Flow Modeling Strategy

for COHYST

Prepared by the Technical Committee

of the Cooperative Hydrology Study (COHYST)

Version 1.0

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The Cooperative Hydrology Study (COHYST) flow modeling strategy describes how models of the groundwater flow system within the Platte River Basin in Nebraska will be developed. Several different people will develop a number of flow models and a documented strategy will help make the models consistent with each other. This strategy initially will be a blueprint to build the models and ultimately will become a documentation of how the models were built.

This strategy does not cover COHYST data-collection and data-development efforts. The strategy for those efforts realizes that the data will be useful beyond the COHYST models and the strategy is to provide data at a much finer scale than can be used in the COHYST models.

The flow models, their documentation, and the final model data sets will be developed in accordance with the COHYST Quality Assurance and Quality Control (QA/QC) Plan.

This modeling strategy will be changed as needed as the models are being developed. The date of the creation of this version of the strategy can be found in the footnote.

Purpose of COHYST

COHYST is a cooperative effort among State and local agencies in Nebraska to improve the understanding of the geology and hydrology of the Platte River Basin in Nebraska upstream from Columbus. The study will produce scientifically defensible databases, analyses, and models to:

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

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

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

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

Purpose of COHYST Flow Models

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.

Division of COHYST Area into Modeling Units

The overall area modeled will be subdivided by a series of north-south lines into modeling units. The modeling units will overlap by at least 12 miles. Within the areas of overlap, an effort will be made to make both simulated water levels and simulated groundwater flows to or from streams consistent between the modeling units. However, it will be impossible to make simulated water levels and flows match exactly, so some differences will be tolerated. Narrative descriptions of the differences will be provided and scientifically reconciled.

The COHYST area, shown in figure 1, will be the area of primary effort when constructing the flow models. However, the models may extend beyond this area for the benefit of using actual hydrologic boundaries. Some of the boundaries of the COHYST area are groundwater divides or flow lines and hence are no-flow boundaries. However, groundwater divides or flow lines can move in response to pumping or other stresses. If preliminary simulations indicate that the groundwater divides or flow lines move substantial distances and this movement impacts the models, the model areas may be extended. If the models are extended beyond the COHYST area, published or approved data will be used in extending the model into these areas.

Initially, three modeling units will be used (fig. 1). Modeling units may be redefined at some later date. The western modeling unit will include the area west of Kingsley Dam, the central modeling unit will include the area from Lake McConaughy through Johnson Lake, and the eastern modeling unit will include the area from Johnson Lake east. Because of the overlap, Both the western and central modeling units will include Lake McConaughy and both the central and eastern modeling units will include Johnson Lake.

Model Periods

Ideally, the flow models should start modeling a period prior to any surface-water or groundwater development when natural inflows were in dynamic equilibrium (steady state) with natural outflows. However, the groundwater system received a major perturbation as early as 1890 when water was first diverted into what is now the Tri-State Ditch along the North Platte Valley in the western part of the study area. It is impractical to attempt to formally calibrate a model for the period prior to 1890 because of lack of information. However, the groundwater system may have been in equilibrium with the long-term effects of these early canals long before substantial groundwater pumpage for irrigation began. This period after the system was in equilibrium with surface-water irrigation and before substantial groundwater irritation is considered to be the best starting model period because an equilibrium plateau from surface-water irrigation probably was reached in most areas, and because data collection was initiated at about the same time.

A series of simulations will be made to determine how long it takes for the groundwater system to come back into dynamic equilibrium after a canal has been constructed and an area has come under surface-water irrigation. Depending on the results of those simulations, the predevelopment period may be defined as the period prior to major groundwater development for irrigation but after the groundwater system came to equilibrium with the canals and surface-water irrigation. This may work only for the western part of the COHYST area. It may not work for the eastern part of the COHYST area because of the relatively short time period between surface-water irrigation and substantial groundwater irrigation

The start of major groundwater development for irrigation is defined to be 1946. Very little groundwater development occurred prior to this date except where the depth to water was very shallow. Much of the groundwater development outside the valleys occurred much later.

Nebraska Public Power District and the Central Nebraska Public Power and Irrigation District began to operate large canals in the central and eastern modeling units in the late 1930s. It is uncertain as to whether or not the groundwater flow system had come back into dynamic equilibrium by 1946 in areas with these large canals and their associated surface-water irrigation. Simulation in the modeling units where this occurred may start when the canals were first used. If so, any groundwater pumpage prior to 1946 will be ignored.

Two Levels of Models

A regional flow model will be developed for each modeling unit. These models will cover the entire modeling unit at a level of detail consistent with the selected model grid. After the regional model is constructed, a river-valley model will be constructed with a finer grid and a finer level of detail. These models will extend to the edges of the Platte Valley, North Platte Valley, or South Platte Valley or to canals beyond the edges of the valleys. Boundary conditions for the river-valley models will be a combination of computed groundwater flows plus canal leakage. In most cases, canal leakage probably will dominate the boundary conditions for the river-valley models. The river-valley models are only intermediate steps to constructing new regional models with a finer grid. The river-valley models allow a more concentrated effort within the valleys before expanding the model to cover the entire modeling unit. Unless they prove to be particularly useful, the river-valley models will not be archived or maintained beyond the current study.

Model Grids

A series of models will be constructed with progressively finer grids until the grids are as fine as the data allow or until finer grids no longer improve the quality of the model results. Given the time constraints of the COHYST project, probably no more than three generations of grids can be used in the present study. However, this strategy could be used by any entity to conduct future studies, so grids and data will be developed that may not be used in the present study, but may be useful to future, more detailed studies.

The regional models will initially be constructed using a coarse grid that will capture the essential features of the groundwater flow system within the modeling unit. The coarse grid will minimize the number of cells to allow the model to be conceptualized, constructed, and run quickly. The regional model with the coarse grid will be approximately calibrated, that is, calibration will stop when there is only general agreement between observed and simulated conditions.

After the regional model for a modeling unit is approximately calibrated, a river-valley model of the modeling unit will be constructed with a finer resolution. Once the river-valley model is approximately calibrated, the grid of that model will be expanded to cover the entire modeling unit, and calibration of the new regional model will begin. Once the new regional model is approximately calibrated, a new river-valley model with a finer grid will be constructed. This process may be repeated more than once. Once the grids for the regional models have reached their final resolution, more effort will be spent on calibrating these models.

To construct data sets that will support the various levels of resolution called for in the strategy, the entire COHYST study area will be gridded with hierarchical set of grids as follows:

Grid spacing	Cell area	Approximate number of cells, including inactive cells outside the COHYST area
2 miles	4 square miles	4,000
1 mile	1 square mile	16,000
0.50 mile	160 acres	65,000
0.25 mile	40 acres	260,000
0.125 mile	10 acres	1,000,000

The grids will be constructed with four 1 square-mile cells exactly corresponding to the 4 square-mile cell, four 160 acre cells exactly corresponding to the 1 square-mile cell, and so on. There is no intent for the COHYST models to use the grids finer than 40 acres or 160 acres, but the Technical Committee recognizes that some small-area models may be produced in the future and finer grid sizes would be useful in those models. Based on extrapolation from the 4 square mile and 1 square mile cells, the 10-acre cells may be beyond what is practical in terms of computer time and disk storage. However, the Technical Committee will attempt to aggregate land-use data, and possibly some other coverages, into 10-acre cells for use in models at some later date.

Model Layers

The initial models will first be constructed as single-layer models with additional layers added as needed and as data permit. The geologic information from the Conservation and Survey Division test holes is being processed so the models can have up to seven layers, although all layers probably never exist in any one place. The seven layers correspond to the following:

1. Upper Quaternary age silt
2. Quaternary age gravel
3. Lower Quaternary age silt
4. Upper Tertiary age silt
5. Tertiary age gravel
6. Lower Tertiary age silt
7. Brule Formation or older units

The distinction between layers 3 and 4 is a geologic distinction that may help when interpolating the layers picked at test holes and some irrigation wells to a larger area. Maps of the base of Quaternary sediments or top of Tertiary sediments probably exist, at least for some areas, and these maps may be based on more than just the test holes and some irrigation wells. Units 3 and 4 are known to have similar hydrologic properties and may be treated as either one or two layers in the flow models.

Model layer 7 may or may not be active in the model, depending on the area and how the formations are eventually handled in the models. The Brule Formation is predominately a siltstone, although locally may contain channel deposits of unconsolidated sand and gravel or sandstone. The Brule Formation generally transmits very little water, except where it consists of gravels, sands, or sandstone or where the siltstone is highly fractured. The Brule Formation is an important source of groundwater along Lodgepole Creek, Sidney Draw, Pumpkin Creek, and a few other places in the western part of the COHYST study area.

Model Inputs

All groundwater flow model inputs are grouped into four categories: 1) Model geometry, 2) Boundary conditions, 3) Model parameters, and 4) Model stresses. Model geometry includes the vertical and areal limits of the system and layers being modeled. Boundaries are handled in the model by either specifying the flow across the boundary of the model or the water level at the boundary. Different boundary conditions will be used for different parts of the COHYST models. Model parameters include hydraulic conductivity, specific yield, storage coefficient, streambed conductance, drain conductance, and evapotranspiration parameters. Flow model parameters may vary within and between model layers. Model stresses are generally time-series inputs and include pumpage, recharge, and any other additions or subtractions of water to the groundwater system not accounted for in the boundary conditions. The exchanges of water between the groundwater system and streams, drains, wetlands, and lakes in connections with the aquifer are not included in model stresses because the flow models calculate these exchanges. Likewise, evapotranspiration is not included in model stresses because the models calculate it based on evapotranspiration parameters and simulated water levels. Recharge from precipitation, recharge due to irrigation, and recharge due to impoundment, canal, or lateral leakage are examples of aquifer stresses because they are input directly into the flow model rather than being calculated by the flow model. Pumpage is also an aquifer stress that in input directly into the flow model. In this study, pumpage will come from the Net Recharge Model.

The aquifer geometry depends on the modeling unit as well as the physical geometry of the aquifer and its various layers. The aquifer geometry for a modeling unit will be the same for both the predevelopment period model and the development period model, with the possible exception of river width.

The flow model boundary conditions depend on both the overall area being modeled and the modeling unit (fig. 1). The overall area being modeled was selected such that the boundary consists of real and stable hydrologic boundaries as much as possible. Streams were chosen as boundaries whenever possible because they are more stable than groundwater divides or flow lines. However, the model area still contains artificial boundaries and subdividing the model area into modeling units adds additional artificial boundaries.

Boundary conditions at the artificial boundaries can be either specified flow across the boundary (including zero flow) or specified water level at the boundary. The specified flow or water level can change with time. Specified water levels generally are more forgiving in a flow model in that they can compensate for errors in the model whereas specified flows can magnify errors in the model. Initially, the specified water-level boundary condition will be used at artificial boundaries that are not zero-flow boundaries. Later, after initial calibration simulations, some of these specified water-level boundaries may be changed to specified flow boundaries to make sure the boundary condition is not compensating for errors in the model.

Predevelopment Period Inputs

The model parameters required by the predevelopment period model include hydraulic conductivity, streambed conductance, drain conductance, and evapotranspiration parameters. The model stresses required by the predevelopment period model include recharge due to precipitation, recharge from canal and lateral leakage and deep percolation from surface-water irrigation. How these inputs are initially estimated and subsequently adjusted is discussed in the "Calibration Strategy" section.

Development Period Inputs

The development period model requires two additional model parameters, specific yield and storage coefficient, and several additional model stresses. The additional model stresses include groundwater pumpage, deep percolation from groundwater irrigation, deep percolation from surface-water irrigation not included in the predevelopment period model, enhanced recharge due to erosion control or other land uses, recharge from canal and lateral leakage not included in the predevelopment period model, and recharge from surface-water impoundments not included in the predevelopment period model.

Some of the outputs from the Net Recharge Model, including pumpage, deep percolation from irrigation, recharge on dryland fields, and recharge on range land, will be summed on a monthly basis for input to the development-period flow model. However, the flow model may be insensitive to month-to-month changes in pumpage and recharge. Initial simulations will be made to determine if simulated water levels and groundwater discharges to and from streams are sensitive to month-to-month changes in model stresses. If they are, these stresses will be changed on a monthly basis. If they are not, these stresses will be summed to a seasonal, annual, or longer basis. No matter how model stresses are summed, they will not be lumped into periods that are longer than 5 years.

Recharge from canal and lateral leakage and from surface-water impoundments will be estimated from diversion and delivery records as long-term averages. If evidence indicates that they have changed over time, this change will be incorporated into the model. Enhanced recharge due to erosion control or other land-use changes will be incorporated into the models if the models indicate that enhanced recharge has happened and has a significant effect on water levels and groundwater discharges to and from streams.

Annual, seasonal, and possibly monthly, simulated water levels and streamflows will be compared to observed conditions for general trends. Statistics measuring goodness of fit between simulated and observed conditions will be generated for each decade simulated.

Calibration Strategy

Calibration consists of systematically varying uncertain model inputs within reasonable ranges to make simulated water levels and groundwater discharges to and from streams match observed conditions. Model inputs will be varied over large areas within ranges supported by known or suspected geologic and hydrologic conditions. Model inputs will not be varied over small areas simply to improve local model fit.

The overall strategy is to start simple and add detail to the model as required. The detail of some of the data sets developed for the COHYST study allows this strategy to be pursued. If the added detail does not improve the fit between observed and simulated water levels or groundwater discharges to and from streams, the added detail will not be used in the model. For example, the model may begin with a uniform value for hydraulic conductivity within a layer. After the best value for hydraulic conductivity has been determined for each layer, some areal distributions of hydraulic conductivity for the layer may be tested. If an areal distribution improves model fit, it will be retained; if it does not, it will not be used in the model.

Notes will be kept during model calibration that will allow the modelers to retrace their general steps during the calibration process and later document the important findings of the calibration. These notes may also may be used to answer technical questions about the models. The notes will be kept in such a manner that other equally qualified modelers could retrace and replicate the general steps taken during the calibration. Notes will not necessary document each simulation, but will document major advancements and important conclusions.

The predevelopment period, steady-state model will be calibrated first. The values for model parameters and stresses determined during the predevelopment period calibration generally will not be changed during the development period calibration. If the development period model suggests that one or more predevelopment period parameters or stresses need to be changed, the predevelopment calibration will be repeated to determine if the changes improve or degrade the predevelopment model fit. If the predevelopment fit is improved, the changes will be retained. If the predevelopment fit is degraded, other development period parameters or stresses will be investigated to improve the fit.

Predevelopment period calibration strategy

Some or all of the predevelopment water levels will be selected as calibration points for each modeling unit. If the number of potential water-level calibration points is small, most or all may have to be selected. However, if the number of potential points is large, only the best points may be selected. Criteria will be established for the selection of water-level calibration points prior to calibration. The criteria may exclude points that appear to be less reliable because of date of measurement, method of measurement, lack of such information, or other such things. The criteria also may exclude points in a generally random fashion in order to maintain a somewhat uniform coverage. Whatever criteria are developed, they will be applied uniformly. General notes will be kept on this first stage of selecting water-level calibration points. If, after the data set is selected, points are later discarded because they are suspect, more detailed notes will be kept as to why these points were purged from the data set.

All available estimates of dry-weather predevelopment discharge to or from streams from the groundwater system will be used as calibration points. This data set is expected to be relatively small, so there are no plans to trim it. These estimates will be given various weights based on the known or perceived quality of the estimates. Notes will be kept on the source of the discharge estimates and their perceived quality.

Predevelopment recharge from precipitation will be estimated using a simple predevelopment, steady-state, water budget. The modeling unit or subunit budget will account for inflow from and outflow to adjacent areas, groundwater discharge to and from streams and drains, and evapotranspiration. The predevelopment water budget assumes that the system is in a state of dynamic equilibrium with inflow and outflow being in balance. Total recharge will be assumed to be equal to the net outflow from the modeling unit and will be distributed uniformly over the modeling unit. This uniform recharge would then be adjusted as appropriate during the calibration process.

Recharge due to leakage along segments of canals and laterals will be estimated based on previous groundwater models, LB-198 applications, and information obtained from irrigation and power entities that operate the major canals in the area. The level of detail in these estimates will be consistent with the information obtained. It is not known whether on not it will be necessary to adjust these estimates for recharge from canal and lateral leakage during the calibration process.

Recharge due to land application of surface-water or groundwater irrigation water will be estimated external from the models. This recharge will vary by area and by time period. Because these estimates are likely to be poorly constrained, they may be changed during the calibration process.

Hydraulic conductivity for each layer within each model unit will be estimated from lithologic logs and published estimates of hydraulic conductivity for various lithologic units. This value will be used as the initial estimate for uniform hydraulic conductivity for the layer. This uniform hydraulic conductivity may be adjusted during the calibration process.

Stream and drain conductances initially will be set to large values so that the conductance is not a limiting factor on flow to or from streams and drains. For streams, this essentially makes the cell a specified water-level boundary. During calibration, the values for large streams, small streams, and drains will be reduced until the models start to become sensitive to them. This causes the cells to become variable water-level cells. Different values for conductance may be used for large streams, small streams, and drains, but only one value is initially likely to be used for each category. The values will then be fixed at those values for the first stage of calibration.

The flow model requires estimates of stream elevation, stream width, stream depth, and the relation between stream stage and stream discharge. Some initial simulations will be made to determine how accurately these inputs need to be estimated. Stream elevations will be estimated using topographic maps and the estimates will be checked using surveyed datums at gaging stations. Stream width and stream depth will be estimated from measurements made at streamflow gaging stations. If the flow model proves to be sensitive to these parameters within the range that they have changed over the historical period, these changes will be incorporated into the flow model. If the flow model is not sensitive within the range of historical changes in these parameters, a constant estimate over time will be used.

Evapotranspiration parameters will be set to generally accepted values for the area. For the first stage of calibration, the same extinction depth and the same relationship of evapotranspiration surface to land surface will be used for each land category that has evapotranspiration from groundwater. The maximum evapotranspiration rate may initially have some simple spatial variation.

Uniform hydraulic conductivity for various layers will be increased or decreased to better the model fit. The notes will indicate the initial estimate for each layer, the best-fit value for each layer, and whether the model fit is sensitive or insensitive to the hydraulic conductivity of the layer.

If a large difference exists between simulated and estimated discharge to and from streams, either recharge will have to be adjusted or evapotranspiration parameters will have to be adjusted. Which input is to be adjusted will be a judgement based on the spatial relation of the differences and the evapotranspiration areas and the amount of evapotranspiration simulated verses what is thought to actually occur. The reasoning behind the judgements and the results of the adjustment will be documented.

The above simulations will be the "uniform parameter" calibrations and will provide the basis to determine if added complexity improves the models. Simulations with spatially varying parameters will be compared to the "uniform parameter" calibrations. If the spatially varying simulations better fit the observed data, the added complexity improves the model and is warranted by the observed data. If these simulations are no better than the "uniform parameter" calibrations, the added complexity is not warranted and will not be added to the model at that time.

Simulations will be made with spatial variation in recharge with all other parameters kept uniform. The spatial variation will be based on physical processes related to recharge and will not be based on where recharge needs to be increased or decreased to make the model better fit the observations within a local area. If data are available, a number of different spatial variations in recharge will be investigated and the one that most improves the model will be selected.

Simulations also will be made with spatial variation in hydraulic conductivity with all other parameters kept uniform. The spatial variation will be based on physical processes related to hydraulic conductivity and will not be based on where hydraulic conductivity needs to be increased or decreased to make the model better fit the observations within a local area. If data are available, a number of different spatial variations in hydraulic conductivity will be investigated and the one that most improves the model will be selected.

Simulations will be made to determine whether simultaneous spatial variation in recharge and hydraulic conductivity is warranted. This will be done even if the model does not seem to indicate that spatial variation in either recharge or hydraulic conductivity alone is warranted. These two model inputs usually act the same with respect to simulated water levels, so it is possible that jointly they require spatial variation even if individually they do not. If warranted, spatial variation in both will be introduced into the model.

Simulations will be made 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. Simulations with the complex spatial variation will be compared to those using the uniform or less complex spatial variations determined with the flow model alone. This will be done primarily to determine if the effort to estimate recharge independently from the flow models was warranted and actually improved the flow models. Unless the independently determined estimates seriously degrade the model, they will be used because these estimates are more physically based and rigorous than those made with the flow models.

Unless the models appear to be very sensitive to evapotranspiration parameters, streambed conductance, or drain conductance, spatial variation in these parameters will not be introduced until after spatial variation in recharge and/or hydraulic conductivity is introduced. If spatial variation is introduced into evapotranspiration parameters, the variation should be based on physical processes related to evapotranspiration, such as climatic parameters, potential evapotranspiration, soils, or plant types. Streambed and drain conductance generally have little physical basis but any spatial variation on these parameters still will require some justification beyond the need to increase or decrease them to make the model fit better within a local area.

Development period calibration strategy

Strategy for the development period calibration is only partially developed and the final strategy will depend somewhat on the success of the predevelopment period strategy outlined above.

The general modeling strategy will continue to be to start simple and add complexity only as required. The general data-collection strategy of starting complex will allow this to occur.

Average specific yield for each layer will be estimated from lithologic logs based on published estimates for specific yield for various lithologic units, previous modeling studies, and aquifer test specifically designed to measure this parameter. This value will be used as the initial estimate for uniform specific yield for the layer. This uniform specific yield may be adjusted during the calibration process.

Average storage coefficient for each layer will be estimated from previous modeling studies and aquifer tests specifically designed to measure this parameter. This value will be used as the initial estimate for uniform storage coefficient for the layer. This uniform storage coefficient may be adjusted during the calibration process.

Recharge from canal and lateral leakage not included in the predevelopment period model and recharge from surface-water impoundments not included in the predevelopment period model will be estimated the same way that they were estimated in the calibrated predevelopment period models. If those estimates had spatial variation in them in the final predevelopment period models, that spatial variation will be retained in the development period models. The method of estimating this recharge will be changed in the development period only if there is a clear reason for doing so. If the method is changed, it will be clearly documented and justified in the notes, and any effects on the predevelopment calibration will be explained.

Some of the model stresses in the development period model are being developed independently of the flow model and these inputs will be spatially complex. These stresses include groundwater pumpage, deep percolation due to groundwater application, and deep percolation from surface-water application not included in the predevelopment period model. The spatial complexity of these model stresses probably will be maintained from the beginning of the development period calibration. If the development period calibration indicates that these model stresses need to be changed, they will be changed uniformly or the assumptions in the way in which they are calculated will be changed and the stresses recalculated independently of the flow model.

Calibration of the development period models will consider enhanced recharge due to erosion control or other changes in land use or irrigation methods. Such recharge will be added to the models only if it clearly enhances the models and if some evidence exists beyond that provided by the models that such enhanced recharge actually exists.

Model Documentation

Once calibrated, the models will be documented in a series of short technical papers. There may be separate technical papers for each of the modeling units and the predevelopment period calibration may be described separately from the development period calibration. Technical papers also may be written on specific topics that transcend individual modeling units. For example, a short technical papers may be prepared to describe how soil units were combined to compute recharge or how existing contour maps or other spatial data were interpolated to provide model inputs. These technical papers will not be in publication format and will be more of a summary notebook entry. These papers will be detailed enough that a hydrologist familiar with modeling could understand the essential points of the models. The papers will describe the conceptual model of the flow system and how the final model inputs were generated. The papers will include a discussion of model strengths and weaknesses, comparisons between observed and simulated conditions, and a discussion of potential uses and misuses of the models. The primary purpose of these technical papers is to document the work that was done in some detail. These technical papers will be filed with the various entities that make up the COHYST Sponsors. These papers should provide the basis for published technical papers, journal articles, or presentations before technical audiences, although no such publications are specifically planned at this time.

These technical papers will describe the model inputs and outputs, as used in the calibrated models. The inputs may be described with maps, tables, graphs, or written description. The descriptions will be of sufficient detail to let the reader become generally familiar with the model without having to resort to looking at long listings of model inputs and outputs. Calibrated model inputs and outputs can be examined for those desiring all the details.

The technical papers will not attempt to document all the things that were tested but were not found to be useful in the calibrated models. However, if things that seem probable and are part of "conventional wisdom" are found not to be useful in the calibrated models, these will be documented in the general study notes to possibly prevent someone from spending time in the future investigating the same thing.

The technical papers will be accompanied by complete sets of model inputs and outputs, auxiliary files found useful in constructing the models, and any other items that the modelers believe might be useful to someone in the future who attempts to reconstruct the essence of the models. These data sets will match the model as described in the documentation. This more detailed data will be preserved in machine-readable format on some media that is likely to persist for a number of years, although this media may be difficult to predict. This data will be archived with the Nebraska Natural Resources Commission.

A short, less technical description of each of the models also will be prepared. These will be for a more general audience and will be posted on the COHYST Internet site. These descriptions will be sufficient to give a general feel for the models. They may be suitable to accompany some typical model simulations on an Internet site.

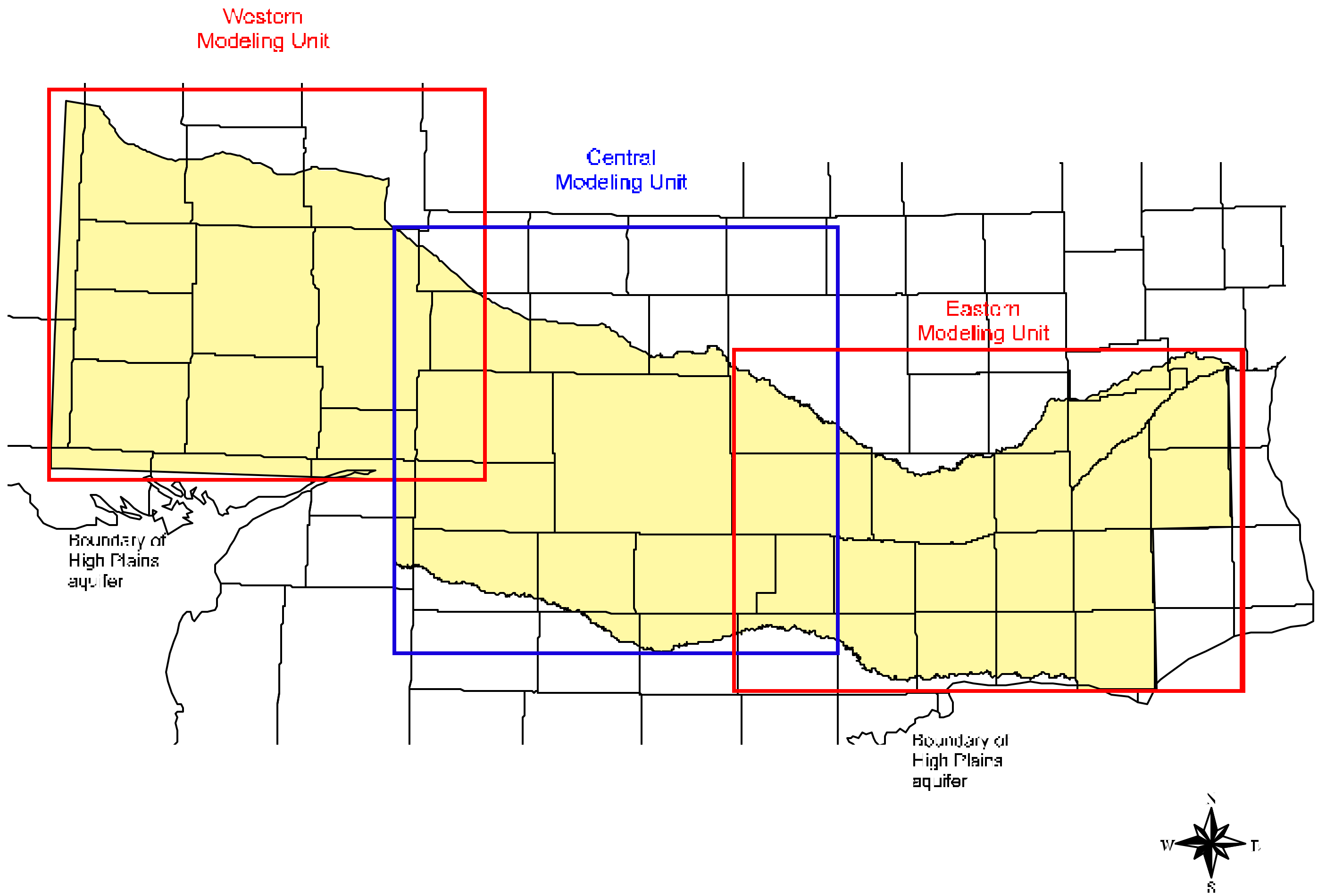

Figure 1. Cooperative Hydrology Study (COHYST) area and modeling units.