GIS BASED GROUNDWATER FLOW SYSTEM MODELING TO SUPPORT PHC PREDICTION, CHIA, AND ECONOMIC DEVELOPMENT.

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This project will bring together the large volume of stratigraphic and hydrologic data that exist for western North Dakota into a Geographic Information System (GIS). Use of data that have been acquired over the last 40 years will be maximized in the production of graphic and statistical models of shallow groundwater flow systems on sub-regional scale.

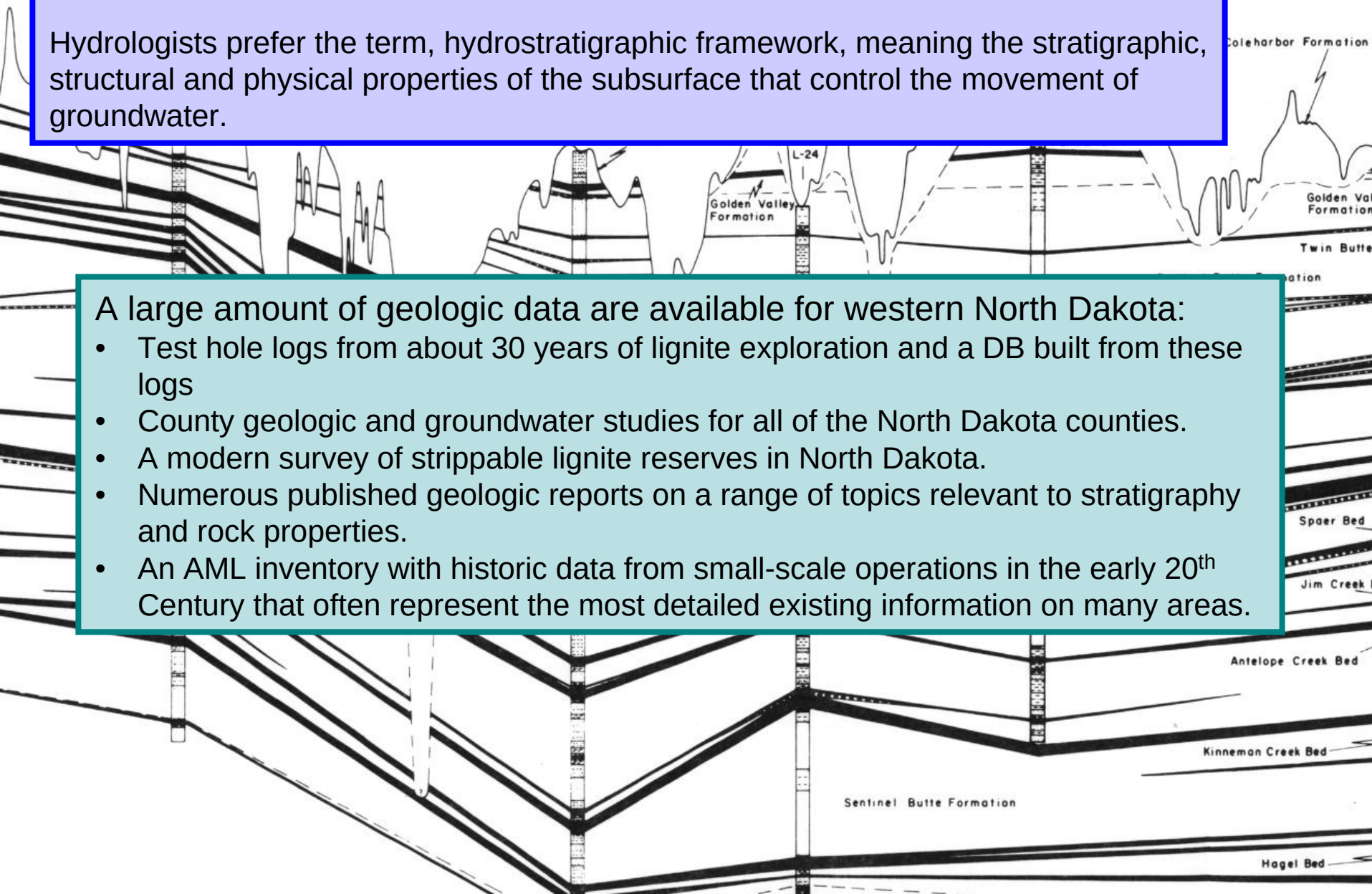
Sub-regional scale is here defined as being of the magnitude of about 6 townships or about 200 sq. mi. Areas of this magnitude approximate the characteristic footprint a lignite reserve large enough to support a modern surface mine in North Dakota.

The resolution of existing data will generally support the development of useful models at this scale. The data, excluding those at mines already developed, are not dense enough to support detailed geohydrologic analysis, detailed mine development, or permit baseline information. However, models from these data can guide and significantly decrease costs of acquiring development and baseline data, and their insight can contribute to the quality of PHC models and inferences for mine permitting.

"All models are wrong. Some models are useful." – George Box

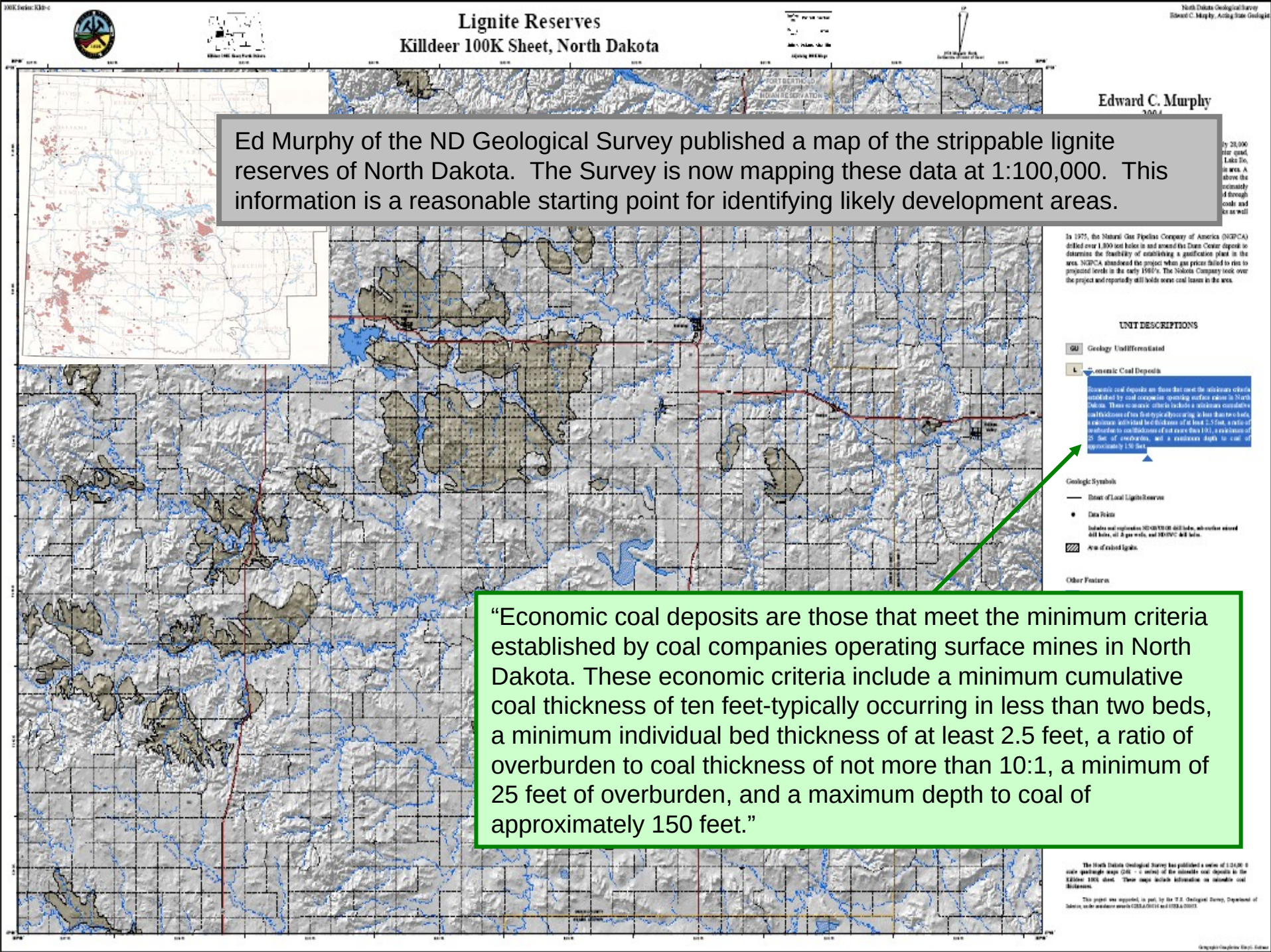
All groundwater modeling begins with a geologic model.

Hydrologists prefer the term, hydrostratigraphic framework, meaning the stratigraphic, structural and physical properties of the subsurface that control the movement of groundwater.



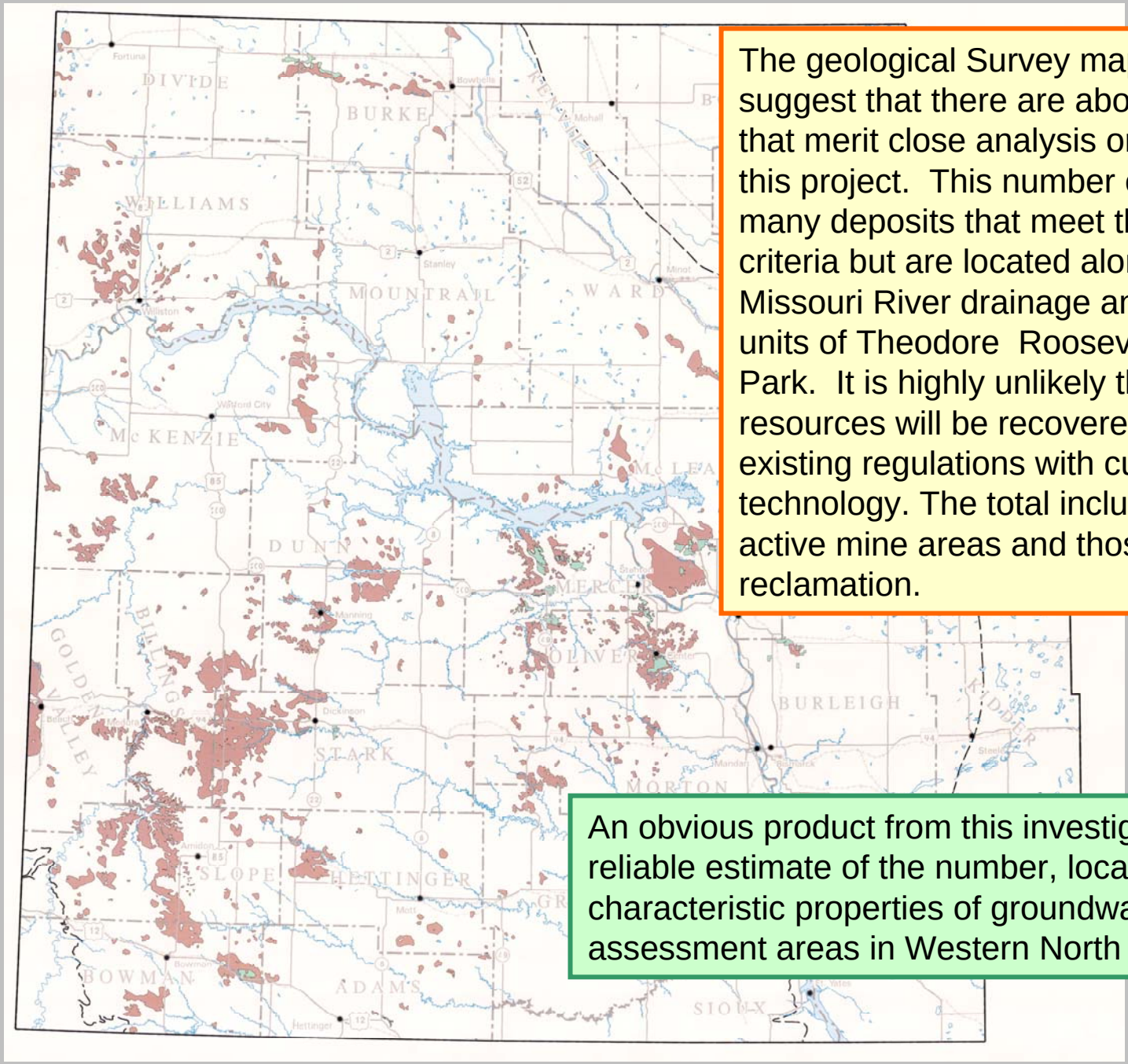
A large amount of geologic data are available for western North Dakota:

- Test hole logs from about 30 years of lignite exploration and a DB built from these logs
- County geologic and groundwater studies for all of the North Dakota counties.
- A modern survey of strippable lignite reserves in North Dakota.
- Numerous published geologic reports on a range of topics relevant to stratigraphy and rock properties.
- An AML inventory with historic data from small-scale operations in the early 20th Century that often represent the most detailed existing information on many areas.



Ed Murphy of the ND Geological Survey published a map of the strippable lignite reserves of North Dakota. The Survey is now mapping these data at 1:100,000. This information is a reasonable starting point for identifying likely development areas.

"Economic coal deposits are those that meet the minimum criteria established by coal companies operating surface mines in North Dakota. These economic criteria include a minimum cumulative coal thickness of ten feet-typically occurring in less than two beds, a minimum individual bed thickness of at least 2.5 feet, a ratio of overburden to coal thickness of not more than 10:1, a minimum of 25 feet of overburden, and a maximum depth to coal of approximately 150 feet."



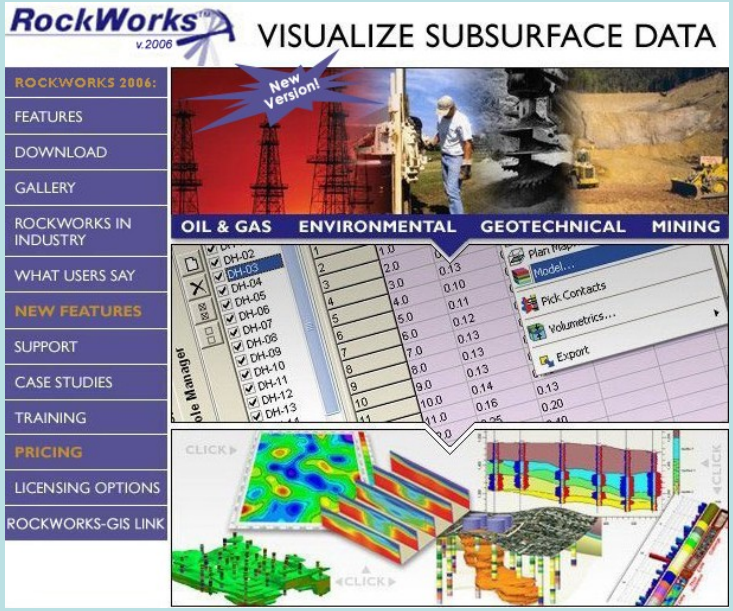
The geological Survey mappings suggest that there are about 45-50 areas that merit close analysis or modeling in this project. This number excludes many deposits that meet the mining criteria but are located along the Little Missouri River drainage and close to the units of Theodore Roosevelt National Park. It is highly unlikely these resources will be recovered under existing regulations with current technology. The total includes existing active mine areas and those in final reclamation.

An obvious product from this investigation will be a reliable estimate of the number, location and characteristic properties of groundwater hydrologic assessment areas in Western North Dakota.

The ND Geological Survey (NDGS) has regulated coal exploration in North Dakota since the start of our permanent program. Over the years, logs for about 19,000 permitted test holes have been filed, geologic contacts picked and stored in a DB. Survey geologists, primarily Ed Murphy, have supplemented these with stratigraphic data from a number of oil wells. These data supported the Survey's mapping of lignite reserves.

In 2005, the Reclamation Division retrieved these data from the Stratifact DB that had been in use by NDGS until that application ceased to function and be supported in recent Windows versions. The data structure was minimally altered and prepared for storage in MS SQL Server. The PSC proposed to maintain and serve the data from that platform.

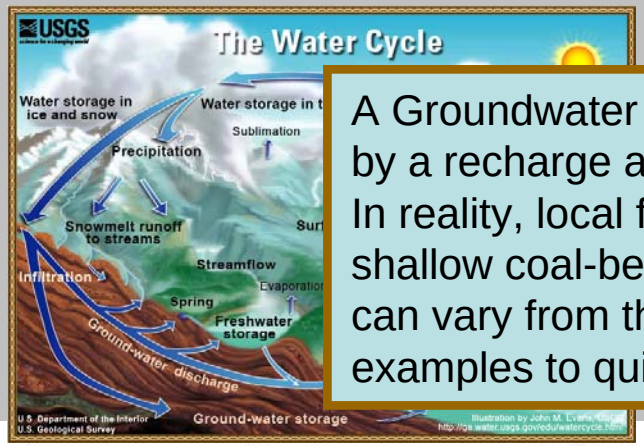
A remaining task is to find a software application to replace Stratifact for end-user data manipulation and geologic/hydrologic graphic modeling; that is, generation of cross-sections, fence diagrams, contouring and strip logs in a user-friendly fashion. Many applications aimed at geotechnical data provide some of these functions. Few support the level of stratigraphic complexity used by geologists and groundwater hydrologists.



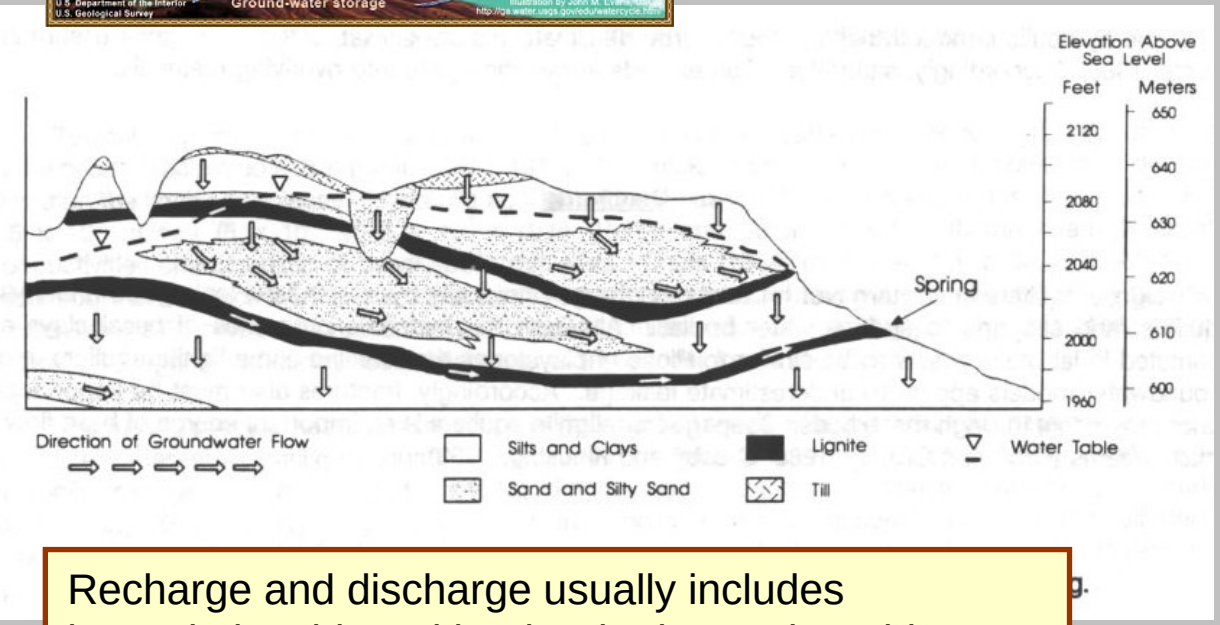
A review of several products suggests that Rockware's Rockworks may be our best choice. Review and testing of this application, especially the ease of moving data and results between it and ArcGIS, is still needed.

Status and Summary: Geologic Framework

- Test hole database ready for storage in MS SQL Server
- Visualization and analysis application to be selected
- NDGS still producing the 100K coal resources maps
- Layers from completed coal resource maps need to be acquired for the GIS (NDGS cartographic production with ArcGIS)
- Coordination and review procedure needs to be set with Ed Murphy to benefit in the process from his experience and work notes
- Storing and presenting geologic visualization and analysis products within the GIS environment needs to be addressed
- Geologic frameworks need to be developed for a few typical areas to test the GIS system.



A Groundwater flow system is bounded by a recharge area and discharge area. In reality, local flow systems in the shallow coal-bearing rocks of this region can vary from the simplicity of textbook examples to quite complex.



Recharge and discharge usually includes interrelationships with other hydrostratigraphic units. However, first-approximation modeling at a sub-regional scale usually lacks the data, other than characteristic values, to infer vertical and lateral flow to and from other rock units.

In the absence of data to model potentiometric surfaces, the location of recharge areas for shallow aquifers can be inferred from topographic information. Significant recharge areas are usually geographic features in western North Dakota since negative topographic features such as drainageways, wetlands and flat areas accumulate snow and snowmelt water. These areas provide most of the annual addition to the saturated zone. Well-drained uplands and positive features provide little if any significant contribution to groundwater. Vegetation actively consumes most water from rainfall events in summer months.

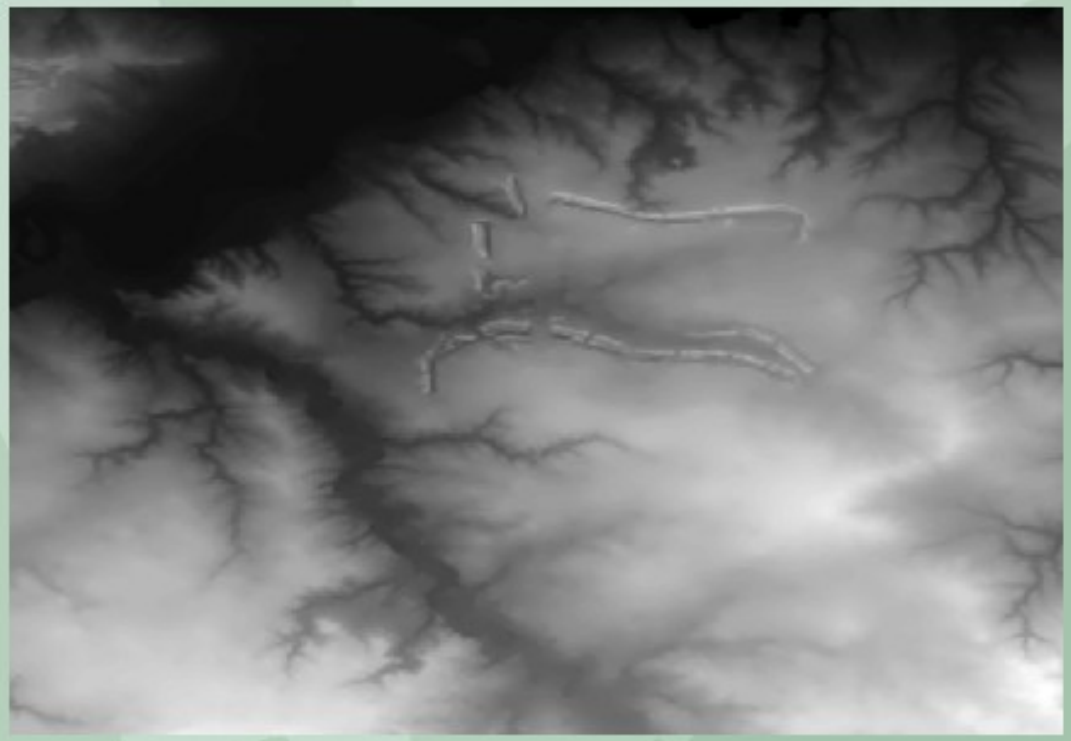
The classic approach to identifying likely recharge areas is to inspect topographic maps over the extent of the hydrostratigraphic unit under investigation.

Discharge areas are the down-gradient portions of a hydrostratigraphic unit that groundwater moves toward in response to hydrostatic pressure and gravity.

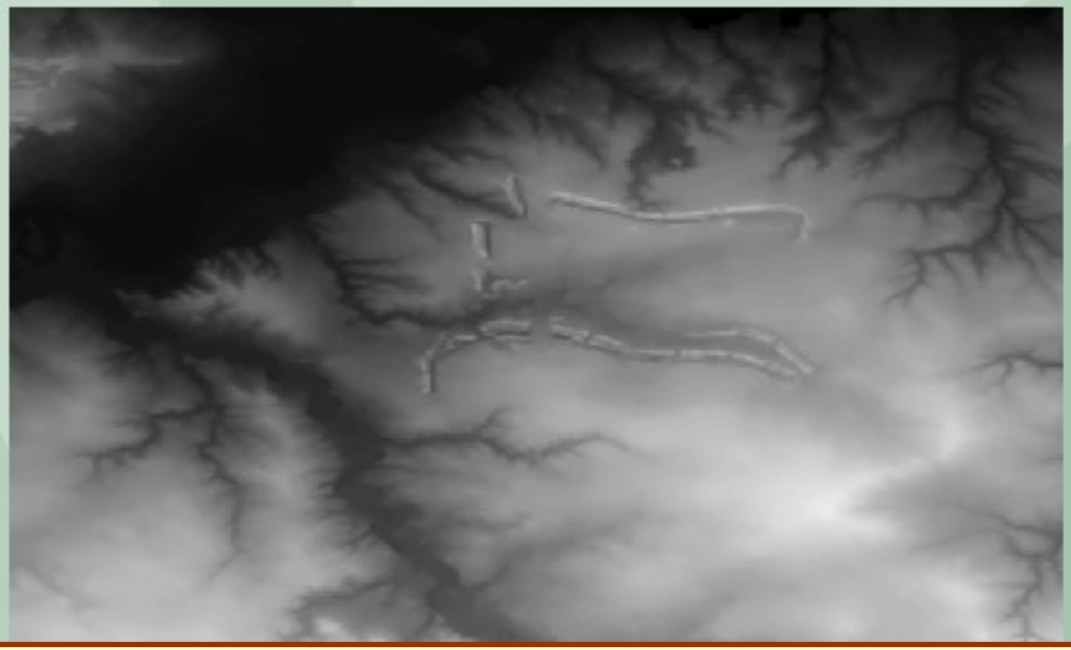
Direction of groundwater flow in shallow coal-bearing strata can usually be inferred from the strike and dip of beds shown by a good geologic model since strike and dip is a primary control of groundwater flow in shallow lignite aquifers.

Discharge areas, and often recharge areas, are defined by outcrops and subcrops of hydrostratigraphic units; in other words, the intersection of the bounding surfaces of these units with land surfaces. Projecting the “contour” modeled surfaces of hydrostratigraphic units to intercepts with land surfaces is the principle tool for inferring discharge areas, and this can be a simple task with ArcGIS.

We are currently exploring the feasibility of using USGS Seamless site DEM (30m coverage statewide, 10m in some western ND areas) to identify and categorize the density of depressions and low gradient drainages as a way to identify areas with high recharge potential. Supplementing these data with NRCS soils information is still to be explored.



The goal is to develop a methodology that uses Internet-available data to identify areas of high recharge potential in Western North Dakota. These areas can be correlated with mappings of the geographic extent and structure of probable water-bearing units to infer their recharge sources. These inferences will be supplemented with information in county groundwater studies and other sources where available.



We plan to test the usefulness of projecting the top and bottom surfaces of the principal coals onto DEM surface models as a tool for inferring recharge and discharge areas.

There are limited existing maps for western north Dakota that delineate crop line areas for the major hydrostratigraphic units in spite of the good density of subsurface data to support such models. Most of the existing maps are in paper format and need to be scanned, georeferenced and the information incorporated into GIS feature classes.

At this stage, we assume models from DEM and analyzed subsurface data will be used in conjunction with existing geologic data for cross-validation; however, most of the model will be built with crop line traces from this project.

A final step will be to use familiar environmental features to refine projected and inferred crop lines into useful information for geohydrologic models. These features include:

- Spring and seep locations.
- Wetland soils.
- Wetlands.
- Vegetation color and type as soil moisture indicators.
- Erosional landforms associated with crop lines.

NRCS soils maps and National Wetland Inventory maps are obvious data sources. These features can also be identified by analysis of earth surface imagery, from the classic interpretation of black and white aerial photography to automated analysis of multisprectral imagery.

(Most of the Northern Plains coal reserves held by Northern Pacific RR were evaluated as modern mining assets, in the early post-steam locomotive era ca. 1950-60, by using aerial photography to reduce the costs of traditional field evaluation.)

Status and Summary: Recharge and Discharge Areas

This part of the project is in its early stages.

TOTAL PROJECT SUMMARY: Planned Outcomes and Key Points

- A set of GIS-based graphic models providing a gross hydrogeologic framework, groundwater flow system and GIS managed database for each area will be the primary product.
- Only existing published and unpublished data will be located, transformed to suitable format and analyzed with no requirement for additonal data acquisition.
- An inventory and initial geohydrologic assessment of approximately 50 likely lignite development areas in North Dakota will be completed.
- A companion assessment of surface water hydrology and delineation of integrated assessment areas will be feasible.
- Characterization of the groundwater hydrologic properties of North Dakota lignite resource areas will be possible from the amassed data. Characteristic values for many numerical modeling parameters can be inferred from the data.
- The models can guide and reduce development and baseline data acquisition costs for new projects.