	Figure 1
		Previous Studies	X	No discussion of gaps or needed improvement in previous studies
	Study Time Domain	Applicable periods used	X	
	Who performed modeling	Individuals and responsibilities	No	No list of principal authors or modelers, or agencies. Should have included a section on this as significant work on recharge and pumpage was done by others (Neb DNR, Rich Kern)
Conceptual Model		Boundaries and General Description	X	Statement on p 13 justifying boundary selection is not clear. Arbitrary selection of project boundaries at political boundaries instead of hydrologic boundaries. No discussion of upper and lower model boundary definition, but figure 12 shows configuration of base of modeled units.
	Aquifer system	Geologic	X	p 20, Table 1, Figure 10, Fig 12
		Hydrogeologic	X	

Attachment C.-- Central Model Unit Completeness Review Checklist (cont.)

Project Element				Included in Report	Comment/ Adequacy Summary
Conceptual Model (cont.)	Hydrologic Boundaries	Locations		X	Fig 9
		Flux (type 2)		X	Western, Eastern, Boundaries and portion of northern boundary in McPherson Co
		Gradient GHB, (type 3)		No	See comments on preferred use of GHB to handle model overlap areas.
		Head (type 1)		X	Used for Reservoirs. Note model used General Head Boundary, not fixed head.
		Horizontal Flow (Wall) Barrier		No	Not used
		Rivers	General Discussion	X	See comments about more appropriate use of Stream BC for all Rivers to allow Platte River to go dry during anticipated future simulation scenarios. Stream aquifer interaction discussion needs to state which parameters control the interaction rather than the general statement included. River BC for Frenchman Cr not appropriate
			Riverbed elevation	No	Not Discussed in Conceptual Model Section see Numerical Model Section
			River Stage	No	Not Discussed in Conceptual Model Section see Numerical Model Section
			Riverbed conductance	No	Not Discussed in Conceptual Model Section see Numerical Model Section
		Streams	General Discussion	X	See comments about more appropriate use of Stream BC for all Rivers to allow Platte River to go dry during anticipated future simulation scenarios. Stream aquifer interaction discussion needs to state which parameters control the interaction rather than the general statement included. River BC for Frenchman Cr not appropriate
			Streambed elevation	No	Not Discussed in Conceptual Model Section see Numerical Model Section
			Stream Stage	No	Not Discussed in Conceptual Model Section see Numerical Model Section
			Streambed conductance	No	Not Discussed in Conceptual Model Section see Numerical Model Section
		Drains	General Discussion	No	Inadequate discussion of the operation of drains. i.e. flow when the watertable rises to the specified elevation of the drain, no flow when watertable is below drain elevation
			Drain elevation	No	Not Discussed in Conceptual Model Section see Numerical Model Section
			Drain Conductance	No	Not Discussed in Conceptual Model Section see Numerical Model Section

Attachment C.-- Central Model Unit Completeness Review Checklist (cont.)

Project Element			Included in Report	Comment/ Adequacy Summary
Conceptual Model (cont.)	Hydraulic Properties	Layer Selection and Thicknesses	X	p 27.
		Hydraulic Conductivity	X	No discussion or rationale as to why a single value of Kh was used for layers 1, 6 & 7. No discussion regarding anisotropy. COHYST Test hole database used, but methodology using grain size correlation not discussed or referenced. No support for degree of vertical to horizontal anisotropy used.
		Confined, Unconfined, or Convertible	No	Not discussed in text for any layer
		Specific Storage	No	Not discussed at all however the model datasets show that a value of the Primary Storage Coefficient that is approximately equal to the layer thickness x the compressibility of water was used (0.00001/ft)
		Specific Yield	No	Mentioned in Executive Summary and in numerical model construction section, but basis for selection is not described not in conceptual model section. Text says Initial constant value of 0.20 for all layers modified by calibration. Values for layer 1 in predevelopment data set are all set to 0.16 for layer 1 and spatially vary for all other layers. Not clear which values were used for the pre-development calibration
		Porosity	No	Not discussed - not needed unless particle tracking is used
	Time Domain	Steady State	No	Not Discussed in Conceptual Model Section see Numerical Model Section
		Series of Steady States	No	Not Discussed in Conceptual Model Section see Numerical Model Section
		Transient	No	Not Discussed in Conceptual Model Section see Numerical Model Section

Attachment C.-- Central Model Unit Completeness Review Checklist (cont.)

Project Element				Included in Report	Comment/ Adequacy Summary
Conceptual Model (concluded)	Sources and Sinks		Wells/Pumpage	No	Not Discussed in Conceptual Model Section see Numerical Model Section
			Recharge	No	Canals are mentioned, but not the mechanism used to simulate them or the rationale for their elevations. No discussion of areally distributed recharge or the basis for determining it is included in the conceptual model section
			ET from GW	X	p 27 However, the ET surface used is not discussed in the conceptual model section, it is not discussed until the model calibration section.
	Water Budget		Conceptual/semi quantitative	No	Not included in conceptual model
Computer Code Description	Code Selection		Code description	X	
			Selection Criteria	X	No criteria given regarding ease of future use, use by others, etc
	Assumptions		Justify based upon study objectives	X	P 28
	Limitations		Impacts on study objectives	No	GMS with properly formulated conceptual model is probably the best and easiest tool to assess changes in gw/sw interaction, However not discussed in report
			Solution Techniques		Not discussed in report. Model datasets show that all models used the Strongly Implicit Method, SIP
Model Construction	Model Domain	Map on topography		No	Not topographic map. Topographic region map included as Figure 17
		Model grid size and layer selection		X	Grid selection and layers described in Numerical Model Section.
		Preprocessing	Methods	X	GMS Selected and used, although full conceptual model datasets not provided for review
			Codes used	X	GMS
	Time Domain		Steady State	X	Model strategy called for pre-Development period to be steady state, this apparently was abandoned and conditions in 1895 were simulated using a quasi steady state approach. Convergence problems caused by thin layers required by the GMS approach mandated this
			Series of Steady States	No	not used because of thin, highly permeable, continuous layers constructed in GMS
			Transient	X	Pre-Settlement, pre-Development, and development periods were transient

Attachment C.-- Central Model Unit Completeness Review Checklist (cont.)

Project Element				Included in Report	Comment/ Adequacy Summary
Model Construction (cont)	Hydraulic Properties	Hydraulic Conductivity		X	Lateral variation within each layer based upon test hole logs for layers 2,3,4 & 5, Uniform values uysed for Layers 1,6,& 7
		Specific Storage		No	In model datasets at 1e05, not discussed in reports value is low for silts and clays
		Specific Yield		X	Spatially varied values used in accordance with the HU Report, Calibration parameter.
		Porosity		No	Not included - no particle tracking used
	Sources and Sinks	Wells/Pumpage		X	Net Irr. Requirement pumpage computed by CROPSIM and by NEBGUIDE. Assignment of pumpage to only one layer, real world wells often interconnect Pleistocene and Ogallala deposits.
		Recharge		X	Recharge from precipitation was a model calibration parameter. Why was CROPSIM or similar method not used for rangeland recharge, using assumption that pre-1950 climate was similar to post 1950 period when climatic data was available?. Recharge from surface water irr. and canal leakage computed with help of canal records.
		ET from GW		No	Not discussed in Numerical Model Construction section
	Hydrologic Boundaries	Locations		X	Figure 9
		Flux (type 2)		X	Used at arbitrary political boundaries.
		Gradient GHB, (type 3)		X	Used on Reservoirs on streams tributary to Republican R and Lake McConoughy although Fig 7 calls this BC a fixed head boundary. No discussion as to why GHB not used for arbitrary model boundaries, including those where models overlap.
		Head (type 1)		X	Fig 9 states that Reservoirs were Fixed Head BC, but model dataset shows that it is a general head BC
		Rivers	Riverbed elevation	X	Digital Elevation used for nodes on rivers and streams, GMS linear interpolation between nodes. No discussion re accuracy or resolution of DEM used.
			River Stage	No	No discussion in report regarding values used. Used stage = 2 ft above bed elevation based upon examination of model datasets, Note WMU used bed + 1 ft for stage, and EMU used bed + 2 ft for stage.
			Riverbed conductance	X	Initial values assigned based on size and character of stream and consideration of bed conductance studies. Values changed during calibration

Attachment C.-- Central Model Unit Completeness Review Checklist (cont.)

Project Element				Included in Report	Comment/ Adequacy Summary
Model Construction (concluded)	Hydrologic Boundaries (concluded)	Streams	Streambed elevation	X	Digital Elevation used for nodes on rivers and streams, GMS linear interpolation between nodes. No discussion re accuracy or resolution of DEM used.
			Stream Stage	No	No discussion in report regarding values used. Used stage = 2 ft above bed elevation based upon examination of model datasets, Note WMU used bed + 1 ft for stage, and CMU used bed + 2 ft for stage.
			Streambed conductance	X	Initial values assigned based on size and character of stream and consideration of bed conductance studies and author observations. Values changed during calibration
		Drains	Drain elevation	X	Digital Elevation used for nodes on rivers and streams, GMS linear interpolation between nodes. No discussion re accuracy or resolution of DEM used.
			Drain Conductance	X	Estimated from observed flows, and calibration parameter
	Numerical Parameters	Method used		No	Not discussed in report. Model datasets show SIP used.
		Parameters for Numerical Method		No	Not discussed in report. Model datasets show 5 SIP iteration parameters initially computed at start of simulation & Acceleration Parameter of 1.0
		Closure Criteria		No	Not discussed in report. Model datasets show head convergence criteria set at 0.001 ft
Calibration	Calibration Targets and Goals	Targets	Selection	X	Selection of head for pre-Development and head change for Development period
			Justification re project goals	No	No discussion of selection of model calibration targets relative to model goals
			Justification re project limits	No	No discussion of model limitations resulting from selection of calibration targets
		Goals	Selection	No	No discussion re what constituted the goal of model calibration for this project. I.E. no numerical metrics of acceptable calibration discussed
			Justification re project goals	No	No discussion of selection of model calibration goals relative to project goals
			Justification re project limits	No	No discussion of model limitations resulting from selection of calibration goals

Attachment C.-- Central Model Unit Completeness Review Checklist (cont.)

Project Element				Included in Report	Comment/ Adequacy Summary
Calibration (cont)	Selection of Calibration Targets	Distinct Hydrologic Condition Grouping	heads	No	No grouping of calibration targets by distinct Hus
			flows	X	Streams and River reach gains from baseflow estimate report for CMU
		Presentation of Target Data	maps	No	Not included in report,
			tables	X?	Head and water level change data not included in report, separate spreadsheets provided on request. Stream and river reach gains summarized for 1950 only in report, no analysis included to assess temporal changes
		Data Support for Targets	heads	No	Not included in report, separate spreadsheets provided
			flows	No	Summary tables showing only one point in time included, no analysis to assess temporal changes
	Selection of Calibration Parameters	Method Used	Sensitivity analyses to initial values	No	Not reported to have been used
			Ad Hoc Reasoning	X	Apparent method used to select calibration parameters. Note that claim of uniqueness in calibrated hydraulic conductivity and recharge for pre-development is not supported because streambed/riverbed conductance was also used as a calibration parameter. Not clear from report if ET parameters were changed during calibration.
		Summary of Calibration Parameters Selected		No	No table summarizing parameters and selection criteria
	History Matching	Methods Used	Manual	?	No documentation as to the calibration method(s) used
			Automatic	?	No documentation as to the calibration method(s) used
			Mixed	?	No documentation as to the calibration method(s) used
		Computed vs. Target Residuals Computed	Heads	X	Discussion of heads and head changes discussed, but no scatter charts included.
			Flows	No	No residuals computed, only simulated reach gain in 1950 compared to being "within range" of values estimated in the baseflow estimation reports. No assessment of changes during the calibration period for flows. Basis for flow target ranges uses arbitrary statistics, and does not account for observed temporal changes to some reach gains and losses

Attachment C.-- Central Model Unit Completeness Review Checklist (cont.)

Project Element				Included in Report	Comment/ Adequacy Summary
Calibration (concluded)	Residual Statistics	Max and Min	Heads	No	Not included as a reported statistic
			Flows	No	Not included as a reported statistic
		First Order: Means	Heads	X	
			Flows	No	No residual reported for flows
		First Order: Absolute Means	Heads	X	Tables 6, 10, & 11
			Flows	No	No residual reported for flows
		Second Order: Standard Deviation/RMS	Heads	X	Tables 6, 10, & 11
			Flows	X	Tables 6, 10, & 11
		Second Order: Standard Error of Estimate	Heads	No	Statistic not computed or reported
			Flows	No	Statistic not computed or reported
		Second Order RMS normalized to observed max - min	Heads	No	Statistic not computed or reported
			Flows	No	Statistic not computed or reported
	Residual Correlation	Listing	Heads	No	No table of residuals
			Flows	?	No residuals computed, but Table 5 shows computed 1950 reach gains compared to base flow estimates using period of record 7Q5 and 14Q2 flows
		Scattergram observed vs. computed	Heads	No	Not included in report, data to do so provided in separate spreadsheets
			Flows	No	No measured vs. observed means or other stats plotted
		Spatial Correlation (Maps)	Heads	X	Maps comparing simulated and observed or otherwise estimated heads included in Figures 19, 20, & 21. Comparison of simulated and observed or otherwise estimated head changes shown in Figures 25, 26, & 27.
			Flows	No	No maps showing comparison of observed and simulated reach gains
		Temporal Correlation (Transient Analyses)	Heads	No	No analysis of the correlation of residuals over the 4 transient calibration periods
			Flows	No	No temporal calibration to flows
	Resultant Calibrated Model Parameters	Comparison to Initial Estimates	Range	No	No table, map, or discussion in text of changes to mean or range of values
			Means	No	No table, map, or discussion in text of changes to mean or range of values
		Justification of Changes from Calibration		No	No discussion of the justification of the changes that were made to any calibration parameters

Attachment C.-- Central Model Unit Completeness Review Checklist (cont.)

Project Element				Included in Report	Comment/ Adequacy Summary
Sensitivity Analyses	Sensitivity Analyses with Calibrated Model	Goals		No	No discussion of the goals of sensitivity analyses: I.E. to assess model uncertainty
		Procedures used		X	For parameters used the method is discussed in the text
		Justification of parameters and ranges used	parameters	No	Not all calibration parameters were used in sensitivity analyses
			ranges	No	Ranges selected were apparently arbitrary, and not based upon the amount of change during calibration or on other criteria to set reasonable ranges.
		Justification of model output used for analyses		No	Analyses apparently did not consider the most important metric for which the models are to be used: changes to reach gains and losses of the Platte River. Only flow sensitivity analyses included were for small tributaries.
		Method used	MF2k	No	MODFOW 96 was used
			Ad hoc	X	From report, it appears an arbitrary ad-hoc method was used
			Mixed	No	
		Sensitivity Types Identified for each Parameter (Change in Conclusions vs. Change in Calibration	Type I	No	No Sensitivity Error Analyses included
			Type II	No	No Sensitivity Error Analyses included
			Type III	No	No Sensitivity Error Analyses included
			Type IV	No	No Sensitivity Error Analyses included
		Results Reported	Charts	X	Figures 29, 30, and 31
			Maps	No	No maps showing sensitivity by area included, therefore, no map showing relative model reliability was included
			Statistics Tables	No	No
Model Verification	Model Verification Simulation	Included?		No	Amount of historical data assembled for COHYST is adequate to use verification analyses, and it would have strengthened confidence in models
		Goals		No	
		Results	maps	No	
			tables	No	
		Residuals	maps	No	
			tables	No	
	Mass Balance Analysis	Model-wide Mass Balance and Water Budget	Tables	X	Tables 7 and 12
			Discussion of Components	X	No discussion of the differences in relative magnitude of mass balance components between pre-Development and Development Periods. No presentation or discussion of time changes of components over time.
			Compare to Conceptual Model	No	No water balance discussion included under Conceptual Model section of report.
			Precision	No	No discussion in report
		Zones or areas of Interest Mass Balances	Included	No	No zonal water balances for areas of interest included in report
			Rationale for selection	No	No zonal water balances for areas of interest included in report

Attachment C.-- Central Model Unit Completeness Review Checklist (concluded)

Project Element				Included in Report	Comment/ Adequacy Summary
Predictive Simulations		Included?		No	
		Description of Simulations	Relate to model objectives	No	No example scenarios were developed for application of predicative analyses
		Changes made to calibrated model	Necessary or done?	No	N/A
			Effect on calibration	No	N/A
		Metrics	Heads	No	N/A
			Flows	No	N/A
		Results	Relevance to COHYST objectives	No	No example scenarios were developed for application of predicative analyses
			maps	No	N/A
			tables	No	N/A
		Mass Balance	discussion of components	No	N/A
			Compare to Conceptual Model	No	N/A
			Relevance to COHYST objectives	No	N/A
Summary and Conclusions		Summary	discussion	X?	No section titled summary and conclusions included. However the Executive Summary provides this
		Conclusions Relative to Model Objectives	met or not	No	No discussion in summary section or Executive Summary
		Model uncertainty discussion	uncertainty summary	No	No summary discussion
			effects on conclusions	No	No summary discussion
		Recommended uses to meet COHYST objectives	discussion	X?	Very limited statement at end of Executive Summary that provides little guidance as to how this model meets or can be used to meet COHYST objectives
References			Included	X	
Model Archive	Data	Final Calibration	Input Data Sets	X	
			Output Data Sets	X	
		Verification Simulation	Input Data Sets	No	
			Output Data Sets	No	
		Sensitivity Analyses	Input Data Sets	Partial	Only selected datasets were provided for Peer Review
			Output Data Sets	Partial	Only selected datasets were provided for Peer Review
		Predictive Simulations	Input Data Sets	No	No predictive simulations included
			Output Data Sets	No	No predictive simulations included
	Computer Codes		Executables	X	MODFLOW and GMS
			Source	X	CROPSIM, Rich Kern Visual Basic Codes, MODFLOW is public domain, GMS is proprietary
			Documentation	No	Cropsim and Rich Kern Codes not published
	Modeling Procedures		Documentation	No	No modeling procedure document for future use provided

Attachment D.—Summary Table of Completeness and Adequacy Review, Western Model Unit

Attachment D.-- Western Model Unit Completeness Review Checklist.

Developed from ASTM D5718, D5490, D5611, D5979, and D5981 and Professional Experience

Project Element			Included in Report	Comment/ Adequacy Summary
Introduction	Objectives	Objectives	X	To follow modeling Strategy (However reasons for changing from original strategy not all documented)
		Purpose & Goals of Study	X	General COHYST purpose
		Applicability of Model as Part of Study	X	Under Modeling Strategy Section
		What types of predictions are to be done	X?	General discussion only Should be more specific up front
	Model Function	How will model be used to satisfy Objectives	X?	General discussion only Should be more specific up front
	Model Area Setting	Study Area Definition	X	Discussion and Map (Figure 1)
		Regional Topography	X	General topography discussed but no altitude range is included
		Geology	X	Geologic and Hydrostratigraphic Units Section
		Hydrology and Hydrogeology	X	Description of Western Model Unit Section: Climate (Precipitation and Lake Evap), Streamflow, Wetlands, ET, Watertable slope. Reference to Hydrostratigraphic units and HU report
		Land Use	X	
		Regional Map	X	Figure 1
		Previous Studies	X	No discussion of gaps or needed improvement in previous studies
	Study Time Domain	Applicable periods used	X	
	Who performed modeling	Individuals and responsibilities	No	No list of principal authors or modelers, or agencies. Should have included a section on this as significant work on recharge and pumpage was done by others (Neb DNR, Rich Kern)
Conceptual Model		Boundaries and General Description	X	Statement on p 13 justifying boundary selection is not clear. Arbitrary selection of project boundaries at political boundaries instead of hydrologic boundaries. No discussion of upper and lower model boundary definition.
	Aquifer system	Geologic	X	p 18, Table 1, Figure 9
		Hydrogeologic	X	Reasons for use of single layer conceptual model discussed in Exec. Summary and Modeling Strategy Section. Use of continuous saturation beneath topographic highs (Wildcat Hills) may be questionable

Attachment D.-- Western Model Unit Completeness Review Checklist (cont.)

Project Element				Included in Report	Comment/ Adequacy Summary
Conceptual Model (cont.)	Hydrologic Boundaries	Locations		X	Fig 10
		Flux (type 2)		X	Western, Eastern, Boundaries and portion of northern boundary in Sioux Co. Zero Flow along topographic divide in Colo. Counties
		Gradient GHB, (type 3)		No	See comments on preferred use of GHB to handle model overlap areas.
		Head (type 1)		X	Used for Reservoirs. Note model used General Head Boundary, not fixed head.
		Horizontal Flow (Wall) Barrier		No	Not used
		Rivers	General Discussion	X	See comments about more appropriate use of Stream BC for all Rivers to allow Platte River to go dry during anticipated future simulation scenarios. Stream aquifer interaction discussion needs to state which parameters control the interaction rather than the general statement included.
			Riverbed elevation	No	Not Discussed in Conceptual Model Section see Numerical Model Section
			River Stage	No	Not Discussed in Conceptual Model Section see Numerical Model Section
			Riverbed conductance	No	Not Discussed in Conceptual Model Section see Numerical Model Section
		Streams	General Discussion	X	See comments about more appropriate use of Stream BC for all Rivers to allow Platte River to go dry during anticipated future simulation scenarios. Stream aquifer interaction discussion needs to state which parameters control the interaction rather than the general statement included.
			Streambed elevation	No	Not Discussed in Conceptual Model Section see Numerical Model Section
			Stream Stage	No	Not Discussed in Conceptual Model Section see Numerical Model Section
			Streambed conductance	No	Not Discussed in Conceptual Model Section see Numerical Model Section
		Drains	General Discussion	No	Drain BC Not used, However, drains are probably as important and for the same reasons as in the CMU and EMU
			Drain elevation	No	Drain BC not used
			Drain Conductance	No	Drain BC not used

Attachment D.-- Western Model Unit Completeness Review Checklist (cont.)

Project Element			Included in Report	Comment/ Adequacy Summary
Conceptual Model (cont.)	Hydraulic Properties	Layer Selection and Thicknesses	X	In Exec. Summary and Modeling Strategy Sections
		Hydraulic Conductivity	No	No discussion or rationale of initial Kh values used. No reference to method used for WMU and CMU or to Kh values reported in HU report. Not included in numerical model construction section either.
		Confined, Unconfined, or Convertible	No	Not discussed in text for any layer
		Specific Storage	No	Not discussed at all however the model datasets show that a value of the Primary Storage Coefficient that is approximately equal to the layer thickness x the compressibility of water was used (0.00001/ft)
		Specific Yield	No	Mentioned in Executive Summary and in model calibration section, but basis for selection is not described not in conceptual model section, Not clear which values were used for the pre-development calibration
		Porosity	No	Not discussed - not needed unless particle tracking is used
	Time Domain	Steady State	No	Not Discussed in Conceptual Model Section see Numerical Model Section
		Series of Steady States	No	Not Discussed in Conceptual Model Section see Numerical Model Section
		Transient	No	Not Discussed in Conceptual Model Section see Numerical Model Section

Attachment D.-- Western Model Unit Completeness Review Checklist (cont.)

Project Element				Included in Report	Comment/ Adequacy Summary
Conceptual Model (concluded)	Sources and Sinks		Wells/Pumpage	No	Not Discussed in Conceptual Model Section see Numerical Model Section
			Recharge	No	Canals are mentioned, but not the mechanism used to simulate them or the rationale for their elevations. No discussion of areally distributed recharge or the basis for determining it is included in the conceptual model section
			ET from GW	X	p 22 However, the ET surface used is not discussed in the conceptual or numerical model sections, it is not discussed until the model calibration section.
	Water Budget		Conceptual/semi quantitative	No	Not included in conceptual model
Computer Code Description	Code Selection		Code description	X	
			Selection Criteria	X	No criteria given regarding ease of future use, use by others, etc
	Assumptions		Justify based upon study objectives	X	P 24
	Limitations		Impacts on study objectives	No	GMS with properly formulated conceptual model is probably the best and easiest tool to assess changes in gw/sw interaction, However not discussed in report
			Solution Techniques		Not discussed in report. Model datasets show that all models used the Strongly Implicit Method, SIP
Model Construction	Model Domain	Map on topography		No	No topographic map or topographic region map.
		Model grid size and layer selection		X	Grid selection described in Numerical Model Section.
		Preprocessing	Methods	X	GMS Selected and used, although full conceptual model datasets not provided for review
			Codes used	X	GMS
	Time Domain		Steady State	X	Model strategy called for pre-Development period to be steady state, this apparently was abandoned and conditions in 1895 were simulated using a quasi steady state approach. Convergence problems caused by thin layers required by the GMS approach mandated this
			Series of Steady States	No	not used because of thin, highly permeable, continuous layer constructed in GMS
			Transient	X	Pre-Settlement, pre-Development, and development periods were transient. No discussion of Sy values for Pre-Settlement or Pre-Development periods

Attachment D.-- Western Model Unit Completeness Review Checklist (cont.)

Project Element				Included in Report	Comment/ Adequacy Summary
Model Construction (cont)	Hydraulic Properties	Hydraulic Conductivity		No	No discussion or rationale of initial Kh values used. No reference to method used for WMU and CMU or to Kh values reported in HU report. Not discussed until model calibration section
		Specific Storage		No	In model datasets at 1e05, not discussed in reports value is low for silts and clays
		Specific Yield		No	Not discussed until Model Calibration Section
		Porosity			Not included - no particle tracking used
	Sources and Sinks	Wells/Pumpage		X	Net Irr. Requirement pumpage computed by CROPSIM and by NEBGUIDE.
		Recharge		X	Recharge from precipitation was a model calibration parameter. Why was CROPSIM or similar method not used for rangeland recharge, using assumption that pre-1950 climate was similar to post 1950 period when climatic data was available?. Recharge from surface water irr. and canal leakage computed with help of canal records.
		ET from GW		No	ET surface used not discussed in Numerical Model Construction section - included in model calibration section
	Hydrologic Boundaries	Locations		X	Figure 10
		Flux (type 2)		X	Used at arbitrary political boundaries. Simulated as positive and negative recharge. CMU and EMU used injection and extraction wells
		Gradient GHB, (type 3)		X	Used on Lake McConaughy although Fig 10 calls this BC a "Lake" boundary which is not a MODFLOW boundary type. Model dataset shows both river and GHB for Lake McConaughy. No discussion as to why GHB not used for arbitrary model boundaries, including those where models overlap.
		Head (type 1)			Not used
		Rivers	Riverbed elevation	X	USGS 7.5 min topo maps used for nodes on rivers and streams, GMS linear interpolation between nodes. EMU and CMU used Digital Elevation Models
			River Stage	No	No discussion in report regarding values used. Used stage = 1 ft above bed elevation based upon examination of model datasets, Note CMU & EMU used bed + 2 ft for stage.
			Riverbed conductance	No	Not discussed in model construction section. Only discussed in model calibration section. Not clear if streambed conductance was a calibration parameter.

Attachment D.-- Western Model Unit Completeness Review Checklist (cont.)

Project Element				Included in Report	Comment/ Adequacy Summary
Model Construction (concluded)	Hydrologic Boundaries (concluded)	Streams	Streambed elevation	X	USGS 7.5 min topo maps used for nodes on rivers and streams, GMS linear interpolation between nodes. EMU and CMU used Digital Elevation Models
			Stream Stage	No	No discussion in report regarding values used. Used stage = 1 ft above bed elevation based upon examination of model datasets, Note CMU & EMU used bed + 2 ft for stage.
			Streambed conductance	No	Drain BC not used
		Drains	Drain elevation	No	Drain BC not used
			Drain Conductance	X	Drain BC not used
	Numerical Parameters	Method used		No	Not discussed in report. Model datasets show SIP used.
		Parameters for Numerical Method		No	Not discussed in report. Model datasets show 5 SIP iteration parameters initially computed at start of simulation & Accel. Parameter of 1.0
		Closure Criteria		No	Not discussed in report. Model datasets show head convergence for SIP set at 0.02 ft.
Calibration	Calibration Targets and Goals	Targets	Selection	X	Selection of head for pre-Development and head change for Development period
			Justification re project goals	No	No discussion of selection of model calibration targets relative to model goals
			Justification re project limits	No	No discussion of model limitations resulting from selection of calibration targets
		Goals	Selection	No	No discussion re what constituted the goal of model calibration for this project. I.E. no numerical metrics of acceptable calibration discussed
			Justification re project goals	No	No discussion of selection of model calibration goals relative to project goals
			Justification re project limits	No	No discussion of model limitations resulting from selection of calibration goals

Attachment D.-- Western Model Unit Completeness Review Checklist (cont.)

Project Element				Included in Report	Comment/ Adequacy Summary
Calibration (cont)	Selection of Calibration Targets	Distinct Hydrologic Condition Grouping	heads	No	No grouping of calibration targets by distinct HUs
			flows	X	Streams and River reach gains from baseflow estimate report for WMU
		Presentation of Target Data	maps	No	Not included in report,
			tables	X?	Head and water level change data not included in report, separate spreadsheets provided on request. Stream and river reach gains summarized for 1950 only in report, no analysis included to assess temporal changes
		Data Support for Targets	heads	No	Not included in report, separate spreadsheets provided
			flows	No	Summary tables showing only one point in time included, no analysis to assess temporal changes
	Selection of Calibration Parameters	Method Used	Sensitivity analyses to initial values	No	Not reported to have been used
			Ad Hoc Reasoning	X	Apparent method used to select calibration parameters. Note that claim of uniqueness in calibrated hydraulic conductivity and recharge for pre-development is not supported because streambed/riverbed conductance may have been also used as a calibration parameter. Not clear from report if ET parameters were changed during calibration.
		Summary of Calibration Parameters Selected		No	No table summarizing parameters and selection criteria
	History Matching	Methods Used	Manual	?	No documentation as to the calibration method(s) used
			Automatic	?	No documentation as to the calibration method(s) used
			Mixed	?	No documentation as to the calibration method(s) used
		Computed vs. Target Residuals Computed	Heads	X	Discussion of heads and head changes discussed, but no scatter charts included.
			Flows	No	No residuals computed, only simulated reach gain in 1950 compared to being "within range" of values estimated in the baseflow estimation reports. No assessment of changes during the calibration period for flows. Basis for flow target ranges uses arbitrary statistics, and does not account for observed temporal changes to some reach gains and losses

Attachment D.-- Western Model Unit Completeness Review Checklist (cont.)

Project Element				Included in Report	Comment/ Adequacy Summary
Calibration (concluded)	Residual Statistics	Max and Min	Heads	No	Not included as a reported statistic
			Flows	No	Not included as a reported statistic
		First Order: Means	Heads		Un-numbered tables on pp 39 & 45
			Flows	No	No residual reported for flows
		First Order: Absolute Means	Heads	X	Un-numbered tables on pp 39 & 45
			Flows	No	No residual reported for flows
		Second Order: Standard Deviation/RMS	Heads	X	Un-numbered tables on pp 39 & 45
			Flows	X	No residual reported for flows
		Second Order: Standard Error of Estimate	Heads	No	Statistic not computed or reported
			Flows	No	Statistic not computed or reported
		Second Order RMS normalized to observed max - min	Heads	No	Statistic not computed or reported
			Flows	No	Statistic not computed or reported
	Residual Correlation	Listing	Heads	No	No table of residuals
			Flows	?	No residuals computed, but Table 3 shows computed 1950 reach gains compared to base flow estimates using period of record 7Q5 and 14Q2 flows
		Scattergram observed vs. computed	Heads	No	Not included in report, data to do so provided in separate spreadsheets
			Flows	No	No measured vs. observed means or other stats plotted
		Spatial Correlation (Maps)	Heads	X	Maps comparing simulated and observed or otherwise estimated heads included in Figure 15. Comparison of simulated and observed or otherwise estimated head changes shown in Figure 18.
			Flows	No	No maps showing comparison of observed and simulated reach gains
		Temporal Correlation (Transient Analyses)	Heads	No	No analysis of the correlation of residuals over the 4 transient calibration periods
			Flows	No	No temporal calibration to flows
	Resultant Calibrated Model Parameters	Comparison to Initial Estimates	Range	No	No table, map, or discussion in text of changes to mean or range of values
			Means	No	No table, map, or discussion in text of changes to mean or range of values
		Justification of Changes from Calibration		No	No discussion of the justification of the changes that were made to any calibration parameters

Attachment D.-- Western Model Unit Completeness Review Checklist (cont.)

Project Element				Included in Report	Comment/ Adequacy Summary
Sensitivity Analyses	Sensitivity Analyses with Calibrated Model	Goals		No	No discussion of the goals of sensitivity analyses: I.E. to assess model uncertainty
		Procedures used		X	For parameters used the method is discussed in the text
		Justification of parameters and ranges used	parameters	No	Not all calibration parameters were used in sensitivity analyses
			ranges	No	Ranges selected were apparently arbitrary, and not based upon the amount of change during calibration or on other criteria to set reasonable ranges.
		Justification of model output used for analyses		No	Analyses apparently did not consider the most important metric for which the models are to be used: changes to reach gains and losses of the North and South Platte rivers. Only flow sensitivity analyses included were for small tributaries.
		Method used	MF2k	No	MODFOW 96 was used
			Ad hoc	X	From report, it appears an arbitrary ad-hoc method was used
			Mixed	No	
		Sensitivity Types Identified for each Parameter (Change in Conclusions vs. Change in Calibration	Type I	No	No Sensitivity Error Analyses included
			Type II	No	No Sensitivity Error Analyses included
			Type III	No	No Sensitivity Error Analyses included
			Type IV	No	No Sensitivity Error Analyses included
		Results Reported	Charts	X	Figures 20, 21, and 22
			Maps	No	No maps showing sensitivity by area included, therefore, no map showing relative model reliability was included
			Statistics Tables	No	No
Model Verification	Model Verification Simulation	Included?		No	Amount of historical data assembled for COHYST is adequate to use verification analyses, and it would have strengthened confidence in models
		Goals		No	
		Results	maps	No	
			tables	No	
		Residuals	maps	No	
			tables	No	
	Mass Balance Analysis	Model-wide Mass Balance and Water Budget	Tables	X	Tables 4 and 5
			Discussion of Components	X	No discussion of the differences in relative magnitude of mass balance components between pre-Development and Development Periods. No presentation or discussion of time changes of components over time.
			Compare to Conceptual Model	No	No water balance discussion included under Conceptual Model section of report.
			Precision	No	No discussion in report
		Zones or areas of Interest Mass Balances	Included	No	No zonal water balances for areas of interest included in report
			Rationale for selection	No	No zonal water balances for areas of interest included in report

Attachment D.-- Western Model Unit Completeness Review Checklist (concluded).

<table>
<tr><th colspan="4">Project Element</th><th>Included in Report</th><th>Comment/ Adequacy Summary</th></tr>
<tr><td colspan="2" rowspan="14">Predictive Simulations</td><td colspan="2">Included?</td><td>No</td><td></td></tr>
<tr><td>Description of Simulations</td><td>Relate to model objectives</td><td>No</td><td>No example scenarios were developed for application of predicative analyses</td></tr>
<tr><td rowspan="2">Changes made to calibrated model</td><td>Necessary or done?</td><td>No</td><td>N/A</td></tr>
<tr><td>Effect on calibration</td><td>No</td><td>N/A</td></tr>
<tr><td rowspan="2">Metrics</td><td>Heads</td><td>No</td><td>N/A</td></tr>
<tr><td>Flows</td><td>No</td><td>N/A</td></tr>
<tr><td rowspan="3">Results</td><td>Relevance to COHYST objectives</td><td>No</td><td>No example scenarios were developed for application of predicative analyses</td></tr>
<tr><td>maps</td><td>No</td><td>N/A</td></tr>
<tr><td>tables</td><td>No</td><td>N/A</td></tr>
<tr><td rowspan="3">Mass Balance</td><td>discussion of components</td><td>No</td><td>N/A</td></tr>
<tr><td>Compare to Conceptual Model</td><td>No</td><td>N/A</td></tr>
<tr><td>Relevance to COHYST objectives</td><td>No</td><td>N/A</td></tr>
<tr style="display:none"></tr>
<tr style="display:none"></tr>
<tr><td colspan="2" rowspan="5">Summary and Conclusions</td><td>Summary</td><td>discussion</td><td>X?</td><td>No section titled summary and conclusions included. However the Executive Summary provides this</td></tr>
<tr><td>Conclusions Relative to Model Objectives</td><td>met or not</td><td>No</td><td>No discussion in summary section or Executive Summary</td></tr>
<tr><td rowspan="2">Model uncertainty discussion</td><td>uncertainty summary</td><td>No</td><td>No summary discussion</td></tr>
<tr><td>effects on conclusions</td><td>No</td><td>No summary discussion</td></tr>
<tr><td>Recommended uses to meet COHYST objectives</td><td>discussion</td><td>X?</td><td>Very limited statement at end of Executive Summary that provides little guidance as to how this model meets or can be used to meet COHYST objectives</td></tr>
<tr><td>References</td><td></td><td></td><td>Included</td><td>X</td><td></td></tr>
<tr><td rowspan="13">Model Archive</td><td rowspan="8">Data</td><td rowspan="2">Final Calibration</td><td>Input Data Sets</td><td>X</td><td></td></tr>
<tr><td>Output Data Sets</td><td>X</td><td></td></tr>
<tr><td rowspan="2">Verification Simulation</td><td>Input Data Sets</td><td>No</td><td></td></tr>
<tr><td>Output Data Sets</td><td>No</td><td></td></tr>
<tr><td rowspan="2">Sensitivity Analyses</td><td>Input Data Sets</td><td>Partial</td><td>Only selected datasets were provided for Peer Review</td></tr>
<tr><td>Output Data Sets</td><td>Partial</td><td>Only selected datasets were provided for Peer Review</td></tr>
<tr><td rowspan="2">Predictive Simulations</td><td>Input Data Sets</td><td>No</td><td>No predictive simulations included</td></tr>
<tr><td>Output Data Sets</td><td>No</td><td>No predictive simulations included</td></tr>
<tr><td colspan="2" rowspan="3">Computer Codes</td><td>Executables</td><td>X</td><td>MODFLOW and GMS</td></tr>
<tr><td>Source</td><td>X</td><td>CROPSIM, Rich Kern Visual Basic Codes, MODFLOW is public domain, GMS is proprietary</td></tr>
<tr><td>Documentation</td><td>No</td><td>Cropsim and Rich Kern Codes not published</td></tr>
<tr><td colspan="2">Modeling Procedures</td><td>Documentation</td><td>No</td><td>No modeling procedure document for future use provided</td></tr>
</table>

Attachment E.—Specific Review Comments: Eastern Model Unit Report

1. Executive summary page 6. Statement says that hydraulic conductivity for layers 1 and 6 was set to a constant, while there are only 5 model layers. The methodology used to assign hydraulic conductivity (grain size analysis) is not mentioned anywhere in the report.

2. Executive summary page 6 statement says that specific yield was set to a constant value for layer 1 and spatially varied for layers 2 through 5. However the report text at the conceptual model section does not include this information, and in fact states that the a constant initial estimate Sy was set to 0.20 for all the layers. The Executive summary should not include information not in the body of the report. The basis for assigning Sy based upon test hole data is not discussed here or in the body of the report.

3. Boundaries of the model apparently were chosen based in part upon arbitrary political boundaries rather than hydrogeologic or hydrologic boundaries. While this is acceptable, it would help to include a section in the introduction that states that the study area was pre-defined by whatever was used to predefine it (funding approval, organizations participating, etc) and that this necessitated use of arbitrary model boundaries. The statement on p 18 should be clarified as these boundaries were chosen because they were the study area boundaries (not because they have little influence on the internal area of the model).

4. Page 15 figure 6 states that the pre development watertable was modified from Gutentag et al and Cederstrand and Becker, but no discussion is present as to who modified it and what modifications were made. Since this is a calibration target for the COHYST EMU, this needs to be clarified.

5. There is no mention of models that have been constructed for the Republican River Basin as part of allocating resources between Colorado, Nebraska and Kansas (references) These other studies should be acknowledged and a discussion of any overlap, common or different treatment of boundaries, etc as they may or do affect the results of the COHYST models in the Platte River Basin. A similar assessment should be made of any other models that have been developed and are being used for management decisions for the Loup River basin because the South Loup, Middle Loup and Lower Loup Rivers were used as a portion of the northern Eastern Model boundary.

6. Why was the Platte River not modeled as a steam boundary condition? This would have allowed diversions, etc to be modeled and provided a better tool to assess changes to flows in given reaches of the river, which appears to be one of the major goals of COHYST. Additionally, the use of the river boundary condition will not allow proper simulation of the river going dry.

7. Why were elevations of the river and stream beds not digitized from the DEM at every DEM Tile (30 M) rather than simply picking locations? How were the locations picked to have GMS use linear interpolation between the selected points?

8. Note that the CropSim update report not only acknowledges the settlement modeling in the Republican River basin, but makes an attempt to make CropSim inputs and outputs consistent between these and the COHYST values.

9. Model Boundaries, page 18. The statement: "These boundaries are geographic boundaries of the model area, and were chosen to have relatively small influence on the internal area of the model" is not clear. The model boundaries were selected as the project boundaries. The project boundaries were selected in some cases to be hydrologic boundaries and some not. No testing was done to verify this claim that the selection of boundaries and the boundary conditions assigned did not in fact have a "relatively small" effect. What is meant by a relatively small effect, on what, and where?

10. Why was fixed flow rather than general head boundary condition used at the eastern and western boundaries and a portion of the southern boundary? GHB gives more flexibility by allowing the specification of a distant external head boundary and a conductance between the location of the external head and the model boundary. Specified flow may be appropriate, but as it is common practice to use GHB in these instances, a discussion or analysis and advantages of GHB vs. Flow BC should be included. The GHB is preferred because it can simulate a constant gradient across the boundary (if the distant head and conductance are properly chosen) and hence the flow will change as the head at the boundary of the model changes because the thickness changes). In any case more justification for the use of specified flow rather than GHB is needed as the report is presently written.

11. Did the water level in the Harlan Co Reservoir stay the same throughout the entire model simulation period(s)? If not, a time variant specified head BC should have been used, not a fixed head. (Unless the term fixed head includes time-variant specified head). Note that the model dataset show that a General Head Boundary was used for Harlan Co Res.

12. A discussion is needed to explain why the northern and southern boundaries were not stopped at groundwater divides. Either they do not exist, or cannot readily be defined based upon measured water levels and topography, or the politically defined study area extends north and south of them, and/or there is interest in using the models to assess the migration of these divides as part of water management policy or strategy. These reasons need to be discussed to more clearly lay out why the model boundaries were selected. This discussion needs to include or reference the models of the Republican River basin.

13. Why was the COHYST boundary not extended to the West Fork of the Big Blue River in the county south of York Co? The WMU model was extended in to WY and CO for good reason, and the arbitrary cutoff of the West Fork of the Big Blue River requires unnecessary justification for not using a reasonable hydrologic boundary.

14. Page 18 use of zero flow boundaries along the southern border of York County is not consistent with previous modeling studies (Emery, 1966, Cady and Ginsberg, 1979). Because the west fork of the Big Blue River leaves this boundary and reenters it, the use of a zero flow boundary here assumes that there is no groundwater/surface water interaction a these points, or that the River is coincident with the southern York County boundary, which it is not. Again, use of a general Head BC at this location would be more appropriate if the political boundary is to be maintained.

15. Page 20 references to figures 7 and 8 should be to 8 and 9.

16. Page 20 were drain and ET boundaries conditions applied to the same cells? It does not appear so from the discussion or from examination of the model data sets. In some applications, this can skew the amount of water going to either sink.

17. Page 20 states that the surface used for determining ET extinction was the land surface. However, in the model and as discussed in other sections, an ET surface different from the land surface was used.

18. Figure 9 shows “Topsoil” as much as 50 feet thick. This strains the usual definition of topsoil in soils and hydrogeologic usage which is generally the upper 2-3 feet that contains high organic matter and high biotic activity. I am not aware of any topsoils, including buried paleosols in NE that are 20 to 50 ft thick. If the deposits being described are the wind-deposited loess then it should be so stated.

19. Figure 9 defines the separation between the Quaternary aquifer and the Republican River alluvium using only one test hole along this section (W05-02). Since this barrier is obviously an important hydro-political boundary, more discussion is probably needed to justify it in this report. A map showing its width and extent is needed that shows the testholes used to support this definition (Figure 8 in the report is not sufficient to defend the east west extent of this barrier.)

20. There is no discussion as to what defines the upper and lower conceptual and numerical model boundaries.

21. Confined and unconfined conditions are not discussed in the report anywhere nor are the required conditions and storage parameters used by ModFlow under each condition discussed. However, examination of the model datasets shows that Layer 1 was modeled as confined, and layers 2-5 were modeled as convertible from confined to unconfined (correctly).

22. Page 23. The discussion of layers and hydrostratigraphic units is incorrect. Six hydrostratigraphic units were used and five layers were defined. Hydrostratigraphic units 3 & 4 were combined in a single model layer.

23. Page. 23 There is no discussion or rationale given as to why a single value of hydraulic conductivity was assigned to layers 1 and 6. Such a discussion is needed.

24. Page 23 There is no discussion to support isotropic hydraulic conductivity anisotropy that was assumed.

25. Page 23 Specific yield and specific storage. There is no discussion of these parameters under the conceptual model section. It needs to be here along with the support for the values used. The numerical model section states that a uniform value of 0.20 was used initially for all layers. However, the calibrated pre-development dataset (hmMLSTR1-3) shows a uniform value of 0.16 for layer 1, spatially varying values for layers 2-5. However, the specific yield was supposedly not varied during the pre-calibration runs. It appears that the calibrated values from the development period run were used to populate the pre-calibration dataset. However there is no discussion in the report as to whether the pre-development calibrated model was then checked for differences in computed heads and fluxes with these values vs a constant value of 0.20. That is, it is not clear if a constant value of 0.20 was used for all layers everywhere for the pre-development calibration runs and sensitivity, or whether the calibrated values were used.

26. Page 23: First paragraph under Numerical Model. The numerical model is used to quantify and test the conceptual model, and this should be so stated in the first paragraph. the first sentence should read: *A groundwater flow model is a numerical representation of flow within an aquifer and the exchange of water between the aquifer and the external environment* ***as defined by the conceptual model of these processes developed in the previous section of this report.***

27. Page 23 The discussion on simulated canal systems should include how the canals were simulated (as was done in the Western Model report): recharge from leakage, how it was distributed in time and space, etc. Since this is discussed later in the report, a reference forward to that section should be included here.

28. Page 23, Assumption 3: the defense of the constancy of hydraulic properties over the arbitrarily selected model grid size is weak. The justification can and should include the fact that the spacing of testholes used to define hydrostratigraphy and hydraulic properties is much larger than the selected grid size.

29. Page 23 Assumption 3. statement relative to the intended uses of the model: These intended uses are not presented in this report, nor are the scale of such uses presented, so it is not possible to ascertain if the 160 acres is appropriate or not.

(The lack of a clear list of intended uses with examples is a major limitation of all the reports).

30. Page 23, Assumption 4. the use of the words '.. is probably appropriate' weakens the study and report. Again, some discussion of why it is appropriate is needed. Something along the line that uncertainty in the use of this conceptualization was mad non-restrictive by such techniques as making sure the streambed conductance was high enough to not restrict the interaction between groundwater and surface water except where independent measurements support the use of restrictive numbers, or where during calibration streambed conductance was adjusted to enable better calibration to observed (or calculated) streamflow gains and/or losses. A discussion and or reference to the UNL/USGS studies that attempted to measure streambed conductance should be included here to support the statement in assumption 4.

31. Page 23, Assumption 5. Again, the use of the words '..are probably appropriate at the scale of the model' is a weak defense of the use of the assumption. A more rigorous discussion should be included, based upon an analysis of depositional patterns, etc. There is an argument to be made that the cretaceous erosion surface may have a 'fabric' to it that has drainage and hence higher permeability deposits in an nw-se direction and hence anisotropy that a) may exist, and b) is not collinear with the orientation of the computational grid used. To dismiss this a discussion should be included that the scale of these features is larger than the model grid and the it is included by the use of heterogeneous, distributed values of hydraulic properties. This discussion should also include a similar discussion relative to the wind-laid deposits (dune sands and loess) which appear to have a nw-se depositional pattern to them.

32. Page 23 Assumption 5 should state that initial Kh/Kv ratio was 10 used and that it was (or was not) modified during model calibration. Also, the use of 10 should be defended more rigorously, as the model results are not sensitive to the value used (executive summary). If the models are not sensitive to Kh/Kv, then the principal of parsimony requires isotropic conditions to be used. To be consistent with the COHYST approach of beginning with simple models and making them more complex based upon the need for more detail, etc, it would have been more defensible to begin with an assumption of vertical isotropy and then test/defend it with the sensitivity analyses.

33. Page 23 ***continua*** should be used instead of continiums.

34. Page 23, again the statement that the finite difference method introduces a negligible error into the solution is not defended. Because the model uses a constant grid spacing of 2640 ft, the model cannot resolve head gradients on a smaller scale than this, and hence cannot be used to analyze flow to streams, wells, etc at a smaller scale.

35. As a general comment, the use of statements such as those discussed above that require the reader to take on faith that the author is an undisputed expert who can make such statements without defending them is not consistent with the scientific method or acceptable engineering practice. Reasons, not assumptions need to be provided. All assumptions need to be tested with sensitivity analyses or defended by reference to independent sources.

36. Page 24, Statement about the flow equation being linear is not correct. In actuality, it is only a linear set of equations for the layers below the one that contain the watertable. The watertable layer is non-linear because the solution (water-table elevation) depends upon the thickness of the unit, which is defined by the difference between the base of the layer and the watertable elevation. ModFlow handles this using iteration. There are actually two uses of the iteration used to solve the equations: 1) the solution of nonlinearities such as the presence of water-table layer, re-wetting, ET extraction from groundwater, and stream/ river interaction with the aquifer; and 2) to solve the liberalized set of equations sets of equations for each linearization iteration There is therefore an inner iteration loop that is used to solve the linear set of equations that result at the end of each iteration and an outer iteration that adjusts the parameters that depend upon the heads determined from the previous iteration.

37. Page 24 There is no discussion of the GHB package which was used to simulate certain reservoirs, such as Harlan County Reservoir.

38. Page 24 The discussion of calibration of hydraulic conductivity should more clearly state that model calibration was used to refine the spatially distribution of Kh in each layer and refer forward to the model calibration section of the report.

39. Page 24. The source, and horizontal and vertical resolution of the DEM used to define the elevations of drains, rivers, etc. needs to be provided. What adjustment was made, if any of incision of drains, streams, and rivers below the average value used from the DEM? This an issue for the streams as the stream package defines the beginning and end of the stream elevation across a cell and the average elevation used for determining interaction with groundwater is based upon the length of the channel within the cell, not only the width of the cell.

40. Since the DEMs were used to pick drain and river elevations, how are some streams located in layer 2, if the top of layer 1 represents the land surface?

41. Page 24 The feature that the horizontal flow barrier (wall) boundary condition was used to simulate needs to be referenced here, not just later in the report, as it is an unusual use of this function in ModFlow.

42. If the DEM was also used to define the top of the upper layer (the land surface), it needs to be so stated, along with the method used to interpolate from the DEM grid to the model grid.

43. Report needs a section titled model time frames and a table similar to Table 2 in the CMU report for consistency and clarity.

44. The basis for the value of conductance per unit length used for 'large' streams of 10 ft per day and for small streams of 1 ft per day? (page 27) needs additional explanation.

45. Page 27 The basis for rangeland recharge used for the quasi-steady state pre-Settlement run needs to be explained, as well as the value for Sy that was used because this analysis was transient.

46. Page 27 What was the rationale for using a different value for conductance of tributaries to the Republican River vs. the rest of the model?

47. Page 27 What was the 40% of canal diversions assumed to be losses base upon. Again, do not ask the reader to take on faith your assumptions. Is this an average based upon canals where records, data are available, estimates by operators of the systems, or what?

48. Table 2 showing canal leakage applied to the model would be improved by using a column showing the range of years a particular recharge rate was applied rather than the starting year. As it is it implies that the values were only applied for the year shown.

49. A statement is needed on page 30 in the second full paragraph regarding value of Sy used for the 'steady state 1000 year simulation' The explanation should be along the line that Sy only affects the rate at which water levels change, and that since the model was run until water levels reached a quasi-steady state, the only impact that using a constant Sy had was the time that it took the model to achieve this state. Such a statement is needed to address questions readers may have about whether modifying Sy during the development period calibration had any affects on the calibration of Kh and pre-development recharge during pre-development calibration. A statement would also be helpful to the effect that the solutions to the groundwater flow equation require specification of an initial condition for transient simulations, and that using interpolated measured data to specify this condition may have the effect of creating an artificial time trend in water level changes caused by in errors in measurement and interpolation of water levels that do not balance the hydraulic conductivity and recharge specified. Use of a simulated steady state condition assures that such artificial trends are not present.

50. Page 30 Second paragraph, last sentence – Clarification is needed here and elsewhere to the effect that recharge generated from CropSim was judged to be inadequate and that other, independent means were derived for the basis to adjust cultivated land recharge during model calibration. Because the increased recharge

to cultivated land results in a net increase in the quantity of water in the simulated system over time, the validity of this approach needs to be more rigorously defended. Simply justifying it based upon model calibration is not sufficient. This concept has serious implications for water management in the modeled area that depend upon it being correct.. Because this is such an important concept, the reports should reference studies that have demonstrated such increased recharge using a variety of lines of evidence. See for example: Scanlon, et. al, 2004 and Arnold and Fridel, 2000. Of course the increased recharge under cultivated land also increases the potential for leaching of salts, herbicides, and pesticides into groundwater, a point brought out by these authors.

51. Page 30 The numerical instability caused by thin cells with high Kh is a result of the use of continuous layers *vis a vis* GMS. The use of the new HFU methods in ModFlow2000 would have been better and probably would have eliminated this problem. However, it is recognized that the HFU package documentation was published after the COHYST project had started.

52. Examination of model input files shows that the first day of the pre-Development simulation also used 1000 time steps to go from 1895 to 1900. If the pre 1895 solution was truly steady state, this should not have been required. There does not seem to have been a test run using the 1895 solution for the 1895 to 1998 period to demonstrate that all transients were out of the system in the 1895 solution.

53. Page 30 For clarity, this paragraph needs to be moved to the reorganized section discussing time domains used rather than in the section discussing the method used to set the initial condition (1000 yr simulation).

54. Page 30 Why was the 1950-1998 period not separated into calibration and verification sections. Calibration did nothing with the pumpage or rangeland recharge functions, they only Sy and recharge on cultivated land (p 45 and see comment re this) were varied during calibration.

55. Page 30 The reasons that CropSim was not used to generate any of the recharge values for simulations needs an explanation. Because the same methodology (CropSim) was used to generate Net Irrigation Requirements that were used to calibrate the development period model. If the methodology is inadequate to generate recharge, then it raises the question as to if the same methodology is adequate to generate net irrigation requirements.

56. Model calibration secion: why are scatterplots of measured vs calculated head not included? Acceptable calibration methodology uses visual inspection of these plots to assess needed adjustments in calibration parameters, and as an aid in assessing the adequacy of calibration. The use of the simple statistics in the reports is not adequate. As seen by scatter plots included with this review, the head calibrations for the pre_Development period are better than implied by the statistics and the text of the reports, but the head change calibrations are not. The head change

calibration plots show significant bias that is likely caused by recharge rates that are too high.

57. The report needs to use more sub headings to improve readability. The section on Numerical Model construction needs to include the following:
    a. Numerical Model Construction
        i. Assumptions
        ii. Numerical method and computer code used
        iii. Computational grid used
        iv. Time domains simulated
            1. Development of initial quasi steady state condition
            2. Pre-gw development period
            3. GW development period
        v. Hydraulic properties
        vi. Boundary Conditions
        vii. Initial Conditions
        viii. Recharge not determined by boundary conditions
            1. Dryland recharge
            2. Leakage from canals and reservoirs
            3. Excess irrigation from sw and gw
        ix. Discharge not determined by boundary conditions
            1. ET from groundwater
            2. net pumpage from wells

58. Page 31 The second paragraph that describes the aggregation process is inconsistent. First, it states that the land use data used as the basis for computing pumpage and recharge was available at a 2.5 m resolution. Then it states that because of computational burden, this data was aggregated to 640 acres. Then it states that pumpage was constant over 640 acres, not 160 acres because data was not available to do otherwise. This is not the reason, the reason is the computational burden. The real reason 640 acres was used is because 640 acres was the initial grid size used in the groundwater model, and pumpage was computed for this grid. While there is nothing inherently wrong with this approach, the real reasons used should be clearly stated.

59. Because the resolution of pumpage data as a result of the process used to aggregate it is only 640 acres (one square mile) the resolution of simulated water levels and stream-aquifer interactions that are determined by pumpage is limited to one mile. Why was no attempt made to at least assess the impact of the variability within the 640 acre cells once the decision was made to go with the 160 acre cells?? Since the 1997 land use data was saved to 10-acre cells, it should be a straightforward process to assess the variability of pumpage within the 640 acre cells using this data.

60. Page 32 First and second paragraphs the statement that daily potential ET was not available from CropSim does not make sense. Daily PET is an OUTPUT of CropSim, not an input, and is computed using climatic data. If the reason PET was

not available from CropSim is that CropSim was judged to be an inadequate method, it should be so stated. However, since CropSim, and the ET computed with it was used for computing net irrigation requirement, the ral method used for ET needs to be correctly reported. Review of the CropSim model code, draft model documentation, and the CropSim Scenario and Update Report all discuss different ET methods that were supposedly used.

61. The use of Blaney-Criddle is not mentioned at all in the reports by Rich Kern of NNDR. Based upon examination of the CropSim computer code and the CropSim Update and Scenario report provided for review, CropSim uses Hargreaves with the weighting factor computed by calibration to Penman-Monteith, the most data intensive, but most physically based model, for stations where PM data was available. The real reason Blaney-Criddle was used , who did it, and where its use is not documented. However, the draft CropSim documentation report obtained by our request says that it IS Blaney-Criddle that was calibrated using station calibration factors. At a minimum, there needs to be consistency between reports as to what method was used.

62. The discussion of reducing the net pumpage arbitrarily infers that this was required as a result of model calibration problems. If so, it should be so stated. If CropSim underestimated recharge, it likely also overestimated net irrigation requirements. If this was a finding of the COHYST study, it should be so stated.

63. It is misleading to use the word calibrated because it implies that Blaney-Criddle calculations were checked against measured Evaporation or PET values at the met stations, which they clearly were not. Based upon review of other reports, the ETr values used in CropSim were calibrated against another method of computing ETr, namely the Penman-Monteith method. Why is the term “a” Blaney-Criddle method used instead of “the” Blaney-Criddle method?? To my knowledge there is only one such method. If more than one was considered, the basis for the selection of the particular one used needs to be provided.

64. Page 32. What is meant by the term substandard locations? This is not defined. p 32 simulation of the make up of irrigation demand for surface irrigation was assumed to come from groundwater and simulated as negative recharge. Because recharge (positive or negative) is applied to the highest active cell, this assumes that the pumpage comes from the uppermost active cell. Why was negative recharge applied at all? What was the rationale for doing this? Were registered wells present where this occurred, or was it arbitrarily applied?

65. Page. 33 Check of number of wells in report table with provided calibration spreadsheets: 1950-61 report has 132, dataset has 131 valid points; 1961-1973 report and dataset agree at 219 points; 1973-1985 report and dataset agree at 280 points; 1985-1998, report and dataset agree at 405 points; 1950-1998, report and dataset agree at 78 points; pre-development period report has 428 points but dataset only has 424 valid points.

66. Page 35 Calibration for the pre development period: Not clear what method was used for calibration, manual, automatic using PEST or other codes, or a mixture of both.

67. Page 36 Use of evapotranspiration surface. Based upon this discussion, the ET Surface should always be less than the mean land surface elevation in a cell. I assume the mean land surface is also equal to the top elevation of the cells in layer 1. A check using GMS grid math shows that the ET surface ranges from 43 feet ABOVE the land surface to 65 feet BELOW the land surface. Check of ET differences between ET surface and mean cell land surface (top of layer 1) by importing into ArcGIS shows that > 30% of cells where ET was simulated have the surface above the land surface, which effectively limits or eliminates EG from groundwater in these areas.

68. Using heads as calibration targets for the pre-development period and head changes for the development period is appropriate and the reason given for not propagating error from the pre to the development period is also appropriate. Using head differences for calibration targets however means that there cannot be any verification runs of the calibrated parameters from the pre-calibration period.

69. Using the head differences pre-defines why the model is not sensitive to hydraulic conductivity, as it will determine the head, and not the difference in head, which is a function of the storage capacity of the aquifer and the net removal or addition of water from a cell. However, the head difference at a point is totally a function of the pumpage/recharge balance as shown in the sensitivity runs because the sensitivity to Sy is essentially zero.

70. Why was no sensitivity analysis done using streambed conductance during both the pre-Development and Development periods? Since this interaction is what the whole study is about (or most of it) the lack of such analyses means that any bias built in to the pre-calibration period is carried forward.

71. Why in the pre-development model were only three relatively small streams selected for sensitivity analysis, and no reach gains on the Platte used?

72. Streamflow stations used for calibration. There are no stations in large areas that are affected by groundwater pumpage in Buffalo and Hall Counties. The baseflow analysis report included 6 stations that are outside the modeled area that are tributary to the Loup/SouthLoup from the north. With the dearth of streamflow data, the use of an assumed pre development low flow that was computed using pre and post development data, and the assumption that the 7-day 5-yr low flow represented conditions in 1950, and the model calibration comparison only was within the range of the high and low values, it is not apparent that the model has been calibrated at all to baseflow. Sensitivity analyses were only run on three small tributaries that are not in areas where interchange with the Platte R is important.

73. Using Loup and Republican River stations in an attempt to show calibration is specious because they receive groundwater discharge from areas outside the model. If such a comparison is to be made, some allocation formula needs to be presented and defended that determines the relative contribution from within and without the modeled area

74. Mass curve analyses of reach gains and losses is a better way to illustrate the gains and losses and changes to these as a function of time.

75. Page 45 Calibration for the development period: Why was recharge to cultivated land varied during calibration? Why was the CropSim calculated data not used? This would have reduced the uncertainty in this parameter and hence reduced the uncertainty in the model. The reasons that CropSim recharge was judged to be inadequate need to be discussed.

76. Why cannot yearly ET change dramatically from station to station? It is based upon temperature data which changes from east to west across the modeled area. What variation was there and why was it judged to be too extreme?

77. Why was ETr using CropSim not used for the maximum ET from groundwater?

78. Page 47, Table 6. Mr. Peterson's personal observations of groundwater discharge are not documented. Since groundwater discharge cannot be directly observed or measured in streams that have a surface water component, the basis or support for these statements need to be more fully supported. While the values may in fact be reasonable, simply citing the author's judgment is a weak defense of the numbers, and says nothing about their values. For example, the small values could easily be changed by factors of 2 to 8 and still be reasonable, but would imply different degrees of connection with the groundwater system. It is not explained how the USGS 1:100000 topographic maps were used to determine groundwater discharge rates. These maps only show where streams become perennial at the time the aerial photography used to make them was flown. As stated in the report, it implies that Mr. Peterson was present so as to make observations during the pre-Development period, which is impossible.

79. Page 48 The mass balance discussion needs to explain where the water coming out of storage is going and what implication this has on use of this as an initial condition to the development period simulation. This period simulated no extraction of water from wells, so water coming out of storage cannot be going there. It is not reasonable for the water coming out of storage to be going to streams because this implies that either the base level of the streams was lowered (not possible or reasonable) or that the recharge rate is declining. The imbalance between specified inflow and outflow at the western and eastern boundaries cannot account for the rate water is coming out of storage. The only thing left that can account for the change in storage is ET. This implies that ET is mining

groundwater, which is not reasonable, because ET is a self correcting extraction process. ET and its parameters were not calibrated during the pre-development period. They should have been.

80. The mass balance data from the calibrated models need to be presented as functions of time.

81. ET from groundwater is probably the most important process that affects the interaction between groundwater and surface water. Why was it not evaluated more rigorously and why was it not a sensitivity analysis factor?. It is more important than rangeland recharge, hydraulic conductivity, storage, net pumpage, and recharge from canal leakage to effects on streamflow because it operates in areas that are the closest to the streams. By not including it in the calibration and sensitivity analysis processes, the models may be biased by the arbitrary selection of the parameters used to define ET from groundwater (maximum ET rate and extinction depth).

82. The use of maximum ET rates that are the difference between lake evaporation and precipitation is not correct. ET from gw is driven by atmospheric demand, not by the difference between this demand and precipitation. The method used assumes that no precipitation becomes runoff.

83. Recharge was apparently also applied where ET from groundwater was simulated.

84. Why is there no water budget included for the quasi-steady state (pre-Settlement, or initial condition) analysis?

85. It is not clear whether ET was included in the quasi-steady state analysis.

86. Page 48 Pre groundwater development model mass balance: If there is not groundwater pumping, where is the water from storage coming from? It is approximately equal to ETout.

87. There is no time period given for the pre-development mass balance in Table 7. Since this obviously was a transient simulation, it is necessary to specify this. Why was a time history of the mass balance components not included?

88. The project did not include any verification runs of the calibrated model. The volume and length of record of water levels, pumpage, and canal data available to COHYST would seem to warrant such runs, and they would increase confidence in the models.

89. Page 49 Why was CropSim or a similar method not used to develop recharge?

90. Because the most sensitive parameter in all the models is the forcing function (the balance between recharge from all sources and net withdrawals from all sources at a

given cell). The methodology used to develop it by Rich Kern needs to be published as a peer reviewed document for completeness of the COHYST archive.

91. There are inconsistencies in the documents prepared by Rich Kern and statements in the EMU report that imply that the EMU model either did not use the Rich Kern outputs for net pumpage or that the EMU author was not aware that CropSim uses Hargreaves ET calibrated to climatic stations where Penman Monteith data are not available. Examination of the CropSim code shows that Hargreaves, NOT Blaney Criddle is used.

92. Page 51 The discussion of temporal changes in simulated reach gains and losses is necessary to demonstrate improved understanding of the hydrologic system. This discussion would be helped by separating the simulation results under a separate heading as was done in the CMU report and by the inclusion of either a map or charts to demonstrate the temporal changes and agreement with observations.

93. Why was a single layer model not constructed using the thickness-weighted hydraulic conductivities and tested against a simulation with the multiple layers? This should have been part of a sensitivity analysis.

94. Verification: Why were the Sy values from the calibrated development period model not used to re-simulate the pre-development period as a double check on the Sy values that were not adjusted during the predevelopment period?

95. References: note that Boss International has been removed by EMS-i as a valid distributor and supporter of GMS – probably should cite the authors of the code, EMS-i or EMSU at BYU.

96. Model Calibration: Comparison of Base flow of streams uses only the simulated value for 1950 compared to the range in base flow for the entire pre-development period. This comparison assumes that no changes in base flow occurred during the pre-development period. This is not the case, as baseflow likely increased in areas where large water level rises associated with surface water irrigation and canal losses occurred.

97. Model Calibration. The use of winter baseflow (which is what was developed and used) as a calibration target requires that the modeled baseflows from the winter only to be used. Since the pre-development period did not use seasonal time periods, this was not possible. The assumption was apparently made that baseflow is constant.

98. Model Calibration. Selection of targets, flow: since limiting changes to streamflow beyond base conditions is one of the COHYST goals (2005 PPT presentation and project purpose documents), the target should have been changes in streamflow between locations and over time, not the absolute flows. The rationale for selection of this target should have been the same as it was for using changes in water levels

during the development period. As it is there is no information from the model calibration that sheds any light on how well the models reproduce historical changes in streamflow between gages and over time.

99. Use of the models. Why do the reports not include a section on example uses of the models with limitations discussed. For example the sdf computation using the one-mile grid models. This application is not discussed in the model report.

100. There is no documentation of streamflow changes over time during the development period. Why was this not compared to changes in baseflow over time, which has occurred

101. Why were the only three streams selected for sensitivity analysis in the Republican River portion of the model? Why was reach gain and loss on the Platte not assessed? For the models to be of utility to the COHYST purposes, the Platte needs to be included in the sensitivity analyses.

102. The most important use of the models, groundwater/surface water interaction is given the least amount of discussion in the model calibration and sensitivity sections.

103. Model Sensitivity: Sensitivity analyses did not draw conclusions regarding the Type of sensitivity (type I, II, III, or IV) because no model goals, or conclusions were tested. This is a major oversight because no potential Type IV parameters were identified (or eliminated) Type IV results from insensitivity of calibration statistics and model goals not being met. See ASTM D5611-94.

104. Model Sensitivity and utility: Because the model goals were not identified and quantified (as they might have been in the case on the one application to which the EMU has been applied [Computation of SDF maps]), the calibration of the models relative to their intended use is untested.

105. While the models may agree well with the conceptual model, their utility is limited because of the lack of quantifying model objectives or goals and testing the models against them.

106. There should have been a set of sample questions with defined metrics that the models were expected to meet at a minimum. Examples from our understanding of COHYST objectives: 1) Change in streamflow between two stations caused by increased groundwater withdrawals is less than a specified percentage of some low flow minimum; 2) Change in ET from groundwater that is ‘salvaged’ by water level declines caused by pumping; maintaining a minimum depth to water beneath wildlife impacted wetland areas, including areas that are modeled as rivers (sensitivity to streambed leakance and et parameters).

107. Conceptual Model, regarding the use of do not allow cell drying.: Comparison of Figure 6 conceptual model heads to simulation with cell drying not allowed actually reproduces the 1900 ft high in Webster County, whereas the Calibrated Pre-Development head shown on Fig 18 does not – which is more realistic? Need to explain the lack of agreement here.

108. Calibration Targets: Why were not vertical heads beneath streams and rivers not collected and used for targets? This is the only way to properly see if the streambed conductance values used are reasonable.

109. Calibration Targets: Where were the wells screened that were selected for use in calibration – need to clarify and document in report

Attachment F.—Specific Review Comments: Central Model Unit Report

Note: Where sections of the CMU Report are identical to those for the Eastern Model unit, the comments made in Attachment E pertain to the same sections of the Central Model Unit Report.

1. There are two copies of Figure 8 in the report – one at p. 21 and one at p 25.

2. Why was the southwest boundary of the model at Frenchman Creek rather than the Republican River? This does not seem consistent with the rest of the modeling strategy in for treatment of the Republican River in the EMU.

3. Pre-development initial conditions model – why was it necessary to run 5000 yrs for the CMU – Steady state was apparently reached sooner than 1000 yrs in EMU and WMU – these sound like arbitrary time periods.

4. Conceptual model: need a discussion regarding use of 6 layers in CMU, 5 layers in WMU, and one layer in the WMU and how the models should compare given these differences. There is no discussion of the computed vertical gradients in any of the models that as developed.

5. Page 24. The upper model boundary is not the watertable in the conceptual model or the numerical model. Rather, the upper model boundary is defined as a combination of the land surface, drain elevations, river and stream stage elevations, constant head and general head driving heads, and the et surface. It would be correct and simple to state here that the upper model boundary is the land surface

6. Page 27. Model boundary conditions: The discussion on Fixed Water level boundaries should be discussed as general head boundaries, as this is what was used in the model datasets.

7. Page 28 The discussion of the linear finite difference equation – same comment as for EMU. The equation is quasi-linear because the watertable is being solved for in the uppermost saturated layer and the lateral cell to cell flow is a function of the saturated thickness which depends on the solution variable. Similarly, use of ET and leakance source/sinks that depend on head make it quasi-linear which has to be solved by an outer iteration loop in the model iteration

8. Page 27 There is no discussion or rationale given as to the reasoning behind the use of a single value of hydraulic conductivity was assigned to layers 1 and 6. Such a discussion is needed.

9. Page 27 There is no discussion to support vertical to horizontal hydraulic conductivity ratio used.

10. Page 31 The capabilities of GMS to build the conceptual model from borehole data was apparently not used, rather contour maps of the various HUs by Cannia and others were imported to construct the tops and bottoms of the layers in the model. A statement as to why this powerful conceptual modeling capability of GMS was not used should be included.

11. Page 31 Discussion of allowing cells to go dry (and rewet) was checked with the model datasets and the CMU properly modeled this function.

12. Page 35 Why was the DEM used for the land surface not used for stream bed elevations as was done in the EMU (EMU p 24). The source, and horizontal and vertical resolution of the DEM used needs to be stated.

13. Page 31 The discussion of the stream and river boundary conditions needs to be deleted here. It does not fit here and it is repeated in the subsequent section on model boundary conditions

14. Page 34 The discussion in the text is inconsistent with the dates in Table 2 – i.e 1895-1928 in the text and 1895-1927 in the table.

15. The thin cell problem re rewetting is a function of the way GMS was used that requires continuous layers to be present throughout the model.

16. Use of Stream BC rather than River BC would have allowed the Platte to go dry and apparently no time-dependent stage data was used for the River boundary condition.

17. Page 35 Reference to Table 2 for canal leakage should be to Table 3.

18. Same comment as for EMU about support for assumed 40% canal leakage.

19. Figure 14 (also in EMU report) why was a statistical fit not used?. It is not apparent that the slope of the 1950-65 and 1973-98 lines is significantly different from zero.

20. Figure 14 vs data in Table 3 for Gothenburg Canal. What was done between 1900 and 1950? Was a linear increase used or a step change in 1950. Not clear from the text or table.

21. Page 38 Inclusion of the equation for rewetting, and the entire discussion on numerical difficulties with rewetting seems inconsistent with the rest of the report and the WMU and EMU reports in that this level of technical detail is lacking in the other reports and elsewhere in this report. While the discussion is helpful, the equation is not necessary.

22. Page 38 What is meant by the phrase “reasonable results…”? Additional clarification is needed.

23. Page 39 Comments on development of net pumpage and recharge from EMU and WMU reports pertain here as it is a duplication of those reports

24. Page 40 Which other methods of estimating net pumpage are being referred to, and why were they deemed not as applicable?

25. Page 40 Comments on the EMU report re use of Blaney Criddle and CropSim pertain here as the text is a duplicate of that report.

26. Model Sensitivity – more on the lack of assessment of Type IV errors from the EMU review: the accuracy of the model with respect to streamflow was not assessed, so the answer vs accuracy chart cannot be used. There was no question posed and hence not answer is possible for the water level sensitivity analysis, so the answer vs accuracy chart cannot be used. This is a problem common to all 3 models

27. Page 41 Regarding not calibrating to changes in flow because there are only 'slight changes in streamflow': Modeled changes should have been computed to make sure that they were at least still only 'slight'. I would not agree that changes in flow have only been slight in the CMU. Frenchman Creek, Stinking Water Creek and others have had significant reductions in flow due to irrigation.

28. Why was groundwater recharge from over application of surface water not estimated and used in the pre-development model in the same manner as used for the development period model?

29. There is no discussion on the process used to adjust streambed conductances to fit streamflow. Was the mean of the 7Q5 and 14Q2 fall flows the real target used during this process?

30. Page 47. Regarding the statement that drain conductances were assigned based upon the values used for the pre-development multilayered model – This report documents that model and this section of the report discusses the pre development calibration. The sentence appears to be misplaced and needs correcting.

31. Throughout – two spellings, gauge, and gage are used interchangeably throughout the report.

32. The method, rationale and results of the estimated rangeland recharge for the pre-development period is more physically based than that used for the EMU, which used arbitrary county boundaries in certain locations to change recharge rates.

33. Apparently a sensitivity analysis was done on Sy and canal seepage for the Pre-development period model, based upon the model files provided but the results of these analyses are not discussed in the report – why not? Note that for both EMU

and WMU my comment was that these analyses should have been done and included but if done, they are not discussed.

34. Sensitivity analyses reported using streamflow gains and losses were reported for only two streams and not for gains and losses to the Platte River, why not?

35. ET Surface for CMU is always lower than mean land surface as represented by the top elevation of layer 1, and maximum distance below mean land surface is 25 ft – note this is not the case for the EMU.

36. Why are the reservoirs along the NPPD and CNPPD canals and other internal lakes not included explicitly in the model? The are of comparable size to on channel reservoirs that are included on tributaries of the Republican River. The text states that they are located at elevations above the watertable. It is not clear form the text how leakage from these lakes was simulated in the model. If it was it included in canal leakage, a discussion of the method used to incorporate it is needed.

37. There are three areas in the western part of the model that have inactive cells in all models: R94 C5,6; R95 C6; R96 C3; R96 C6,7; R115 C25, 26, 27, 28; R116 C25, 26, 27, 28. The IBOUND Array is all 1 at all of these locations, and the top and bottom arrays appear to be fine to, as do the hydraulic conductivities. However, the starting heads in all these cells are set at -888, the code for a dry cell. These do not appear to be bedrock highs or areas of all layers at minimum thickness – what is the reason for this?

38. Why is Plum Cr not in the pre-development or development period simulations? It is mentioned in the text on p 24, but is not in the model dataset for CMU. It is present in the dataset for EMU.

39. Thicknesses and saturated thicknesses do not match adjacent EMU and WMU models in the overlap areas in several areas.

40. There is no check on changes in simulated streamflow, river gains, or drain flow for either the pre development or development periods. A lot of information is present here that could and should have been used for calibration and sensitivity analysis. In particular, the increase in reach gain to the Platte R and to drains on the south side of the Platte caused by canal leakage and excess surface water irrigation. (This comment applies to all models)

41. p 53. discussion of disagreement between modeled river gains combined with drain flow not matching low flow analysis because low flow analysis did not account for drain flow. The low flow analysis on reach gains should have accounted for any drain that discharged to the river in that reach.

42. Assignment of stream and river elevations is inconsistent with the method used to assign drain elevations and results in some stream and river elevations being located

in layer 2 at large distances from the land surface in the model (> 20 ft.) Applies to EMU also.

43. Calibration: There is no discussion or presentation regarding the completion zones for the wells used for calibration purposed. At least some justification needs to be made for the layer in which the observation wells were assumed to be applicable. This is also applicable to the EMU model, although not for the WMU model as it is only one layer

44. Pumping wells. Most irrigation wells are screened the full length from the watertable to the bottom of the well. Consequently they pump from whatever hydrostratigraphic units they cross. How was this taken into consideration in applying pumpage to the models? There was no multiple layer completion option used in any of the models. The wells are assigned (apparently in an arbitrary manner) to layers that appear to be the thickest and most permeable, although this is not always the case.

45. Page 60 additional recharge added to cultivated land. The method used for the CMU (and EMU) is somewhat arbitrary and is not consistent with that used for the WMU which was based on soil moisture holding capacities. An explanation is necessary as to why CropSim did not adequately compute this recharge both under non-irrrigated conditions and under groundwater irrigated conditions. The argument attributed to Peterson to justify the additional recharge is flawed, because if net pumpage is correctly computed using either NEBGUIDE or CropSim as the amount to just meet crop needs by maintaining the root zone at field capacity with NO deep percolation that can become recharge. The argument may be plausible for cultivated dryland that was converted from range land, and for surface water irrigated lands in which the water applied came from outside the area immediately overlying the area where recharge is applied.

46. Page 61 Simulation results: the discussion of simulated time changes in water levels would benefit from the inclusion of a few example simulated hydrographs.

47. The discussion of temporal changes in simulated reach gains and losses is necessary to demonstrate improved understanding of the hydrologic system. However, it does not include such a discussion for the Platte River, the principle focus of COHYST. The discussion would benefit from the use of maps and charts of the temporal changes. See the figures prepared for this peer review.

Attachment G.—Specific Review Comments: Western Model Unit Report

Note: Where sections of the WMU Report are identical to those for the Eastern Model unit, the comments made in Attachment E pertain to the same sections of the Central Model Unit Report.

1. Was the WMU developed and built before the HU report? The discussion on pp 20 and 21 indicates that this is the case. Why is Table 1 used instead of the Table from the HU report?

2. Why is there no map showing the distribution of the HUs and the rationale for lumping them together.

3. The Ogallala underlies the Dune Sand in the northeastern portion – Why was a single layer used here?

4. Why were fixed flow rather than general head boundary conditions used? Was sensitivity to this decision analyzed?

5. There appears to be no use of drain boundary conditions why not? Use of stream boundary condition requires input of flow so that leakage out is limited to flow in stream. Drains were found to be important to include in both the EMU and CMU.

6. Page 24 statement regarding the groundwater system not in equilibrium around Lake McConaughy – where is the discussion re the importance of this (or lack thereof)?

7. Page 24 Statement that 160 acre grid size is presented as adequate for the intended use of the model as a given with no discussion of the intended uses of the model.

8. Statement that the use of vertical flow through a conceptual streambed layer is appropriate over the scale that the model is constructed has no support or basis.

9. Statement that single layer is justified because vertical flow components are ‘probably small compared to horizontal components’ as the justification for a single layer is not supported by independent analysis.

10. A better justification for the single layer is that irrigation wells are open and screened in multiple units where they exist, and observation wells may also be. Therefore, the system as simulated cannot resolve or be use for conditions that say the Ogallala may be managed differently than the Sand Hills.

11. Assumption of isotropy statement on p 24 appears to be circular reasoning

12. The modeling strategy document for all the models stated that the process started with 1 mile grid cells then evolved to the half mile grid where is the discussion of this evolution process, or was the ½ mile (160 acres) selection arbitrary to satisfy the resolution of expected management practices, and if so what were these?

13. The basis for setting stream and river bed conductance is not clear. Was it a calibration parameter, set to the value of the hydraulic conductivity of the cell, or some other rationale?

14. How was the general head boundary condition used for Lake McConaughy? What was assumed for the lake bed conductance?

15. Check of model files shows that both a river and general head boundary were used for Lake McConaughy. Why does the General Head Boundary used for Lake McConaughy not cover the entire reservoir? It only covers the perimeter and the center is a river condition. Check of model data sets shows that the head for the general head boundary condition is set at 3240 and that the in the river boundary condition along the center of the lake ranges from 3112 at the dam to 3189 at the upstream end.

16. Was recharge from canals added to recharge from precipitation in the canal cells? It should be, because the canal only occupies a small portion of the cell.

17. What was used for specific yield for the 2000-yr 'steady state' pre-development condition?

18. What was the basis for the selection of 2000 years for the quasi-steady state run? If such long periods are actually required to achieve a quasi-steady state because of the limitations of thin, high permeability areas of the model, then this may severely limit the utility of the model for completing future analyses that require an assessment of the time it takes the impact of changed water management scenarios to equilibrate.

19. Use of the re-wetting option is not discussed in the report, although the model datasets include it.

20. Page 30. It is not clear which model required the long processing times? Is this a constraint on future uses of the model?

21. The use of NEBGuide necessarily only simulated changes in stress on the aquifer (net pumpage) as a function of the land use estimated for that year, which was a random spatial function . Therefore, pumpage each period was a constant function in time, but a random function of space.

22. How was 'effective precipitation' determined for use in the NEB guide method?

23. Was the 10% reduction in net irrigation driven by model calibration difficulties or analysis or was it completely independently derived based upon agronomic considerations. Clarification of this is needed.

24. General comment: The discussion of the model construction process is fraught with arbitrary statements that things are 'appropriate' or 'adequate for the scale of..'., or 'acceptable', without any justification or reference forward to any such justification that may be derived by sensitivity analyses. This requires the reader to take it on faith that such statements do not require the support for them to be based upon data, analyses, literature values, or other independent sources.

25. Page 32 discussion that PET not ' available ' is not clear. PET is never 'available', it is computed from climatic data or measured for the reference crop in lysimeter studies.

26. The random process of removing irrigated land backwards in time makes sense, and is probably a rational way to estimate historical withdrawals in a model cell. What sensitivity analyses were done on the assumptions of this process? Was only a single realization used or were multiple realizations used and some measure of expected value or central tendency from the multiple realizations selected?

27. The logic of using time-varying effective precipitation to get time-variant net pumpage using average crop consumptive use requirements from NEBguide does not make sense if the defense of using the average consumptive use values is that the model calibration occurred over a multi-year process.

28. Which version of CropSim was used for the WMU – the original one used for COHYST or the updated one reported in the final CropSim report by Flatwater Group?

29. Boundary Conditions: Apparently the fixed flow boundaries in the pre-development model (and I assume in the development period model used recharge to simulate the flow at the boundaries. This was determined by examination of the model data files, but is not discussed in the text. There are several areas where the specified flow is out of the model along the western boundary. (R13C9 thru R34C9 , R9C6 thru R96C6, R123C4 thru R140C4, R141C3ThruR144C3, and R209C1 thru R215C1 What is the support for this? Why was a General Head Boundary Condition not used?

30. Page 47 The discussion of temporal changes in simulated reach gains and losses is necessary to demonstrate improved understanding of the hydrologic system. However, it includes no discussion of such changes to the Platte River. This discussion would be helped by separating the simulation results under a separate heading as was done in the CMU report and by the inclusion of either a map or charts to demonstrate the temporal changes.

31. Page 34 check of the number of wells used for calibration in the table on p 34 with data provided in calibration spreadsheets shows the following: For 1950-48, table has 33 wells, spreadsheet has only 31 valid wells; 1950-61. For 1961-73, table and spreadsheet agree at 45 wells; For 1973-85, table and spreadsheet agree at 42wells; For 1985 – 1998 no spreadsheet was provided for comparison. The estimated number of points by Stanton in the report is 154, but the spreadsheet only includes 145 valid points.

Attachment H.—Review of Baseflow Estimate Reports (K Wahl)

Review of reports on Estimated Groundwater Discharge of Streams in the Western, Central, and Eastern Model Units

as part of

Independent Peer Review of the Cooperative Hydrology Study of the Platte River Basin in Nebraska

Hydrology Report 2005-2

May 8, 2005

Prepared for

Eagle Resources, P.A.
4005 Lake Springs Court
Raleigh, North Carolina 27613-1525

By

Kenneth L. Wahl, P. E.
Ken Wahl Hydrologic Engineering
22155 Highway 34
Akron, Colorado 80720

Review of reports on Estimated Groundwater Discharge of Streams in the Western, Central, and Eastern Model Units

Overview of the Review Process

The common purpose of the three reports is to present estimates of ground-water discharge from the High Plains aquifer to the streams of the individual study units. That purpose is clearly stated in the introduction of each report. The statement of purpose notes that most stream-flow data are affected to some degree by diversions through canals that have been in existence throughout most of the data collection period; furthermore, large-scale development resulting from changing pump technology and 1950s and 1970s droughts is reflected in flow data collected since about 1960.

The reports follow a common format and outline. The introduction and most of the description of the procedures followed are the same in all three reports, changing only the portions that discuss issues specific to the individual study units.

Procedures followed for the review:

1. Reports were read for content and compared for consistency between study units.
2. Lists of gauging stations identified in the reports as being available to the study were compared to the lists of data available from USGS and the State of Nebraska databases.
3. Conceptual models were evaluated, and computations (in this case, low-flow statistical analyses and mass-balance computations) were reviewed for conformance to generally accepted procedures.
4. Computations presented in tables 3 and 4 were spot checked.
5. Data were downloaded from the USGS and State databases for the alternative analyses needed to assess the validity of the low-flow statistics concept of defining ground-water discharge.
6. Results of the alternative analyses were compared to the report results.

Available data

An independent search of surface-water databases of both the USGS and the Nebraska DNR shows that all available data were considered in each of the model units. Because of the desire to use common periods of record to the extent possible, some short records were not used to determine ground-water discharges; those sites are identified in table 2 for each report.

A few stations that were used in the analysis are no longer available for electronic retrieval from the internet. Those sites include 06688500 Otter Creek near Lamoyne in the western unit, 06837300 Red Willow Creek above Harry Strunk Lake in the central unit, and 06770000 Platte River near Odessa in the eastern unit. These data were available on-line until USGS revised the on-line databases after year 2000. The reason the data are no longer available on-line is not known; however, the Odessa data are important to the analysis and were obtained directly from USGS.

The reliability of computations that use canal data is reduced because of the condition of the canal records. The State canal databases have unexplained gaps in the records for many of the canals. Specific canals, such as the Gothenburg Canal (570000) that was added to the Cozad data, have only seasonal records for some periods. For example, the Gothenburg Canal in 1969 shows no data for October, November, and 25 days in December. Beginning about 1973, seasonal data are shown that exclude the winter months. The missing periods vary from year to year, but generally range from October – April. Similarly, the Kearney Power and Irrigation diversion (00730) is added to the flow at Odessa. The record retrieved from the State Canal Database contains numerous missing days; those days may have been zero flow, but that is unclear as other periods of zero flow days are contained in the records. Examples of missing days are given in the specific comments about tables 3 and 4.

The following note included in the Eastern Model Unit directory under Platte\canal\process.notes.txt acknowledges the missing data: "*In several instances, the discharges for flow records are missing for periods of days to months at a time. Therefore, the day notation was deleted where the associated October or November discharge measurement was missing. In cases where those days fell in the month of October or November, the entire set of October and November measurements were deleted, so that that year would not be included in the low flow analysis. This avoids creating a built-in bias that may result from using incomplete October or November results*."

Conceptual models

There is general agreement that the base flows of perennial streams in the study area are derived from ground water. The task is to define those base flows. Doing so, however, is complicated because the Platte River and its principal forks (North and South Platte) are regulated and are affected by diversions and return flows.

The study assumes the impacts of diversions and return flows are minimal during the non-irrigation season, generally October to March. However, because winter-flow data are generally of poorer quality than data for the rest of the year, the studies used data only for the fall of the year, defined herein as October and November. As the study progressed, the investigators recognized that the October flows for many gauged sites showed evidence of the effects of diversions. At those sites, the data were further restricted to just the month of November.

The study uses two concepts to determine ground-water discharge in the study area. The first concept is that low-flow characteristics at gauging stations during the fall are indices to the ground-water discharge passing those points. The second concept is that gains or losses of flow in a reach of stream between gauged points can be determined from a mass-balance approach as the difference between outflow from the reach and inflow to the reach.

Estimated ground-water discharges at individual sites in table 3 of each report are based on the assumption that annual fall-season average 7-day and 14-day low flows are representative of ground-water discharge to the streams. The low-flow determinations were restricted to the months of October and November because those months are believed to be relatively free from diversions and return flows. The studies define the fall 7-day average low flow with a 5-year recurrence interval (0.2 annual non-exceedence probability) as equal to the minimum groundwater flow; the fall 14-day average low flow with a 2-year recurrence interval (0.5 annual non-exceedence probability) as equal to the maximum ground-water flow. The reports explain the process used, but do not establish the basis for the assumption. The validity of this assumption is crucial to the COHYST study. Therefore, in addition to reviewing the computations presented in the reports, this review included an alternative computational approach to test the assumption.

The reach gain/loss computations presented in table 4 of each report also used a frequency-based approach, but relied on the monthly averages rather than the 7-day and 14-day low flows. The reports describe the process in general terms, but leave out the detail that the mass-balance is actually done on a daily basis. A daily-flow mass balance for the reach was computed by subtracting reach inflows from reach outflows. The annual daily net gains or losses were averaged for the fall period (many were restricted to November only), and the frequency analysis was performed on the resulting annual data series. The daily mass-balance computations do not make any allowance for transit time through a reach. Transit times could range from a few hours to more than a day. That may affect the accuracy of gains or losses for individual days, but should have no effect on the final results that are based on averages over 1 or 2 months.

The reach computations could have been done using the results for the individual sites from table 3. Doing so, however, would have required an assumption that the tributaries experience the 7-day 5-year and 14-day 2-year flows at the same time as the main stem. Given the degree to which the main stem of the Platte River system is controlled, that would have been a poor assumption.

The results of the alternative approach are shown in the following section. Specific comments on the low-flow computations reported in table 3 of the reports are summarized in later sections of this report as are comments on the mass-balance computations used to define reach gains and losses.

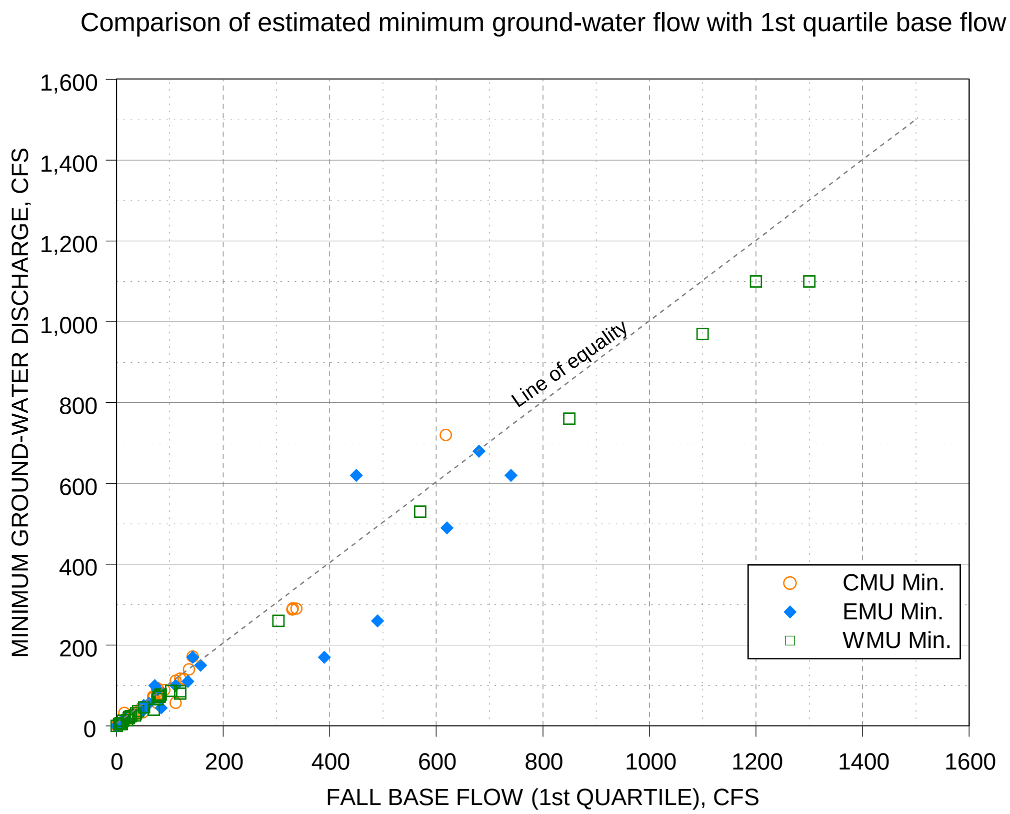
Alternative Approach

The base flow of unregulated streams during periods of minimal evapotranspiration is generally indicative of ground-water flow. Several computerized methods exist for using hydrograph-separation techniques to estimate base flow from daily-mean discharges of streams. The BFI model uses Fortran code developed by Wahl and Wahl (1988. 1995, http://www.usbr.gov/pmts/hydraulics_lab/twahl/bfi/) to estimate the base flow of streams from daily-mean discharge records. The program is based on a computational procedure first described by the Institute of Hydrology (1980). In the original Institute of Hydrology approach, the flow hydrograph for a year was divided into 5-day segments, and the minimum flow in each 5-day segment was flagged as a possible point of the base-flow hydrograph. The minimum points were then compared to adjacent minimums in a rate-of-change test; if 90-percent of a given minimum was less than both adjacent minimums, that minimum was a point on the base-flow hydrograph. The selected points, when joined with straight lines on semi-logarithmic paper, formed the base-flow hydrograph. The BFI code automated this procedure and permitted the user to specify segment lengths other than 5 days and to modify the rate-of-change test. For the current application, however, 5-day segments and the 90-percent test were used.

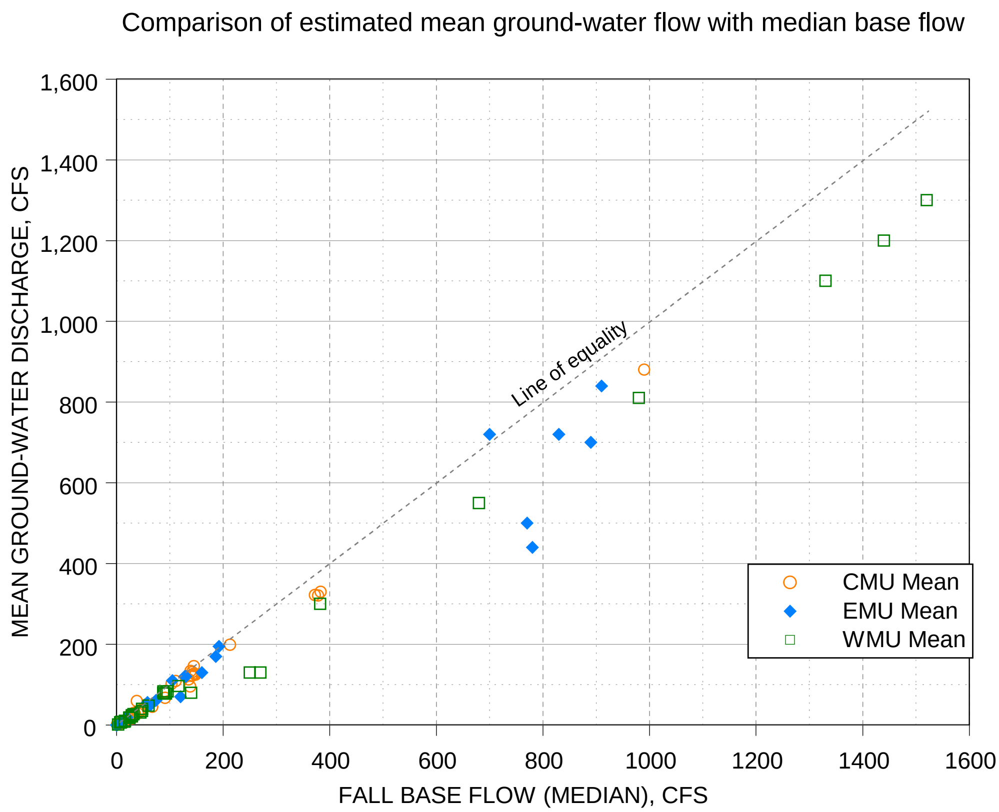
Hydrograph separation is not usually done on regulated streams because a relatively constant release from a reservoir will be interpreted as base flow. However, the purpose of the COHYST study was to define gains from or losses to ground water in the respective reaches. Therefore, BFI was run for selected main-stem stations used in the reports under the assumption that irregularities caused by regulation will be reflected on stations at each end of the respective reaches. Because of the regulation, the resulting values do not necessarily represent base flow; instead they are simply daily values that have had short-duration, high-flow values filtered out. That being the case, however, differences in the estimated base flows between the ends of a reach should be representative of flow to or from the ground-water system.

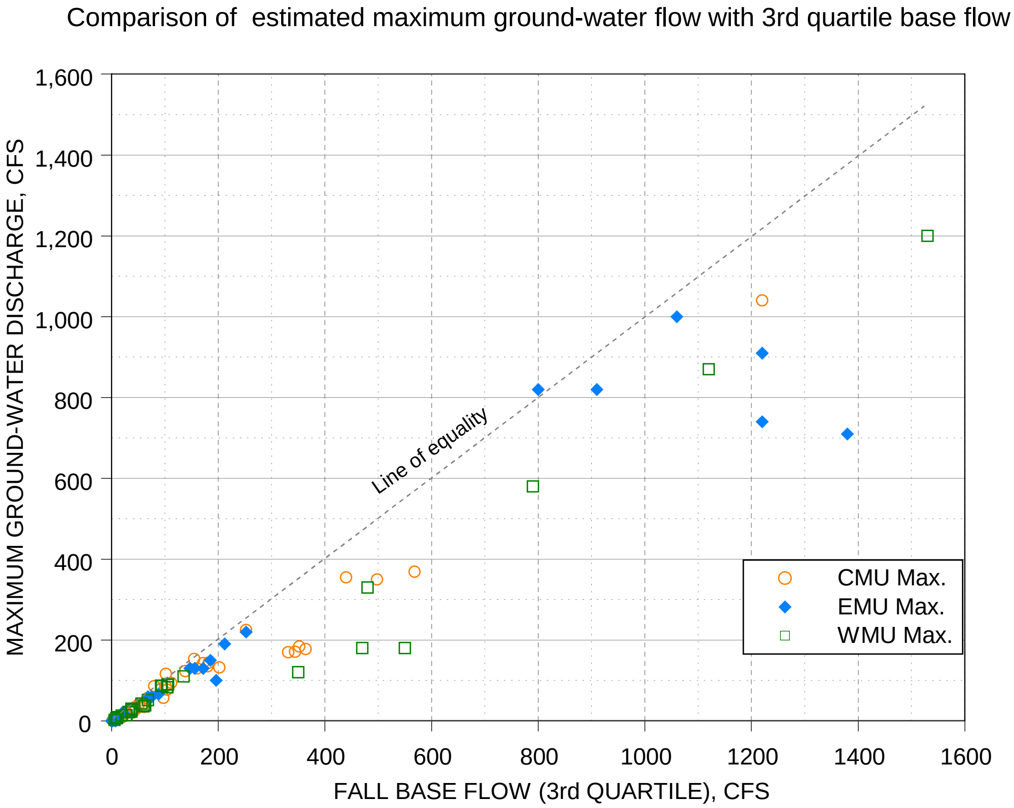
Daily average base flows for both the fall (October-November) and winter (October-March) seasons were defined for most of the sites. The COHYST reports estimated minimum and maximum ground-water discharges, and define the mean as the average of the minimum and maximum. In the alternative approach, the 1st quartile (25th percentile), median (50th percentile), and 3rd quartile (75th percentile) values were defined from all estimated daily base flow values for the individual seasons. The 1st quartile is assumed to be an index to the minimum seasonal base flow and was compared the COHYST minimum; the 3rd quartile is assumed to be representative of the maximum seasonal base flow and is compared to the COHYST maximum. The median flow is compared to the COHYST mean.

The relation between the base flows estimated from BFI and from average 7-day, 5-year and 14-day, 2-year low flows shown in the reports was examined in order to determine the validity of the assumption that the frequency-based estimates represent ground-water flow. Tables showing the base flow estimates for the individual model units are at the end of the report. The following three illustrations compare the minimum, mean, and maximum estimates, respectively.



Comparison of estimated minimum ground-water flow with 1st quartile base flow
MINIMUM GROUND-WATER DISCHARGE, CFS
1,600
1,400
1,200
1,000
800
600
400
200
0
0
200
400
600
800
1000
1200
1400
1600
FALL BASE FLOW (1st QUARTILE), CFS
Line of equality
CMU Min.
EMU Min.
WMU Min.


Comparison of estimated mean ground-water flow with median base flow
MEAN GROUND-WATER DISCHARGE, CFS
1,600
1,400
1,200
1,000
800
600
400
200
0
0
200
400
600
800
1000
1200
1400
1600
FALL BASE FLOW (MEDIAN), CFS
Line of equality
CMU Mean
EMU Mean
WMU Mean

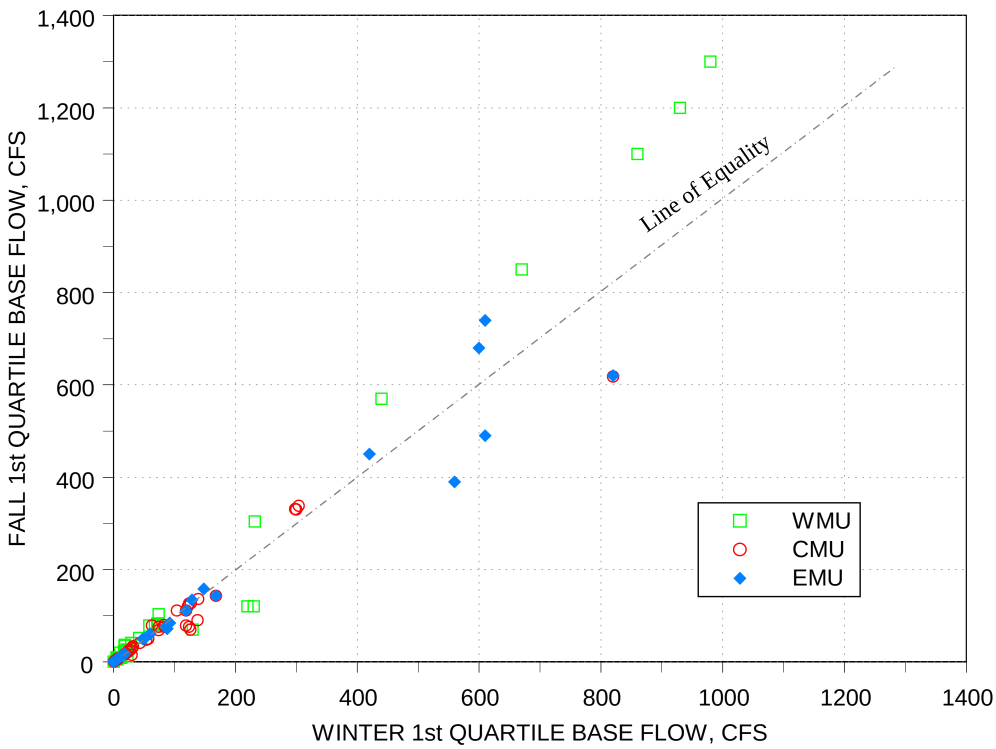


The comparisons of the estimated minimum, mean, and maximum ground-water discharges with estimated base flows are very good for discharges of less than about 300 cfs and for the Loup River system. These are the sites that are largely unregulated. With the exception of the Loup River system, the BFI-estimated base flows at sites with discharges greater than 300 cfs are greater than the COHYST estimated ground-water discharges. Sites with discharges greater than about 300 cfs are generally the North Platte, South Platte, and main-stem Platte sites. Those are regulated in varying degrees, and BFI will likely overestimate base flows because relatively constant discharges over a period of days are labeled as base flows regardless of magnitude.

For these larger, more regulated streams, the comparisons are best for the estimated minimum discharges and worst for the estimated maximum discharges. That is not unexpected given that the COHYST estimates are based on frequencies of monthly (November) or seasonal (October-November) mean values and the alternative approach is based on statistics of all daily mean values for the season.

A second assumption, that the fall (Oct.-Nov.) low flows were representative of non-irrigation season flows was addressed by comparing base flow estimates from BFI for the fall and winter (Oct.-Mar.) seasons. The illustration below shows that the fall base flows are generally representative of base flows for the longer winter season. The upper points on the plot where fall flows exceed winter flows by substantial amounts represent the North Platte River gauges that are regulated. The higher fall flows may represent deliveries from upstream to downstream reservoirs. The overall conclusion, however, is that fall flows are a reasonable representation of winter-season flows.

Comparison of Fall (Oct.-Nov.) and Winter (Oct.-Mar.) Base Flow Estimates



Summary of findings of the alternative analysis

The conclusion of the alternative analysis is that the frequency-based approach based on the fall season produces acceptable estimates of winter-season base flow. For unregulated streams, those estimates should represent ground-water discharge to the streams. For regulated streams, low flows have no hydrologic basis as they are simply the result of the regulation pattern. As such, the low-flow frequencies probably do not reflect ground-water discharges. However, gains or losses in flow over specific reaches should be reflective of ground-water discharge or recharge. Therefore, a mass-balance approach with the correct model should permit estimation of ground-water effects on a stream reach.

Specific Comments on Western Model Unit (WMU)

WMU Table 3

06681000 Winters Creek near Scottsbluff – The recurrence interval for the 14-day low flow was computed based on 48 years of record instead of 65. The reason is unclear as all 65 years of data appear to have been used. The effect of the apparent error is slight, however, as the 2-year recurrence-interval discharge based on 65 years of data only increased by 1 cfs to 52 cfs.

06683000 Bayard Sugar Factory Drain near Bayard – Period of analysis should not include 1987.

06688500 Otter Creek near Lamoyne – The maximum estimate appears to be closer to 22 cfs than to the 19 cfs shown in the table.

06762500 Lodgepole Creek at Bushnell -- Period of record starts with 1934, not 1931.

06764000 S. Platte at Julesburg – 1907 and 1922-23 should not be included in the period of analysis. The estimate of the maximum for 1982-97 should be closer to 170 cfs than 180 cfs. The CMU reported the 1902-07 values at 71 and 184 cfs as compared to 40 and 120 cfs for WMU. Although not labeled as such, the CMU estimates for 1902-97 are based only on November flows.

WMU Table 4

The reports do not document the models used in the reach analysis; in order to see which records were combined one has to work through the individual spreadsheets. The following table summarizes the individual models.

Reach	Model
SL-Mitch	06679500 -06674500 -06677500 -06678000
Mitchell - Minitare	06682000 -06679500 -40 -06681000 -06681500
Minitare - Bridgept	06684500 -06682000 -8 -06682500 -06683000 -06684000
Bridgeport - Lisco	06686000 -06684500 -06685000
Lisco - Lewellen	06687500 -06686000 -06687000
Bushnell - Ralton	06765500 -06762500
Julesburg - Roscoe	06764880 -06764000

The “40” in the Mitchell to Minitare reach represents station 06680000, and the “8” in the Minitare to Bridgeport reach represents 06682200. Neither station had a complete record for the 1941-97 period used so average values of 40 and 8, respectively, were used for all years.

The numbers presented in the gain/loss per mile of reach appear to have been computed from numbers before rounding. That would explain why checks of those numbers using values from the table produce results about 0.1 different.

Specific Comments on Central Model Unit (CMU)

CMU Table 3

The following irregularities were noted in Table 3:

06764000 S. Platte River at Julesburg -- 1907 and 1922-23 should not be included in the period of analysis. CMU and WMU give substantially different values for 1902-97. The CMU reported the 1902-07 values at 71 and 184 cfs as compared to 40 and 120 cfs for WMU. Although not labeled as such, the CMU estimates for 1902-97 are based only on November flows, while WMU results are for the fall. The November results for Julesburg are generally at least 50 percent greater than results for the fall (Oct. – Nov.) WMU gives results for 1982-97; CMU gives three other periods (1924-97, 1946-69, and 1946-97); results are comparable.

06765000 S. Platte River at Paxton – All results shown are for November flows only and only for the river flow at Paxton; the flow of Korty Canal has not been added to the river flow. These results do not appear to have been used for any analyses, and they should not be used. The gauge is just downstream from the Korty Canal (06764900). Any meaningful analysis of low-flow frequency would have to be done on the combined daily flows of the river and canal. For the period 1946-69, the combined November daily flows had a median of 324 cfs, and 75 percent were greater than 166 cfs. The daily flows were combined for the reach analysis, as indicated by the "remarks" column of table 3.

06765500 S. Platte River at North Platte – Results for 1931-97 are for November. Results for other periods appear to be for the fall, but there is little difference between November and fall results.

06766000 Platte River near Brady – The station number 06693000 shown in the table is incorrect. CMU results are for November (and are labeled as such), but EMU gives slightly different results that are based on fall. Period of analysis shows 1939-97 (CMU) and 1940-97 (EMU), but results differ by only small amounts. Most of the difference is due to differences in November and fall low flows.

06766500 Platte River near Cozad – Both CMU and EMU report November results (fall values are much lower), but periods of analysis differ with CMU reporting 1939-97 and EMU reporting 1940-97. Reported results differ by only minor amounts.

06833500 Frenchman Creek near Hamlet and at Culbertson (06835500) are repeated in the table.

06768000 Platte River near Overton period of analysis is 1939-97 for CMU and 1940-97 for EMU. Results differ substantially. EMU gives minimum and maximums of 490 and 910 cfs while CMU gives 720 cfs and 1,040 cfs. CMU gives results for November; EMU reports fall values, and figure 7 of the EMU report shows Overton (October-November) as an example. Using only November for EMU would have given values of about 750 cfs (minimum) and about 1,100 cfs (maximum); those values compare to the results for the CMU.

06764900 Korty Diversion, South Platte Supply Canal –The numbers shown in the table are for fall flows of the canal only. These results do not appear to have been used in the computations, and they should not be used. Any meaningful analysis of low-flow frequency would have to be done on the combined daily flows of the river at Paxton (06765000) and the canal. For the period 1946-69, the combined November daily flows had a median of 324 cfs, and 75 percent were greater than 166 cfs. The daily flows were combined for the reach analysis, as indicated by the "remarks" column of table 3.

06692000 Birdwood Creek near Hersey – Results are for November; fall would be about 10 percent less.

06830000 Republican River near Culbertson – Period of analysis is 1935-49; 1950 is not included. Results are for November.

06837000 Republican River near McCook – Results appear to be for November; fall minimum would be about 60 percent of the reported value.

06843500 Republican River near Cambridge – Results are for November; the fall minimum would be about one half the value presented.

06844500 Republican River near Orleans – Results are for November; the fall minimum would be less than one half the value presented.

06831500 Frenchman Creek near Imperial – The maximum for 1941-97 should be about 58 cfs instead of the 44 cfs shown.

06835500 Frenchman Creek near Culbertson – The maximum for 1950-73 should be about 82 cfs instead of 77 cfs as reported.

06836000 Blackwood Creek near Culbertson – Station number is 06836000, not 06838000.

06844210 Turkey Creek near Edison – Period of analysis should be 1977-97, not 1977-92.

CMU Table 4

The reports do not document the models used in the reach analysis; in order to see which records were combined one has to work through the individual spreadsheets. The following table summarizes the individual models for the CMU.

Reach	Model
Sutherld. – N. Platte	06693000 –06691000 –06692000
Brady – Cozad	06766500 –06766000
Cozad – Overton	06768000 –06766500 –144000
Julesburg – Paxton	(06765000 +06764900) –06764000
Paxton - N. Platte	06765500 –06765000
Champion – Hamlet	06833500 –06831000
Palisade – Culbert.	06835500 –06834000 –06835000
McCook – Camb.	06843500 –06837000 –06838000 –06841000
Camb. – Orleans	06844500 –06843500 –06844000

N. Platte River, Sutherland to North Platte – Fall data were used for this reach.

Platte River, Brady to Cozad – The value for the mean (2-year R.I.) appears to be closer to 80 than 70. Note: the model used in the CMU does not include 57000 (Gothenburg Canal); the model used in the EMU includes 57000. The EMU model appears to be correct as the outflow from the reach should be the sum of 06766500 and 57000. The distance is shown here as 23.7 mi, but the EMU table shows 25 mi.

Platte River, Cozad to Overton – Results are based on November only. The results in the spreadsheet appear to yield values closer to Min=-70, Mean=55, and Max=260. The values presented in the EMU table 4 do not match those presented here. The gain/loss values per mile for the minimum should be -5.0 cfs/mi, and the maximum should be 4.9 cfs/mi using the values presented in the table.

S. Platte River, Julesburg to Paxton – Reach computations are based on November data only. The discharges for November 1947 for Korty Canal seem to be only about one-half a large as the values retrieved from the DNR files for this review. Also, data retrieved for 1964 had values only for November 1-8 (other days were missing), but the TRIBS_Korty spreadsheet used in the reach computations contains values (many are zero) for all days of the month. Other years appear to be okay. These discrepancies should have little effect on the estimated reach discharges. The value of the mean change per mile should be –0.2, not +0.2.

Frenchman Creek, Champion to Hamlet – Results are based on November flows only.

Frenchman Creek, Palisade to Culbertson – Results are based on November flows only.

Republican River, McCook to Cambridge – Results are based on November flows only, including tributaries. The gain/loss values per mile for the minimum, mean, and maximum should be –1.5, -1.1, and –0.1 cfs/mi, respectively.

Republican River, Cambridge to Orleans – Results are based on November flows only, including tributaries.

Specific Comments on Eastern Model Unit (EMU)

EMU Table 3

Spot checking of individual results show:

06883000 L. Blue near Deweese results are for November only.

06780000 M. Loup Rockville results are for November only. Fall values would be about 250 and 600 cfs.

75000 (NE) Kearney Power Return to the Platte River near Kearney – The daily discharge values shown in the spreadsheet and used in both the low-flow analysis (table 3) and the reach computations of table 4 do not match the values downloaded for station 75000 from the State Canal database. The spreadsheet values appear to be processed numbers in that they show 4 and 5 decimals. I was unable to determine the source of the numbers.

06784000 S. Loup at St Michael analysis included data for 1998. Because the 1998 flows were among the higher 7-day and 14-day flows, the 2-year and 5-year results are not affected.

06783500 Mud Creek near Sweetwater included data for 1994-97; the data were obtained from the State database. Because 7-day and 14-day average flows for all four years were greater than the median for November, the 2-year and 5-year results would not change appreciably if the analysis were limited to 1946-93 period of analysis.

06766000 Platte near Brady: EMU presents results for fall, but CMU gives results only for November. Results differ by about 10 percent. Period of analysis shows 1939-97 (CMU) and 1940-97 (EMU).

06766500 Platte River near Cozad – EMU says this includes the Gothenburg Canal, but CMU table 3 does not mention the canal. Period of analysis shows 1939-97 (CMU) and 1940-97 (EMU), but results differ by only small amounts.

06768000 Platte near Overton -- EMU presents results for fall, but CMU gives results only for November. Results differ by about 50 percent at the minimum; most of the difference is due to fall versus November.

06768000 Platte River near Overton period of analysis for is 1939-97 for CMU and 1940-97 for EMU. Results differ substantially. EMU gives minimum and maximums of 490 and 910 cfs while CMU gives 720 cfs and 1,040 cfs. CMU gives results for November; EMU reports fall values, and figure 7 of the EMU report shows Overton (October-November) as an example. Using only November for EMU would have given values of about 750 cfs (minimum) and about 1,100 cfs (maximum); those values compare to the results for the CMU.

06769000 Buffalo Creek near Overton included data for 1998.

07769525 Elm Creek near Elm Creek period of analysis should be only 1996-98. These data are not sufficient for statistical analysis, but there were only two days of flow in October and November.

06853500 Republican River near Hardy maximum should have been closer to 90 cfs rather than 100 cfs shown in the table.

06843500 Republican River near Cambridge presents the results only for November; text notes this, but the table remarks do not. Fall data would have given about 40 cfs and about 90 cfs, respectively, for the minimum and maximum.

06844000 Muddy Creek at Arapahoe period of analysis should be 1951-71, 1977-94.

06847500 Sappa Creek near Stamford period of analysis includes 1998.

EMU Table 4

The reports do not document the models used in the reach analysis; in order to see which records were combined one has to work through the individual spreadsheets. The following table summarizes the individual models.

Reach	Model
Brady - Cozad	(06766500 + 57000) –06766000
Cozad - Overton	06768000 –(06766500 +57000) –144000
Overton - Odessa	(06770000 +00730) –06768000
Odessa - G.Island	06770500 –(06770000 +00730) –75000
G Island - Duncan	06774000 –06770500
Cambridge - Orleans	06844500 –06843500 –06844000 –06844210
Orleans - Hardy	06853500 –06844500 –06850200 –06851000 –06851500 –06852000
Sweet. – St. Mich.	06784000 –06783500
St. Mich. - St. Paul	06785000 –06780000 –06784000 –06784800
St. Paul - Genoa	(06793000 +06792500) –06785000 –06792000 –06790500

General: Values of gain/loss per mile between 0 and 10 are shown with two significant figures, implying that the precision is to the nearest 0.1 cfs/mi. However, only the Republican River reaches are carried to that precision; all other values were rounded to the nearest 1 cfs/mi. Values greater than 10 generally have 2-digit precision, but the maximum for the South Loup was rounded from 48 to 50 cfs/mi.

Platte River, Brady to Cozad – The reliability of these and other computations that use canal data is reduced because of the condition of the canal records. The State canal databases have unexplained gaps in the records for many of the canals. Some canals, including the Gothenburg Canal (570000) that was added to the Cozad data, have only seasonal records for some periods. For example, the Gothenburg Canal in 1969 shows no data for October, November, and 25 days in December. Beginning about 1973, seasonal data are shown that exclude the winter months. The missing periods vary from year to year, but generally range from October – April. Calendar years 1973-1980, 1983-84, 1993, and 1997 show no October data; November data are missing in 1973-86, 1989, 1991-93, 1995-97. The Gothenburg Canal flows were treated as zero in the reach computations for those years; there is no apparent basis for assuming that the flows in all the missing periods was zero. Yet the frequency computations in table 4 use the fall (Oct.-Nov.) period for 1940-97.

Platte River, Cozad to Overton – The Gothenburg Canal is summed with the flow at Cozad and subtracted from Overton in this computation so the comments of the Brady-Cozad reach also apply here. The J2 Power return (144000) is also subtracted, but the J2 record appears to be complete. This model is not equal to that used in the CMU. The Gothenburg Canal (57000) was not subtracted in the CMU; the CMU model appears to be correct.

Platte River, Overton to Odessa – The Kearney Power and Irrigation diversion (00730) is added to the flow at Odessa. The record retrieved from the State Canal Database contains numerous missing days; those days may have been zero flow, but that is not known as other periods of zero flow days are contained in the records. Examples of missing days include 10/5-11/30/58, 10/10-11/30/59, 11/13-11/31/60, etc.

Platte River, Odessa to Grand Island -- The daily discharge values shown for Kearney Power Return in the spreadsheet and used in both the low-flow analysis (table 3) and the reach computations of table 4 do not match the values downloaded for station 75000 from the State

Canal database. The spreadsheet values appear to be processed numbers in that they show 4 and 5 decimals. I was unable to determine the source of the numbers. The model appears to incorrectly include (as a subtraction) the flow of 00730.

Platte River, Grand Island to Duncan – The reach model should include subtraction of inflows from the Wood River, but as a practical matter those flows can be ignored; fall and winter flows in the Wood River are near zero.

Republican River, Cambridge to Orleans – The computation uses the period 1940-97, but two of the subtracted tributaries do not have record for the entire period. Muddy Creek (06844000) has record for 1951-89 and Turkey Creek (06844210) has record for 1977-97. During missing periods, those monthly averages are entered as zero. The combined flows of the tributaries averages about 10 percent of the flow in the reach, and the average gain through the reach is about 20 percent of the inflow. Thus, the assumption of zero flow has a material impact on the result. Several options would have been better than using zero flow: (1) flows could have been assigned values based on the ratio of the flows to the reach inflow or outflow, or (2) the average values of the gauged periods could have been used as constants for the un-gauged years.

Republican River, Orleans to Hardy -- The computation uses the period 1940-97, but the four subtracted tributaries do not have record for the entire period. As in the upstream reach, zeros are used for the missing years. Two tributaries are missing data from 1956-67, 1976-76, and 1990-93; three are missing for 1994-97, and all four are missing in 1940. The combined flow of the four tributaries represents about one third of the reach outflow in many years. One of the options discussed in the upstream reach should have been used here as well. The frequency analysis of fragmentary data produces questionable results.

S. Loup at St. Michael to M. Loup at St. Paul -- The frequency analysis for this reach is not valid as it mixes two distinctly different distributions. The reach computation subtracts average flows at M. Loup at Rockville (06780000), S. Loup at St. Michael (06784000), and Turkey Cr near Dannebrog (06784800) from the flow at M. Loup at St. Paul (06785000) for the period 1943-97. The Rockville and Turkey Creek gages do not have record for the entire period, but Turkey Creek contributes so little flow as to not be a significant factor. However, the Rockville gage carries about 80 percent of the flow at the downstream end of the reach (St. Paul). The reach gains/losses when the Rockville gage operated (1955-63, 1967-74) range from +104 to –79 cfs. During the remainder of the 1943-97 period, the range was +1794 to +576 cfs. In effect, the minimum (5-yr) value is based on Rockville being subtracted as inflow while the mean (2-yr) and maximum (1.25-yr) values include the flow past Rockville as part of the gain. The years 1995-97 repeat in the computation spreadsheet, but with different average gains the second time; the source of the latter numbers is uncertain.

Middle Loup River at St. Paul to Loup River at Genoa -- The years 1995-97 repeat in the computation spreadsheet, but with different average gains the second time; the source of the latter numbers is uncertain.

Overall Summary

The following conclusions were reached as a result of this review:

- An independent search of surface-water databases of both the USGS and the Nebraska DNR shows that all available data were considered in each of the model units.

- The low-flow frequencies based on the fall season produce acceptable estimates of winter-season base flow. For unregulated streams, those estimates should represent ground-water discharge to the streams. For regulated streams, low flows are simply the result of the regulation pattern. As such, the low-flow frequencies probably do not reflect ground-water discharges. However, gains or losses in flow over specific reaches should be reflective of ground-water discharge or recharge. Therefore, a mass-balance approach with the correct model should permit estimation of ground-water effects on a stream reach.

- The reports are vague on the specific stations included in the reach computations, requiring the reader to delve into the computational spreadsheets for that information. Documenting the actual station combinations in the report could have helped prevent the model units from using different models for the same reaches.

- Several of the reach gain/loss computations with large diversions just upstream from the reach appear to use improper models, understating the gain (or overstating the loss). Also several reach computations assume zero discharges for tributaries during missing periods of missing record. The end result of assuming zeros can only be assessed by reanalysis of the data with the affected periods omitted. However, the effect on the South Loup to Middle Loup is clear; a mixed population results in which the minimum (5-yr) value does not include the flow past Rockville as a gain while the mean (2-yr) and maximum (1.25-yr) values include the flow past Rockville as part of the gain. The reaches involved are:

    - Brady to Cozad (CMU) – model.
    - Brady to Cozad (EMU) – zeros for missing data.
    - Cozad to Overton (EMU) – model.
    - Republican, Cambridge to Orleans (EMU) -- zeros for missing data.
    - Republican, Orleans to Hardy -- zeros for missing data.
    - South Loup, St. Michaels to Middle Loup, St. Paul -- zeros for missing data.

- Fragmentary data for some important canals in the State Canal database affect the reliability of computations based on those data.

- There are several inconsistencies between individual model units that report the same sites or reaches. The inconsistencies will have to be reconciled in the ground-water models; they could have been avoided if the study units had agreed on (1) the specific season to use for individual gauges, (2) the period of record to be used in defining statistics, and (3) specific reach gain/loss computational models for sites and reaches common to two study units. The reaches involved are:

- South Platte River, Julesburg to Paxton (CMU) – The reach is 45 miles long; the WSU reports on 33 miles from Julesburg to the model boundary that is included in the 45 mile reach.
- Platte River, Brady to Cozad (CMU, EMU)
- Platte River, Cozad to Overton (CMU, EMU)
- Republican River, Cambridge to Orleans ((CMU, EMU)

References

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Wahl, K.L., and Wahl, T.L., 1995, Determining the flow of Comal Springs in New Braunfels, Texas: Proceedings of Texas Water ’95, American Society of Civil Engineers, August 16-17, 1995, San Antonio, Texas, pp. 77-86.

Alternative Analysis Data for the Western Model Unit

Number	Name	Min	table3 Mean	Max	1st Q	Fall Baseflow median	3rd Q	1st Q	Winter Baseflow median	3rd Q
6674500	North Platte River at State line	260	300	330	304	382	480	232	294	420
6677300	Kiowa Creek near Lyman	14	18	21	20	24	33	11	13	20
6677500	Horse Creek near Lyman	26	31	36	35	45	60	18	25	40
6677500		31	35	38	37	48	63	19	27	42
6678000	Sheep Creek near Morrill	66	78	90	77	93	105	68	78	90
6678000		75	83	90	82	96	106	72	80	92
6678800	Dutch Flats Drain near Mitchell	5	6	6	6.7	7.6	9	5.9	6.3	7.3
6679000	Dry Spottedtail Creek at Mitchell	19	21	23	23	29	37	17	23	30
6679500	North Platte River at Mitchell	530	550	580	570	680	790	440	540	690
6680000	Tub Springs Drain near Scottsbluff	37	40	43	41	48	56	29	34	43
6681000	Winters Creek near Scottsbluff	46	48	51	52	60	68	42	48	57
6681500	Gering Drain near Gering	24	27	30	27	32	37	22	26	31
6682000	North Platte River near Minatare	760	810	870	850	980	1120	670	790	980
6682200	Alliance Drain near Minatare	4	8	13	10	15	19	5	8	12
6682500	Ninemile Drain near McGrew	87	96	110	103	116	135	74	87	108
6683000	Bayard Sugar Factory Drain	22	24	27	24	29	38	20	24	30
6684000	Red Willow Creek near Bayard	72	78	83	79	90	105	59	68	84
6684500	North Platte River at Bridgeport	970	1,100	1,200	1,100	1330	1,530	860	1030	1,300
6685000	Pumpkin Creek near Bridgeport	7	10	14	9.7	16	27	13	23	33
6685000		7	10	14	9.2	16	28	12	21	32
6685000		13	18	22	12	24	32	23	30	37
6686000	North Platte River at Lisco	1,100	1,200	1,300	1,200	1,440	1,660	930	1,130	1,420
6687000	Blue Creek near Lewellen	72	79	86	81	88	94	73	86	94
6687000		78	83	87	83	88	93	72	86	93
6687500	North Platte River at Lewellen	1,100	1,300	1,400	1,300	1,520	1,800	980	1,210	1,500
6688500	Otter Creek near Lamoyne	16	18	19						
6762500	Lodgepole Creek at Bushnell	4	6	8	4.8	8	10	5.1	8	11
6762500		6	8	9	7.5	9	11	7.5	9	11
6762500		5	6	8	6.1	7	9.8	6.6	8	9.9
6763500	Lodgepole Creek at Ralton	0	1	2	0.5	3	5.8	0.4	3	8.3
6764000	South Platte River at Julesburg	40	80	120	70	140	350	130	270	460
6764000		80	130	180	120	250	470	230	430	740
6764880	South Platte River at Roscoe	86	130	180	120	270	550	220	420	790

Alternative Analysis Data for the Central Model Unit

Number	Name	table3 Min	Mean	Max	Fall base flow 1st Q	median	3rd Q	Winter base flow 1st Q	median	3rd Q
6691000	North Platte River at Sutherland	57	95	132	111	138	202	104	125	155
6693000	North Platte River at North Platte	290	330	369	338	383	568	304	355	446
6693000		288	322	355	330	372	440	300	344	392
6693000		291	321	350	331	378	498	298	349	410
6764000	South Platte River at Julesburg	72	122	171	76	141	344	124	267	449
6764000		71	127	184	70	145	352	126	273	455
6764000		89	134	178	90	139	364	138	226	548
6764000		80	125	170	79	148	331	119	281	367
6765000	South Platte River at Paxton	6	9	11						
6765000		4	7	9	6	9	13	7	9	12
6765500	South Platte River at North Platte	117	131	144	120	142	182	122	149	224
6765500		116	123	130	126	141	160	124	137	156
6765500		116	126	135	127	147	180	127	150	213
6766000	Platte River near Brady	112	113	143	111	135	172	119	145	216
6766500	Platte River near Cozad	172	199	225	143	213	252	168	220	309
6768000	Platte River near Overton	720	880	1,040	618	990	1,220	820	1,100	1,580
6764900	Korty Diversion	0	13	26						
6692000	Birdwood Creek near Hershey	140	146	153	136	145	155	139	150	160
6830000	Republican River near Culbertson	32	59	86	15	38	80	30	58	103
6837000	Republican River near McCook	73	84	94	69	90	112	74	95	122
6843500	Republican River near Cambridge	87	102	116	80	103	102	83	118	105
6844500	Republican River near Orleans	94	109	123	76	111	138	84	130	169
6834000	Frenchman Creek near Palisade	24	29	34	31	40	61	31	39	59
6834000		19	21	23	23	26	40	24	29	39
6831500	Frenchman Creek near Imperial	47	52	56	48	58	67	54	63	72
6831500		22	33	44	25	41	61	27	48	65
6833500	Frenchman Creek near Hamlet	73	79	85	79	91	102	63	95	105
6835500	Frenchman Creek at Culbertson	57	67	77	76	91	104	74	93	110
6835500	Frenchman Creek at Culbertson	34	45	57	50	67	97	57	79	113
6831000	Frenchman Creek at Champion	26	30	34	26	33	44	26	34	44
6835000	Stinking Water Creek near Palisade	23	26	28	29	35	40	30	36	43
6835000		18	20	23	22	29	35	24	35	38
6834500	Stinking Water Creek near Wauneta	14	15	16	16	20	24	18	21	24
6836000	Blackwood Creek near Culbertson	0.7	0.9	1	0.7	1	2	0.6	1	1.8
6838000	Red Willow Creek near Red Willow	6	7	9	7	9	20	7	10	22
6838000	Red Willow Creek near Red Willow	14	17	20	18	24	28	20	25	31
6838000	Red Willow Creek near Red Willow	6	6	7	6	7	9	7	8	9
6837300	Red Willow Creek NW of McCook	12	15	17						
6841000	Medicine Creek NW of Cambridge	35	38	42	41	47	52	43	50	57
6843000	Medicine Creek at Cambridge	27	33	40	34	44	51	32	41	52
6843000		4	16	28	6	29	45	6	33	49
6844000	Muddy Creek near Arapahoe	1.9	3	4.4	4	5	7	4	6	7
6844000		5	5	6	6	6	7	6	6	7
6840000	Fox Creek near Curtis	4	4	5	4	4	5	4	5	6
6844210	Turkey Creek near Edison	2	3	3.9	3	4	6	3	5	6

Alternative Analysis Data for the Eastern Model Unit

Number	Name	table3 Min	table3 Mean	table3 Max	Fall Base flow 1st Q	Fall Base flow median	Fall Base flow 3rd Q	Winter Base flow 1st Q	Winter Base flow median	Winter Base flow 3rd Q
6794000	Beaver Creek near Genoa	56	61	66	61	74	88	60	75	94
6879900	Big Blue River at Surprise	0	0.2	0.3	0	0.2	1.4	0	0.4	2.6
6768500	Buffalo Creek near Darr	0	0	0	0	0	0	0	0	0
6769000	Buffalo Creek near Overton	0	0.9	1.8	0	1.7	5	0	1	4
6792000	Cedar River near Fullerton	150	170	190	158	186	212	148	182	224
6851000	Center Creek at Franklin	4	5.1	5.7	5.3	5.9	5.9	5.3	6	6.6
6850200	Cottonwood Creek nr Bloomington	4.1	4.3	4.5	4.5	4.8	5.1	4.6	4.8	5.1
6852000	Elm Creek at Amboy	11	12	12	13	14	16	13	14	16
6769500	Elm Creek near Overton	0	0	0	0	0	0	0	0	0
6769525	Elm Creek near Elm Creek	0	0	0						
57000 NE	Gothenburg Canal Diversion	NA	NA	NA						
144000NE	Johnson #2 Power Return	280	470	650						
6880000	Lincoln Creek near Seward	4.8	5.9	7	6.1	7.4	9.7	6.3	8.2	11
6883000	Little Blue River near Deweese	51	56	60	51	58	68	51	62	70
6793000	Loup River near Genoa	1300	1600	1800						
6792500	Loup River Power Canal	NA	NA	NA						
00730 NE	Kearney P&I Diversion	NA	NA	NA						
75000 NE	Kearney Power Return	0	2	4						
6785000	Middle Loup River at St. Paul	680	840	1000	680	910	1060	600	860	1080
6780000	Middle Loup River nr Rockville	620	720	820	450	700	800	420	690	830
6844000	Muddy Creek at Arapahoe	3.6	4.5	5.4	4.7	5.9	6.9	4.9	6.2	7.2
6783500	Mud Creek near Sweetwater	15	18	20	13	18	20	15	19	25
6790500	North Loup River nr St. Paul	620	720	820	740	830	910	610	790	920
6766000	Platte River near Brady	100	120	130	111	130	172	119	150	216
6766500	Platte River near Cozad+GCD	170	195	220	143	192	252	168	220	308
6774000	Platte River near Duncan	170	440	710	390	780	1380	560	960	1610
6770500	Platte River near Grand Island	260	500	740	490	770	1220	610	930	1470
6770000	Platte River near Odessa	320	560	790	508	769	1150	739	1050	1540
6768000	Platte River near Overton	490	700	910	620	890	1220	820	1100	1580
6853500	Republican River near Hardy	45	70	100	84	120	196	92	140	230
6843500	Republican River at Cambridge	90	110	130	77	105	147	86	120	184
6844500	Republican River near Orleans	100	120	130	72	128	156	88	130	220
6847500	Sappa Creek near Stamford	0	0	0	0	0.1	7.3	0	1.6	10
6784000	South Loup River at St. Michael	110	130	150	134	160	185	129	160	198
6851500	Thompson Creek at Riverton	17	19	20	18	20	22	18	20	22
6844210	Turkey Creek at Edison	2.4	3.6	4.8	3.4	4.9	7.3	3.5	5.5	5.5
6784800	Turkey Creek near Dannebrog	4	6	8	5.1	8.4	11	5.5	8.7	11
6880800	WF Big Blue River nr Dorchester	38	49	60	50	63	75	48	60	75
6772000	Wood River near Alda	0	0	0	0	0	1.1	0	0	0
6771500	Wood River near Gibbon	0	0	0	0	0	0.2	0	0.1	0.8

Attachment I.—Processes and Problems with Using Alternative Approaches to Running MODFLOW

Model Conversion

1. Conversion of COHYST MODFLOW datasets to MODFLOW-2000 (MF2K), the latest release from USGS is necessary because COHYST used MODFLOW96. This conversion is only required if a modeling shell other than GMS that uses MF2K (or no modeling shell) is used.

    a. Conversion program provided with MF2K from UGS is mf96to2k.exe
    b. As compiled and provided by USGS, array sizes have to be increased and conversion program recompiled to handle the EMU and CMU models
        i. In mf96to2k include file change to PARAMETER (LENX=8000000)
    c. Entries in the ModFlow name file, xxxx.mfn supplied by COHYST as generated by GMS includes quotes ("xx") around file names. These must be removed for mf96to2k to run
    d. BAS and BCF files generated by GMS have to have all instances of CONSTANT 1.000000000000000e+000 and INTERNAL 1.000000000000000e+000 manually changed to 1.00 or 1.00e+xxx because Subroutine U2DREL in mf96to2k does not handle the format generated by GMS.

2. Running MF2K in batch (DOS) mode generated problems reading the stream package data generated by GMS. The mf96to2k program does not convert the stream package files.
    a. Error:

        Invalid decimal character . was detected (unit=internal).
        (the relative position causing an error in a record = 16)
        1131 102 3 0 1 1.283904000000000e+005 -40 0

    b. Attempted fix: First Record in STR file was changed to 1.283904e+005 (WMU test 326) resulted in the same error:

        Invalid decimal character . was detected (unit=internal).
        (the relative position causing an error in a record = 16)
        1131 102 3 0 1 1.283904e+005 -40 0
        ?
        Error occurs at or near line 27 of _gwf1str6al_
        Called from or near line 587 of _MAIN

    c. Look at gwf1str6.f source , line 27:

```
  READ(LINE,3)MXACTS,NSS,NTRIB,NDIV,ICALC,CONST,ISTCB1,ISTCB2
3 FORMAT(5I10,F10.0,2I10)
```

    Shows that fixed fields of width 10 are expected for all values. Apparently the version of stream package in MF2K used by GMS does not include free format read statements for the header record in the stream package.

d. Latest MF2K package (Version 1.15.01, April 5, 2005) downloaded from USGS website resulted in the same error.

e. Changed first record in stream file to handle fixed 10 column fields and reattempted run: New error detected :

```
Using NAME file: test_326.nam
Run start date and time (yyyy/mm/dd hh:mm:ss): 2005/07/08 11:47:44
Invalid decimal character - was detected (unit=17).
(the relative position causing an error in a record = 12 )
1  86  81  1  1  -1.000000000000000e+000  1.000000000000000e+000
1.281130436793148e+00
4 4.045392549387101e+003 4.046392549387101e+003
          ?
 Error occurs at or near line 686 of _sgwf1str6r_
 Called from or near line 184 of _gwf1str6rpss_
 Called from or near line 942 of _MAIN__
```

f. Checked line 686 of sgwf1str6r.f:

```
READ(IN,5)K,I,J,ISTRM(4,II),ISTRM(5,II),STRM(1,II),STRM(2,II),
     1STRM(3,II),STRM(4,II),STRM(5,II)
            5 FORMAT(5I5,F15.0,4F10.0)
```

Conclusion: GMS writes STR package using free format, which MF2K stream package cannot read

g. Solutions: change MF2K and recompile or have GMS fix the bug – This is out of current scope of work of Peer Review

3. Check of STR package in EMU appears to have the correct format for the MF2K STR package
   a. Ran mf96convto2k on clean hmMLSTR1-3 dataset after fixing the BCF and BAS files as in 1d above
   b. So apparently the COHYST datasets for the EMU and presumably the CMU do not have the stream package format conversion problems that the WMU does.

Conversion to Visual ModFlow (VMP)

1. Visual ModFlow Pro version 4.1™ from Waterloo Hydrogeologic was used for this comparison

2. Test dataset used: WMU.Test_326

3. File/Import command in VMP
   a. Units were not read from MF2K dataset – VMP assumes default of M/sec

   b. Have to manually change units to those from GMS-generated dataset

   c. All packages generated by GMS show up as being imported, except STR

d. STR package conversion is not supported by VMP
    i. However when VMOD is run, it detects the STR package and asks if it should be included – response should be yes

e. Warning messages during import:
    i. "More than one RIV boundary condition has been assigned to C234R237L1 only using the last"

    ii. Repeated error for for C220R210L1, C211R213L1, C2064R217L1, C247R205L1, C182R161L1, C158R146L1, C076R106L1, C104R120L1, C105R120L1, C130R131L1, C023R079L1, C234R207L1 sequence is repeated 2 times

f. Imported Kx and Sy as distributed arrays
    i. Check with VMP cell inspector shows values same as from GMS
    ii. However, the distributed values do not show up on the map with VMP

g. Re-imported Kx and Sy as zones – now they show up properly in VMP

h. Check of recharge rates shows that only one stress period was imported.

i. Same check on all boundary conditions (Rivers, GHB, and ET) shows that all stress periods were imported

i. Note: North Platte River boundary condition is not continuous as shown in the VMP screen – has several breaks
    1. GMS version of this dataset has the same problem

4. Main/File/Run Command
    a. No transient vs. steady state option box comes up (probably because no data was created o the mf96to2k conversion to use the capability in MF2K to allow any sequence of steady state and transient stress periods.
    b. Check of stress period and time step dialog shows that all stress periods were imported.
    c. Although VMP did not import the stream package into the Visual interface, a dialog box comes up asking to use it.
    d. Model converges with out oscillation for first two stress periods, then does not converge using SIP
    e. Using Pre-Conjugate Gradient, WHS Solver, GMG, and SAMG solvers have the same problem.
    f. Turning wetting option off does not solve the oscillation problem.
    g. Comparison of heads at end of stress period 1 and 2 show that while they appear to be reasonable, they do not agree with figures published in the WMU model report or the maps produced with GMS for this dataset.

Conclusion

1. ModFlow datasets generated with GMS can be converted and run with other modeling shells.

2. However the conversion is tedious and prone to introduction of errors

3. The power of GMS to generate and query conceptual model features such as streams and rivers is lost when the datasets are imported into other modeling shells or when no modeling shell at all is used.

4. Differences in simulated results for the first two simulated stress periods for the test dataset are most likely the result of errors in the importation of recharge datasets

5. COHYST should either :
    i. Continue to GMS to further develop the models, to use them to build sub-models, and to perform predictive analyses, and/or
    ii. Develop a written, published protocol for subsequent users to properly use the COHYST datasets outside of the GMS environment.

Attachment J.—Specific Review Comments: Hydrostratigraphic Units and Aquifer Characterization Report

Review Comments, Hydrostratigraphic Units Report

1. The pdf copy of the report provided for review still has comment notes posted within it by Jim Cannia. The comments appear to have been addressed.

2. The report is well written, well organized, and clearly describes the process used to develop the hydrostratigraphic units.

3. p. 8. The term ‘selected hydrologic boundary’ is one of common usage, and implies that there is something ‘hydrologic’ about the boundary, which is not the case. Suggest simply referring to these as arbitrary boundaries that were simulated in ways to assure that their selection would have little likely effect on simulated water levels or groundwater surface water interactions within the COHYST project area.

4. p. 8. Statement that no modeled results are presented in Wyoming or Colorado is not consistent with the Central and Western Model Unit reports. Maps are present in both these reports that show simulated water levels or changes in water levels. Correct the statement in this report or modify the CMU and WMU reports. My recommendation is to correct the statement in the Hydrostratigraphic Unit Report

5. p. 32. Which Digital Elevation Model (DEM) is being referred to?fa We assume it is the 30 meter model published by the USGS which has a 1 meter vertical resolution. However, there are often multiple DEMs of varying accuracy and resolution that can be used. The actual source and resolution that was used should be stated.

6. p 32. Why was the extra step of preparing a 100 ft contour map used to determine elevations of outcrops? With ArcGIS this could be more accurately and quickly determined by intersecting the contact arcs with the DEM grid.

7. p 38. Were certain of the test holes converted to monitoring wells, or were separate wells completed? What was the screened interval for these wells and the criteria used to select these intervals?

8. Figure 17. It would clarify the report if the same colors were used for the areas on the map as for the curves in the well development chart.

9. Figure 18, and text describing it. Was no attempt made to incorporate similar data from WY and CO where the project boundaries extended into those states? If not, how was consistency across state lines assured?

10. p. 57. Which other base of aquifer maps are being referred to? Was the base of the modeled system shown on Figure 26 prepared by hand contouring or by merging the hand contours within ArcGIS?

11. p. 59. How were the hand-drawn contours turned into gridded values for the model? Which Arc commands or ArcGIS functions were used to accomplish this and what were the parameters used?

12. p. 60 was ArcGIS 3D Analyst or GMS used to prepare the cross sections, or were they prepared by hand? From the appearance of the figures, it appears that GMS was used because all layers are present everywhere, even if they are only one foot thick. The text needs to refer to this method of constructing the layers for MODFLOW and describe limitations on model construction, numerical problems, and future use of the models with this construct being used.

13. p. 70. Because the Reed and Piskin method for estimating hydraulic conductivity relies on grain size and textural descriptions from samples from well logs which may be representative of a volume of at most a few cubic feet, and because the model grid is 2640 ft square, a discussion is necessary of the translation from the test-hole sample scale to the model grid scale. Aquifer performance tests on wells typically are used to obtain hydraulic properties at a scale larger than the test hole scale, but generally still smaller than the scale of the grids used. A discussion of historical comparison of the Reed and Piskin method with the results of aquifer tests which I believe exist in Nebraska would help such an explanation.

14. p 70 and Figure 37. Text and figure title uses ‘permeability’, Map title uses Hydraulic Conductivity. Hydraulic Conductivity is correct, as permeability is used to refer to the intrinsic property of the formation alone, while hydraulic conductivity represents the combination of the permeability and the density and viscosity of water. Hydraulic conductivity should be used.

15. pp. 78 and 87. There should be an explanation of the origin of the values in the table for specific yield, and a discussion of why the method used by Peckenpaugh and Dugan was apparently not used. (It is not clear from the text as to whether it was used or not).

Attachment K.—Specific Review Comments: Final CropSim Update and Scenario Report and CropSim Documentation

1. On page 20 of the update model report it states that Dr Martin is preparing a draft model documentation. Therefore it cannot apparently be reviewed and released to the public.
2. CropSim What is the justification for using the Hargreaves PET method? It can commonly over-estimate PET compared to Priestly-Taylor.
3. If the Hargreaves equation was calibrated to the Penman-Monteith Model, why was the PM model not used directly – this needs an explanation (I assume that it is because the PM model requires additional data not available at most stations). Which stations were used for the calibration and do they represent the range of climate for the COHYST project?
4. CropSim: is air dry water content supposed to be equal to irreducible moisture content.
5. CropSim appears to have a new FORTRAN source code compiled for each scenario. This is generally considered poor programming practice as it does not maintain separation between the source and data files, and there is no assurance that changes have been made to the code from scenario to scenario that change conditions or values that should remain constant without a line by line comparison of the code.
6. How does CropSim fill in missing data for precipitation and temperature?
    a. Code review (lines 3305 – 3315 looks like a 3-term moving average is used with the first day of the year having default values assigned
    b. For long sequences of missing data, this will decay to the average from the last present sequence of three non-missing days.
    c. Why are synthetic climate generation algorithms not used (as in SWAT)
    d. Apparently nothing is done with pan evaporation as no missing record or moving average statements for this parameter are included
7. There appears to be no sensitivity analysis done with CropSim, or even an identification of the parameters that may contribute the most to sensitivity.
8. p 42 Why did the GW team request these soils only (411 and 722) which runs used these values. Not explained in any of the modeling reports
9. What was the Average ET run used for? This was not explained in the EMU or WMU Reports.
10. The CropSim report provided compares ETr (reference crop ET) for the COHYST and Republican River Settlement models, but not to any independent measurements or other methods of determining it. The general comparison with the NVmod_Test_326 values is not helpful because of the rage in ET in NEBguide, and the lack of discussion of the methods used to determine NEBguide numbers
11. . There is no documentation as to the source of the crop coefficients used to apply to the ETr se numbers.
12. Review of code CropSimv5-1_98etr82.f90:

e. Where did the ETr reduction factors used to apply to the Penman-Monteith values come from?
f. What are the HPCC stations and field conditions
g. Only 10 months of monthly data (i.e. Crop Coefficients) are used. I assume there are two months when nothing is simulated? Which two months are not used? Where is this documented?
h. What are the Wright Crop Coefficients for
i. Subroutine READWEAT. This routine assumes that the file is sorted on Day of Year, because although DOY is read, the position in the data array is assigned using a counter that is incremented one at a time. If the file is not sorted, then this will cause errors. Should either use DOY in array assignment or read the data into a dummy array and sort it, or both
j. Only crops 1-7 and 10(Alfalfa) were simulated, no dryland rangeland, etc) why not? Kco (crop coefficient) for corn was computed elsewhere – and not read in
k. It looks like all soils are processed for all weather stations and all crops. This looks inefficient, as all soil types are not present in all weather station zones

Attachment L.— Specific Review Comments Unpublished Reports by Rich Kern, NDNR on Development of Recharge and Net Pumpage Datasets

1. **Weighting System for Distribution of Simulated Historical Land Use**
2. **Simulated Historical Land Use Distribution**
3. **Distributed Historical Pumpage/Recharge Estimates**
4. **Model Input Preparation**
5. **Development of Pumpage/Recharge Estimates**
6. **Pumpage/Recharge Preparation**

These reports all need to be combined and published as a report that documents the actual process used to generate the net pumpage values for all Development Period model runs. This report also needs to provide explanation as to why recharge generated with CropSim was not used in the model analyses because the flow chart included in the Model Overview document and the methodology described in documents 1 through 6 implies that it was used.

Attachment M.—Specific Review Comments: Planning and Strategy Documents

Cooperative Hydrology Study Work Plan (1998)

Flow Modeling Strategy for COHYST

Cooperative Hydrology Modeling & Assessment of Activities Impacting Threatened & Endangered Species Target Flows (COHYST II) Work Plan

1. Boundary Conditions. There is no mention of a General Head Boundary at all. Modflow96 included this package, and it is a more general and recommended method of treating arbitrary flows as it allows both the head and the flow to vary at the boundary. Using this boundary could have been used to advantage to tie the models together.

2. p 7 Predevelopment period inputs section does not mention Specific Yield and Storage Coefficient. Since the Predevelopment model runs were not steady state, they are still a required input. This situation apparently arose after the Strategy document was prepared.

3. Conceptual models should have included discussion of the Platte River becoming perennial as a result of increased seepage and drain discharge cause by canal leakage and excess surface water irrigation south of the river.

4. Sensitivity of flows and changes in flows to seasonal time steps – see plots of drains and streamflow gains.

5. Need for seasonal vs yearly time averaged stress data is not thoroughly discussed.

6. No discussion in strategy document regarding the screened interval of existing and future extraction wells extending from the watertable to total depth, and interconnecting hydrostratigraphic units and the implications when these are used as calibration targets.

7. Modeling strategy should have included a simple→ complex→ simple path rather than simply simple→complex, with sensitivity analyses with the complex models used to see if the model simplified from the complex one was as accurate and representative. Review of model output datasets shows that vertical gradients are essentially zero for all models and between all layers. The only vertical gradients appear to be in areas of high groundwater discharge along streams and rivers. Consequently, a vertically averaged, single layer model would probably be the simplest and most defensible tool.

8. The 2001, COHYST II Model Work Plan included the following specific questions to be answered by the models.
    a. Identify or assess the net contribution to the program in-stream flows from water conservation or supply project with a groundwater component.
    b. Identify the location and magnitude of any inter-relationship between GW and SW or target flows in the Platte River.
    c. Identify the location and magnitude of any new GW related activities that need to be managed and / or offset.
9. The Modeling Strategy should have been revised included a list of questions based upon these general questions to be asked of the models with specific metrics that could be tested.

10. Modeling strategy should have included a step to identify the most important processes/features, etc that have and will drive model answers such as the increase in reach gain on the Platte by canal leakage and drain flows.

11. The area of model overlap between the EMU and CMU is where all the action is with regard to groundwater / surface water interactions that are pertinent to project objectives. It appears that the model areas were chosen for more or less equal areas rather than with regard to providing a tool(s) that had the most consistent, reliable representation of the conceptual model in this area.

12. Model Work Plan II (dc012wkplanII_03.doc , Task 406) stated that a stream package parameter generator was to be developed. This is not documented anywhere, nor is it mentioned in any of the reports.

13. Model Strategy Document, p 6. The statement that flow boundaries can magnify errors internal to the model apparently was not checked or verified. All the models use specified flow boundaries at arbitrary model boundaries. Use of General Head Boundaries eliminates this problem.

14. Model Strategy Document, p 7 There was no planned sensitivity analysis to demonstrate the sensitivity of water levels and stream gains and losses to the length of time that recharge and pumpage are held constant. This would be valuable information that would improve model credibility.

15. Model Strategy Document states that two simulation periods will be used: a Steady State pre-Groundwater development period and a Groundwater development period. Documentation in the model reports as to why this was changed to a pre-1895 quasi-steady state (but still transient), pre-GW development transient, and development period analyses does not discuss the limitations this change had on model usability.

16. No calibration metrics are listed in the strategy document.

Other comments on the 1998 and 2001 Work Plan documents have been incorporated into the body of this Peer Review Report.

Attachment N.—Specific Review Comments: The 40-Year, 28-Percent Stream Depletion Lines for the COHYST Area West of Elm Creek, Nebraska (August 2004 version)

Comments on this document have been incorporated in the body of this Peer Review Report.

Attachment O. Response to Comments on Draft Peer Review Report provided by Richard R. Luckey, Steven J. Peterson, and Clint Case.

Comments on Draft Peer Review Findings Report by Richard R. Luckey and Responses by Eagle Resources.

Notes on "Cooperative Hydrology Study (COHYST) Independent Peer Review Findings," draft dated September 15, 2005, and meeting on September 20 in Kearney on same subject.

Prepared by Richard R. Luckey, September 22, 2005.

This document is only meant to address potential misunderstanding in the review and help in preparation of a final document. Some points covered here were raised at the September 20 meeting.

Comment 1: Various places – CropSim and recharge: As discussed at the meeting, CropSim simulated recharge was not used in any of the calibrated models. As discussed in some documents, the original intent was to use CropSim recharge in the models, but during calibration, this proved infeasible. Rangeland and land-use based recharge were calibration parameters. Recharge from surface-water irrigation and canal leakage was calculated outside the model and was not a calibration parameter. The discussion of recharge in addition to CropSim recharge needs to be modified in a number of places. A recommendation to clarify this point in the documentations may be in order.

Response: We appreciate the clarification that recharge simulated from CropSim was not used in any of the calibrated models. However, the model documents do not clearly state that recharge from CropSim was considered unacceptable, nor did they include an explanation of why it was so considered. We have modified the body and Attachments of the Peer Review Report to incorporate this clarification. However, the issues that were raised by our comments are still of concern. These are stated in the review document and are summarized as follows:

1. Use of rangeland recharge, stream bed conductance, hydraulic conductivity and in some cases, ET from groundwater parameters as calibration parameters likely resulted in non-unique combinations of these. This is because more parameters were used as independent variables in the calibration process than the two dependent variables used (heads and groundwater discharge to streams). Use of CropSim, or a similar independent methodology to estimate rangeland recharge would have reduced the number of independent variables, and provided more confidence that the hydraulic conductivity and stream leakance values resulting from calibration better represented the modeled system.

2. As shown by the scatter-plots of simulated vs. observed water level changes included in the Peer Review Report, there is an apparent bias in the calibrated models that can easily be explained by the balance between pumpage and recharge in the areas of the observations that adds too much water to the system.

3. CropSim was used to generate the net irrigation requirement for the development period calibration, and may be used to generate this requirement for future simulation scenarios. Because the methods, equations, parameters, and variables used by CropSim to generate recharge and net irrigation requirement are the same, if the recharge values were in some measure unacceptable, it is likely that the net irrigation requirements are also unacceptable for the same reasons.

4. Simply stating that using CropSim values for calibration was 'infeasible' without providing the reasons for such infeasibility does not resolve this situation. The revised documentation should clearly address these reasons, address the impacts of not using CropSim for recharge, but using it for Net Irrigation Requirement, and make a recommendation as to any future use of CropSim as part of the COHYST Decision Support System. The analysis of this issue should also include citation of available studies on the High Plains and elsewhere that have documented such increases in recharge under cultivated land by measuring soil moisture tension and geochemical profiles (See references 22 and 23).

Comment 2: Sensitivity analyses – A citation on the need/industry standard on sensitivity analyses would be helpful. The lack of emphasis on sensitivity analyses in the documentations is my doing because I perceive little value in sensitivity analyses in many cases.

Response: ASTM has published a separate guidance document on the importance and recommended methods for sensitivity analyses (D5611.Conducting a Sensitivity Analysis for a Ground-Water Flow Model Application, reference 10). ASTM standards and guidance are one of the generally accepted yardsticks against which to measure conformance with industry standards.
The importance of sensitivity analyses as an integral part of model calibration is also clearly evident from all the work that the U.S.G.S put into developing the formal computation of sensitivity to model parameters as part of ModFlow-2000. See Anderman, E.R, and M.A. Hill, 2000 (reference 20). Because ModFlow-2000 is considered the industry standard groundwater flow model, it is clear that the inclusion of sensitivity analysis capabilities by its authors is also an industry standard.

Both the industry standard modeling shells, GMS and Visual ModFlow include formal sensitivity analysis capabilities, either through the use of the capabilities of ModFlow-2000 or independent methods included in the PEST code.

Sensitivity analyses are the only method by which uncertainty in model parameters, variables, and assumptions can be translated into uncertainty in the output of models, and hence into uncertainty into management decisions that are made using such output. COHYST was conceived and implemented to provide models as tools to help make such management decisions, and such decisions are likely to have significant economic and political consequences. Consequently, COHYST is clearly not one of the cases in which the perception of 'little value' in sensitivity analyses pertains.

As another measure of the importance ascribed to sensitivity analyses by the industry, which includes practicing, published professionals, educational institutions, and government regulatory agencies, a Google™ search of the words (sensitivity analysis groundwater model) returned over 1.5 million citations.

The following quote is from the introduction of a 2000 class at the University of Colorado entitled Groundwater Model Calibration and Uncertainty Analysis taught by Mary Hill and Richard Cooley of the U.S. Geological Survey:

> "Models are used extensively to evaluate ground-water systems and to predict their response to such things as changes in pumpage and proposed remediation efforts. Because many aspects of ground-water systems are unknown, most models are calibrated. Calibration commonly is achieved by trial and error alone, but these methods provide less insight than is possible. This course teaches how sensitivity analysis, nonlinear regression, and associated statistics can be used to greatly improve how data is used to calibrate and test ground-water models. For example, parameters that can not be estimated accurately and uniquely with the available data can be quickly identified. Parameter values that produce the best fit between simulated and observed hydraulic heads, concentrations, and so on can be estimated by nonlinear regression. Measures of prediction uncertainty and measures of the importance of existing and potential observations are a natural consequence of regression methods."
>
> (http://wwwbrr.cr.usgs.gov/projects/GW_Subsurf/mchill/upcoming/cu2000_cal_uncert.shtml)

Clearly the industry recognizes the importance and necessity of sensitivity analysis to address the issue of model uncertainty.

Comment 3: Simplification – A citation on the need/industry standard for making models simple would be helpful. The perception that more complex equals better is prevalent in the community of people potentially affected by water management.

Response: The principle of parsimony is the accepted standard for all scientific and engineering investigations and analyses. The course outline presented by EMS-i for GMS includes it in the first day's topic of Groundwater Modeling Concepts. Clearly the authors of GMS consider it an important concept. A Google™ search for the words(parsimony groundwater model) returned 904 responses. Clearly the plans, guidance, studies, and reports produced by the groundwater industry consider this not only an important concept, but a guiding concept.
It is the responsibility of the scientists and engineers conducting such investigations to a) determine the minimum level of complexity that will explain the simulated system to meet the intended uses of the model(s) used for simulation; and b) clearly communicate

the level of complexity needed to the community of persons potentially affected by water management decisions.

It is also not the responsibility of those constructing models to determine their end use. That is the responsibility of the end users of the analyses to be performed with the models. The Peer Review Report discussed the lack of specific management scenarios and metrics needed by water mangers that could have been developed at the outset of COHYST, but were not. The degree of complexity built into analysis tools (models) should be driven by the end uses of the models, and the uncertainty that is considered acceptable by the end users of the model analyses.

Comment 4: Attachments – Only Attachment H was provided, so other attachments could not be examined for potential misunderstandings.

Response: All Attachments are included in this Final Report.

Comment 5: Page 3, bullet 8 – I don't know what the additional recharge on rangeland is about. This could be related to CropSim recharge. Rangeland recharge was a calibration parameter estimated in the predevelopment models. Then, during the development period, extra recharge was added to rangeland recharge on dryland and irrigated land as described in the documentations.

Response: The portion of this paragraph and elsewhere in the report that refer to additional rangeland recharge added have been corrected. However, the portion of this comment that addresses the need for checking values of Sy from development period calibration on pre-development calibration results remain.

Comment 6: Page 12 – Item 6 is Central Model Unit and item 12 is Western Model Unit.

Response: Table 1 has been corrected.

Comment 7: Page 22, section 4.4.1.1 – Is there any practical difference between using head versus flow boundaries? I was thinking that flow boundaries might have less impact on management analyses near the boundary. Expansion of text would be helpful here.

Response: The General Head Boundary (GHB) that we discuss is not a Constant, or even Time-Variant Specified Head boundary which is located at the physical model boundary. Rather, the head that is specified is located some distance laterally from the physical model boundary and may be a known hydrologic condition such as a river, lake or groundwater level in an area that is not expected to vary much compared to expected values at the model boundary. For COHYST, this head could also be the modeled head somewhere within an adjacent model. If this is the case, it makes the adjacent models more tightly coupled than otherwise. This method should also use the heads in the adjacent models as part of a further model calibration process, by iteratively calibrating one model, using the calibrated head as the GHB head for the adjacent model, and checking the calibration of the second model, and so forth for the third model.

Comment 8: Page 23 and elsewhere – Is this a suggestion that the ET rate be varied monthly or that it just be turned off in the non-irrigation season. The maximum ET rate in the models was the estimated annual rate divided by 365. Is the review suggesting that the rate be changed to the annual rate divided by 153 or zero, depending on the season? If the suggestion is something like a monthly rate, some data sets could get very large. Is either change likely to have a practical effect or is this a matter of perception? More specific recommendations on what to do with ET would be very helpful.

Response: A similar argument could be made to only use pumpage rates averaged over a year. The reasons used by COHYST to segregate the year into growing and non-growing seasons are the same ones that should apply to other stresses on the aquifer that are dependent upon the seasons, including ET. Our recommendation is to change ET to align with these seasons, and to use maximum rates determined from climatic data modeling methods such as are used to determine reference crop ETr, and distribute it by climatic stations used for such analysis. Subdivisions of the year into time period shorter than growing and non-growing seasons probably are more appropriately left to sub-models that may be used to analyze the importance of ET from groundwater during the growing season on water levels and changes to groundwater discharge to streams and rivers.

Comment 9: Page 25, section 5.1.3.3 – The anisotropy ratio should be checked again. It apparently was 10 when the models were run.

Response: Subsequent checks of datasets for all three models that were opened in GMS 5.1 using the option to convert the BCF files to the true layer approach showed that the anisotropy ratio was in fact 10. The comment in the draft report indicating otherwise was made by not invoking this option in GMS. The anisotropy is actually in the BCF datasets as the VCONT array, but apparently GMS does not recognize this and sets the factor to 1.0 when examining the hydraulic conductivity arrays with the BCF option used. The text in the draft report has been corrected to reflect this.

Comment 10: Page 25, section 5.1.3.4 – The conductance of the river boundary or the conductance of the general head boundary should have been set to zero at various times to prevent multiple boundary conditions. This might need to be checked. I think setting conductance to zero effectively removes the river or the lake.

Response: To avoid confusion and potential uncertainty in the model, the general head boundary should be used, as it represents Lake McConaughy. However, it should be expanded to cover the complete footprint of the lake, not just the boundary, although with a one-layer model this is probably not necessary.

Comment 11: Page 31 and elsewhere – The issue about which stream system was being affected when the SDF lines were generated was because the total water budget from MODFLOW was used to assess impacts. When the well potentially affected Republican River tributaries, the results did not indicate whether the Platte or the Republican was affected. The fix would be ZoneBudget or equivalent. This is not so much a model issue but how the model output was used. Perhaps the problem and the solution could be clarified in the review.

Response: The uncertainty in how the model was used is precisely why this example was cited in our review. Our opinion is that it is a model issue, because how the models are constructed should be a function of how they are used, not the reverse.

Comment 12: Page 37, section 6.1.4 – Section state the 1973-85 period has the largest observation data set, but I count 463 for that period and 718 for 1985-98. These are the sums from the three documentations and there are certainly overlaps, but I think 1985-98 is the largest data set.

Response: Your assessment is correct and the text has been changed. However, the point being made is that the time period that has the most data should be used for calibration and the other time periods used for verification analyses. The section changed is on page 38, not page 37.

Comment 13: Page 46, last paragraph – Could the review expand on the computation sequence? This is not something that I was aware of and could be an important point.

Response: Paragraph referred to is now on page 47. Review of the ModFlow 96 Programmer's Guide (Reference 25), p. 5 shows that within the loop to formulate the finite difference equations, the necessary non-linear terms are updated by calling the appropriate subroutines in the following order: Wells, Drains, Rivers, ET, General Head, and Recharge. The terms for Drains, Rivers, and ET are all dependent upon the head solved for in the previous iteration, and hence are non-linear. The iterative process is supposed to result in a head solution that satisfying all these non-linear terms. However, depending upon the closure criteria used, and whether the model did not require convergence before moving to the next time step (which was the case with some COHYST datasets), it is possible that drains get first call on the discharge from the aquifer at the expense of ET. The importance of this should be tested to ascertain if it is a concern for the COHYST models by removing first ET then drains where they are common to cells and comparing the results. While drain flow is a small component of the overall water budget for the two models that used drains (EMU and CMU), drain flow may be important to future sub-models.

Comment 14: Page 56 and elsewhere – "Blow up" of comparison for 0-200 cubic feet per second part of graph would be very useful as most of the data are contained in this range.

Response: We have included these expanded views of these graphs on Figures 63 through of the report.

Comment 15: Page 86 – Wrong title on graph. Figure title shows correct dates.

Response: Figure 16 title has been corrected.

Comment 16: No specific page – Is there a reference for Normalized RMS? At meeting, Eric stated that this should be less than 7-8 percent. Is there a reference for this also? Are there also a normalized mean error and a normalized mean absolute error and do they have acceptable limits? Expansion of the text on these points would be helpful.

Response: Normalized root mean square is an industry standard goodness of fit statistic that is reported as part of calibration analyses with Visual ModFlow, one of the industry standard groundwater modeling shells, and the shell that the COHYST model strategy recommended. It is important because it is the ratio of the RMS to the maximum observed change over a modeled domain. As stated in the manual for Visual ModFlow: "The Normalized RMS is expressed as a percentage, and is a more representative measure of the fit than the standard RMS, as it accounts for the scale of the potential range of data values." (Reference 26, p. 463).
The industry standard that we are aware of and which we use in our modeling work is that the RMS should generally be less than 10% of the range of measured heads or head changes over the model domain. For example see References 27, 28, and 29. The 7% to 8% goal for the normalized RMS is an unwritten standard used by the North Carolina Department of Natural Resources, Aquifer Protection Section in assessing the acceptability of models used in support of permitting and remediation of contaminated sites.

Comment 17: Unknown pages – Report stated that development period recharge in Eastern Model Unit was too large, but I am not clear as to which analyses indicate this. More detailed support of this conclusion would be helpful.

Response: This statement refers to apparent bias shown by the difference in slope between the regression line and the line of equality on Figures 8 through 11. This bias is caused by the observed water level declines being greater than the computed ones, and conversely, the observed water level rises being less than the computed ones. The only plausible explanation for this is that too much water is being added to the modeled system compared to the real system. The bias cannot be explained by modeled specific yield because: 1) a lower modeled specific yield would result in greater modeled declines, and hence better agreement with observations; 2) a higher modeled specific yield would result in lower modeled rises, and hence better agreement with observations; but 3) both of these conditions cannot be true at the same time unless independent information shows that specific yield is different in areas of water level decline and rise.

Comments on Draft Peer Review Findings Report by Steven J. Peterson and Responses by Eagle Resources.

Note: The purpose of this document is to either provide clarification to the external peer reviewers on points that may have been misunderstood, or to ask for further clarification of peer review findings. The present document is based on the draft report "Cooperative Hydrology Study (COHYST) Independent Peer Review Findings," dated September 15, 2005, which was downloaded from ftp://cohyst.eagleresources.com@eagleresources.com on September 19, 2005. Questions based solely on presented materials will be individually identified. Typographical and grammatical errors in the peer review report are not included in this list.

Comment 1: (Many places in the document and presentation): recharge to ground water development period models: the report indicated that Cropsim was used to estimate ground water recharge input to the ground water development period simulations. As was pointed out by R.R. Luckey during the 20SEP05 meeting, this is incorrect. Ground water recharge for those simulations was based on a combination of transient land use data and soils, applied as recharge in addition to rangeland recharge used in the pre-ground water development simulations. Also, recharge in each model area was different to account for ground-water recharge from surface-water irrigation projects or other factors specific to each model area.

Response: See response to Richard R. Luckey Comment 1.

Comment 2: (Many places in the document): "the models provide better fits to heads and stream and river gains and losses than are documented in the model reports." Please provide specific examples so that this issue can be more fully evaluated.

Response: The scatter plots of observed vs. computed head (Figures 2 through 6) and modeled reach gains plotted on estimated mean groundwater discharge from spreadsheets provided by COHYST (Figures 33 to 37) provide the specific examples that were discussed in the Peer Review Report.

Comment 3: Section 4.4.1.2 (p. 22) describes the use of head-dependent boundaries as an alternative to fixed-flow boundaries used for the COHYST simulations. However, there is little explanation of why head-dependent boundaries would improve the COHYST simulations. Such an explanation would help identify whether this comment is based mainly on stylistic and conceptual approaches to ground-water models, or if it is based on a need for additional information in the documentation.

Response: See response to Richard R. Luckey Comment 7.

Comment 4: Section 4.4.2 (p. 23) discusses ground-water evapotranspiration in the COHYST simulations.

a. Second paragraph states that constraining evapotranspiration to certain areas is unnecessary. Further clarification is requested, because it is unclear how allowing evapotranspiration to occur everywhere would improve the simulations. Evapotranspiration was restricted to areas where CALMIT land-use data showed vegetation types that were indicative of ground-water evapotranspiration because of the concern that allowing simulated evapotranspiration to occur in areas where it was known not to occur could obscure other potential simulation errors.

b. Fourth paragraph points out that evapotranspiration was simulated in all models throughout the year. While it is true that non-growing season evapotranspiration is unrealistic, the maximum evapotranspiration rates used were based on annual estimates rather than seasonal estimates. Therefore, at the end of each year, the volume of ground water removed by evapotranspiration would be the same as if that rate were modified to a seasonal rate and applied only during the growing season stress periods. Example: if the daily maximum rate of evapotranspiration applied to all stress periods corresponds to 13 in/yr (near the maximum used in any COHYST models), the corresponding rate of 13 in per growing season could be used instead for alternating stress periods, which would have a different daily rate, but amount to the same volume of water on an annual basis.

Response:

a) While there is value in using independent knowledge and reasoning of where ET is likely to occur to restrict the places the model simulates ET, unless such areas are added to account for ET in areas where shallow watertables develop as a result of recharge from canal leakage, excess surface water irrigation, or increased simulated recharge, the model will underestimate ET from such areas. As discussed in the Peer Review Report, allowing ET to potentially occur everywhere would eliminate this problem. The technique of using an ET surface to simulate ET from areas of cells that were lower than the mean land surface elevation appears to have been developed model wide, not simply restricted to the areas where ET was determined to occur *a priori*. At a minimum, this method should be attempted and compared to use of the pre-determined ET areas. Of course for the Eastern Model Unit, the ET surface has to be corrected because the ET surface for that model is higher than the land surface over approximately 30% of the areas where ET was pre-determined to occur.

b) See response to Richard R. Luckey Comment 8.

Comment 5: Section 5.1.3.3 (p. 25) says that the model documentation indicated a K_h/K_v ratio of 10 was used, but the model data shows that a ratio of 1.0 was used. All Eastern Model Unit model datasets have been double-checked, and none were found to have a K_h/K_v ratio of 1.0, even when a model built in GMS 3.1 was opened using GMS 5.1.

Response: See response to Richard R. Luckey Comment 9.

Comment 6: Section 6.1.1.1, last paragraph (p. 31), discusses a report on the computation of stream depletion using the models, and that the report identified difficulties determining which feature had been impacted by pumping; the comment goes further to note that the final model documentation does not show how this problem was addressed. It is felt that such a statement implies omission or failure to address a problem with the simulations or a lack of documentation, however:

c. The issue was not identified in the model documentation because that effort was not strictly part of model development. Because the issue was identified in a report separate from the model documentation, it would seem to be most logical to expect resolution of that problem to also be documented in a separate report, perhaps an update of calculation of stream depletion.
d. The problem which arose during the effort to calculate stream depletion had to do with the mechanics of retrieving the simulation results for specific streams for tens of thousands of simulations, and was not due to a shortcoming of the simulations themselves. This issue could be resolved given sufficient time during an update to that effort, using the existing COHYST simulations, without further modification. The additional time mentioned would be used to resolve issues with the mechanics of retrieving and handling the appropriate data.

Response: See response to Richard R. Luckey Comment 11.

The point that seems to have been missed in the formulation and implementation of the COHYST modeling strategy is that the end use of models needs to be developed and quantified with concrete scenarios and model response metrics **BEFORE** the models are constructed. Developing them after the models are constructed nearly always results in additional effort and cost to redo models to answer the questions after the fact.

Therefore lessons learned from this application should have been applied to the present one-half mile grid models as part of model development to demonstrate that the present models, however the results are tabulated and used can resolve the issues identified. Examples would be to build conceptual model elements in GMS that set up zones of interest and stream reaches that could be specifically looked at with the cell by cell mass balance inspector to answer the questions that were raised.

Comment 7:

Comment 6.1.2.6 (p. 35) says that simulated ground-water discharge to streams from the end of the pre-ground water development simulation does not match simulated ground water discharge to streams at the beginning of the ground water development period simulation, and refers to figures 22-27 which includes plots of simulated ground-water discharge to streams for several reaches of the Platte River in the Eastern Model Unit. Using GMS 3.1, the simulated ground-water discharge to these streams was evaluated for both models at simulated times that were 1 hour apart. The values the Platte River for Cozad to Overton, Overton to Odessa, Odessa to Grand Island, and Grand Island to Duncan for both models were found to be within 0.12 ft^3/s, well within the limit of calculation error. Further, only the values for the Odessa to Grand Island reach were different by more than 0.05 ft^3/s. Figure 25 shows a discrepancy between the two simulations (Grand Island to Duncan reach) that is clearly much larger than any of the values found during this check, and may indicate that either an error was made by the reviewers or the simulated discharge data was not retrieved in the same way. As additional background, it has been noted during the COHYST project that GMS 5.1 does not always reliably report ground-water discharge to streams, so perhaps that could explain the difference between COHYST findings and the peer review findings. In addition, the values on figure 25 seem to be around 12 to 14 ft^3/s (loss), while the values retrieved using GMS 3.1 were about 20 ft^3/s (loss). A brief check showed that while scale issues on figures 22-24 made a strict comparison difficult, it appears that the discharge for each of those three figures was different from what was retrieved using GMS 3.1 (see table).

Platte River Reach	Peer Review discharge (ft^3/s, estimated from figures 22-25)	Discharge (ft^3/s) retrieved with GMS 3.1 (for 5/1/1950)
Cozad to Overton	30 (gain)	21.5 (gain)
Overton to Odessa	7.5 (loss)	6.7 (loss)
Odessa to Grand Island	64 (loss)	56.5 (loss)
Grand Island to Duncan	12 or 14 (loss)	20 (loss)

Response: The difference is attributable to the following. The figures in the Peer Review Report were developed by using GMS to report the gains or losses by selecting cells that represented both river reaches and drains followed by using the cell by cell balance reporting capability. Because we did not have the GMS conceptual model feature files for the river reaches and drains, this was the only method available to us. However, the same cells were selected for the pre-Development and Development period models. The inclusion of the drains accounts for most of the difference from Cozad to Overton.

The point being made in the Peer Review report was that COHYST needs to develop protocols to assure that continuity is maintained between different time periods that use different model data sets. Use of GMS and the included conceptual model coverages was recommended in our report to facilitate this process.

Comment 8: Section 6.1.2.8 states that specific yield was changed during calibration of the ground water development period, but that the effects of this were not checked against the pre-ground water development calibration. The comments imply that different values of specific yield were used for the two simulations, when in fact they used the same values for specific yield. Further clarification of section 6.1.2.8 is necessary.

Response: The model documentation reports do not include this statement. It should be included in a revised version of the reports. This revision should include an explanation of how it was actually implemented because the development period calibration, which changed Sy values presumably occurred after the pre-Development period calibration had been concluded. If this is the case, then the only way that the Sy values can be the same in both model datasets is for the calibrated values to be placed back in the pre-Development dataset. If this was done, then the pre-Development dataset should be re-run to assess the impact of this substitution.

If the pre-Development calibration was done in parallel or after the Development period calibration, then it is not clear how the correct values of hydraulic conductivity were used in the Development period model, because the pre-Development calibration changed their values.

Comment 9: Section 6.1.4 (p. 37) and 6.3.4 (p. 45) state that the largest observation well data set was available for all the models for the the 1973-1985 time period. To verify, the shapefile obs_chng_01, which contains all the ground water development period observed change data for the COHYST area, was examined. The number of observed water-level change points for 1950-61 was 211, for 1961-73 was 283, for 1973-85 was 440, for 1985-98 was 657, and for 1950-98 was 142. Even though some points may lie to close to model boundaries to be used, and some points are probably used in model overlap areas and are counted twice, 1985-98 clearly has the most available observed water-level change data.

Response: See response to Richard R. Luckey Comment 12.

Comment 10: Section 6.5.3 (p. 52) discusses evaluation of the hydrogeology coverages. Figure 38 shows a comparison of initial hydraulic conductivity (K) compared with calibrated K and suggests that the calibrated values (model layer 2) represent 0.25 to 5.0 times the initial values. However, during the calibration, the K values for model layer 2 were uniformly multiplied by 1.6, rather than by a variable value. Similarly, a uniform multiplier (not 1.6) was applied to the K for EMU model layer 5. Additional clarification would be helpful to illustrate whether this is a misunderstanding of some sort, or if there are parts of the model documentation or the geology report that need updates or additional work.

Response: Figure 38 was prepared as follows:

- Use GMS to generate a 2-D Dataset for the hydraulic conductivity values for each of the layers examined

- Save each of the 2-D datasets as an ArcGIS ASCII grid file
- Use ArcTools to import the ASCII grid file to an ArcGrid coverage
- Convert the hydraulic conductivity polygon shapefiles provided from the Hydrostratigraphic Unit report to a grid using ArcTools
- Use Spatial Analyst raster calculator to compute the grids shown in the Peer Review Report with the following equation:

Difference Ratio = (Calibrated Kh – HU report Kh)/ (HU report Kh)

Since this process simply used data sets provided by COHYST any differences from what actually was done need to be further explained by the modeler performing the analysis.

Comment 11: Section 8.1.3 (p. 65) says that multiple boundary conditions were used to represent Lake McConaughy in the Western Model Unit and Harlan County Reservoir in the Eastern Model Unit. This statement is incorrect, as Harlan County Reservoir is always simulated as a fixed water-level boundary, and at that location, no other boundary features (such as rivers) exist. The fixed-water level elevations are different prior to 1950 than after 1950, because that was approximately when reservoir operations started, but Harlan Reservoir was not simulated with a different type of boundary.

Response: This was a typographical error in the Peer Review Draft report which has been corrected.

Comments on Draft Peer Review Findings Report by Clint Case and Responses by Eagle Resources.

Dick and Steve hit it on the head with the model peer review document, I don't have a whole lot to add but further emphasis on comments Steve and Dick made-

Comment 1: We need to emphasize more in the document why we used constant flow boundaries in lieu of the constant heads.

Response: We concur with this comment.

Comment 2: Regarding model simplicity/complexity issues, the model process did begin with the approach of parsimony- the review document didn't seem to acknowledge that, but if I recall we didn't emphasize that in the final documents. Perhaps it should be included.

Response: See response to Richard R. Luckey comment 3.

Comment 3: CMU model end of pre-dev flows in the Platte vs. beginning flows in the dev period: the document showed in figure 26 a disconnect b/t flows from the end of the 1895-1950 simulation and the beginning of the dev period model from Brady to Cozad. The ~6 cfs difference (109 cfs for pre-dev and 103 cfs for dev period) is like attributed to the fact that the dev period output that Eric compared was in October at the end of the 1950 pumping stress period. I looked at an aggregate cell flow budget between Brady and Cozad for that first stress period and the out flow from wells in that area was 72 cfs. I could have the model set to output flows after the first time step of the dev period model, and then compare the results again.

Response: See response to Steven J. Peterson Comment 7

Comment 4: The anisotropy ratios for Kh/Kv were correct in the CMU models

Response: See response to Richard R. Luckey Comment 9.