Hydrologic Observatory in the Platte River Basin of Colorado, Wyoming and Nebraska

PIs: F. Edwin Harvey (U. Nebraska-Lincoln), Jorge Ramirez (Colorado State U.), and Thomas Thurow (U. Wyoming).

Potential Collaborators: Nebraska Geological Survey, USGS, USEPA, Nebraska Department of Natural Resources, Nebraska Game and Parks Commission, Nebraska Department of Environmental Quality, Colorado Division of Water Resources, Colorado Geological Survey, Wyoming Geological Survey, Bureau of Reclamation, Central Nebraska Public Power and Irrigation District, Nebraska Natural Resources Districts.

I. INTRODUCTION

The University of Nebraska-Lincoln (UNL) with Colorado State University (CSU) and the University of Wyoming (UW) propose to host a long-term Hydrologic Observatory (HO) within the Platte River Basin of Colorado, Wyoming and Nebraska (Figure 1).

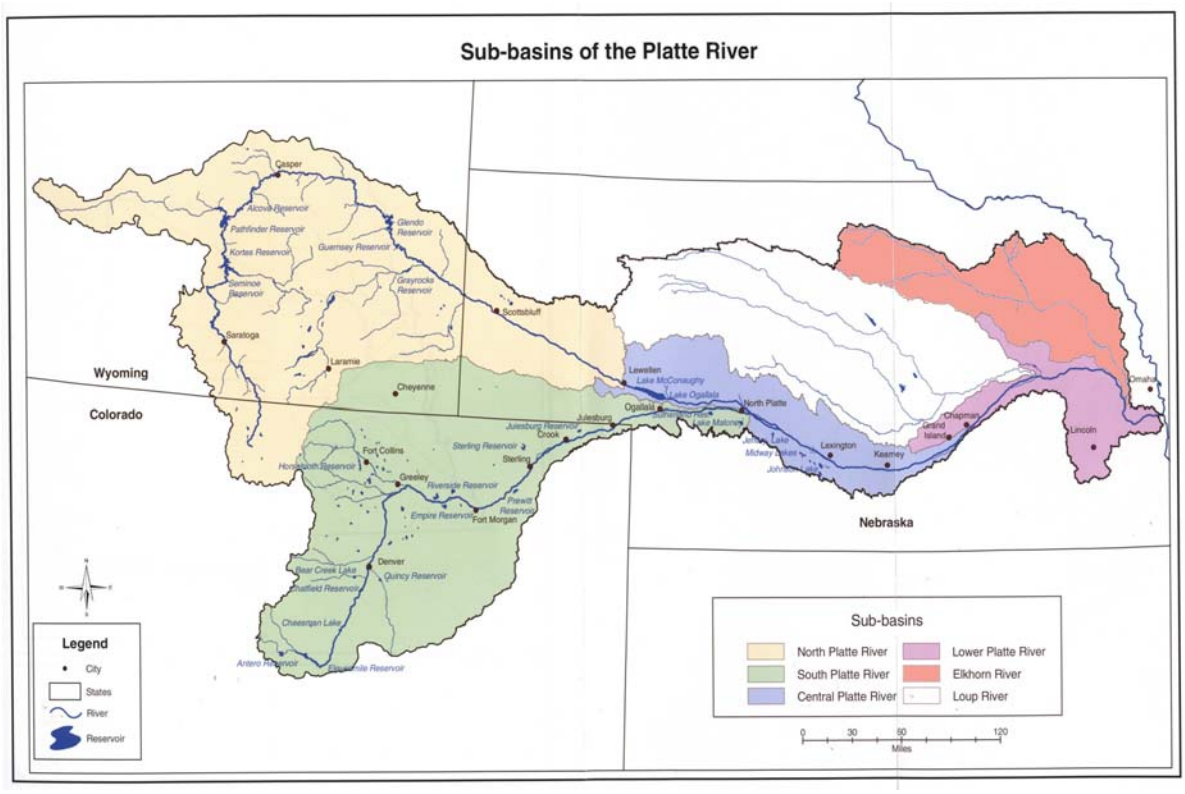

Figure 1: Platte River Basin showing sub-basins. (Adapted from Platte River EIS map)

II. SPATIAL EXTENT OF HYDROLOGIC OBSERVATORY

A. Scientific Rationale for Design

The proposed Platte River Hydrologic Observatory (PRIVHO) affords interdisciplinary and multi-disciplinary research opportunities for scientists to examine the impacts of scaling, to investigate forcing feedbacks and coupling of various interconnected hydrological, geological, climatological and biological systems, and to test the applicability and limits of prediction in keeping with CUAHSI's five priority science criteria and one UNL criteria.

(i*). Linking Hydrologic and Biogeochemical Cycles*: Agriculture and other ecosystems in the Platte River Basin are known to respond nonlinearly to climate forcing. Small changes in already marginal climate conditions for many ecosystems produce disproportionately large impacts. The deep loess soils typical of the Great Plains store large amounts of carbon in the soil organic matter. Moreover, observed changes in the composition and location of ecotones, changes in the extent and intensity of land use, coupled with periodic climate variations have strongly influenced the cycling of nutrients and net exchanges of carbon in the Great Plains.

(ii). *Sustainability of Water Resources*: The Platte River is one of the most over-appropriated rivers in the country with 15 major dams, hundreds of small reservoirs, and thousands of irrigation wells that provide municipal and industrial water supplies for about 3.5 million people, irrigation water for millions of acres of farmland, and generates millions of dollars of hydroelectric power. Decades of development have reduced flows by two-thirds and the river, once described as a mile wide and a foot deep has narrowed in many places to one-tenth of its historic width. In addition to this valuable surface water resource, the basin in underlain over a large portion of its area by the High Plains Aquifer <http://water.usgs.gov/wid/FS_215-95/FS_215-95.html>, the largest aquifer system in North America which provides about 30% of the irrigation water use in the U.S. and serves as the primary drinking water source for much of the region. Understanding the interconnection between the river and aquifer systems in vital to future management and sustainability of the resource.

(iii). *Hydrologic and Ecosystem Interactions*: Many habitats for wildlife, including montane pine forest, native grasslands, lakes, fens, sub-irrigated wet meadows, riverine wetlands, rainwater basin (prairie pothole) wetlands, and eastern deciduous forest are present within PRIVHO providing a plethora of ecosystem types within which interdisciplinary research could be conducted on the interactions of hydrology and ecosystems. Irrigation withdrawals have so negatively impacted habitat that a number of federal and state laws have recently been enacted to conserve fish, wildlife, and ecosystems within the basin.

(iv). *Hydrologic Extremes*: The proposed PRIVHO is typified by strong climatic gradients, with annual precipitation of over 900 mm/yr on the eastern edge to less than 200 mm/yr on the western edge. Its interior continental position produces large inter-seasonal extremes of temperature and precipitation, and the frequency of extreme events, especially droughts, is higher in the Great Plains than in regions near large water bodies. Irrigation withdrawals during drought periods significantly reduce flows (in some instances to dryness) within the basin in summer, while ice jams in the east frequently create flooding in later winter and early spring.

(v). *Fate and Transport of Contaminants*: As the major land use within the Platte River Basin is agriculture, PRIVHO offers excellent opportunities for scientists to study the fate and transport of agriculture non-point source contaminants such as nitrate and various pesticides. Nitrate has been detected in groundwater and surface water within the basin at

numerous locations, as have pesticides. Recently, the University of Nebraska launched a research initiated to identify, monitor and characterize emerging contaminants such as veterinary antibiotics and estrogen in stream waters. As part of this program, the UNL Water Sciences Laboratory is currently developing a schedule for analyzing pharmaceutical and personal care products (PPCPs) in water. In addition to these contaminants, studies are underway at sites within the HO to investigate the fate and transport of other complex organics such TCE, TNT and RDX. In addition to these anthropogenic contaminants, natural levels of arsenic in many of the aquifers in the basin are elevated above the maximum contaminant level (MCL = 10 ìg/L) and have become a health concern across parts of the basin.

(vi). Human Dimensions: In addition to these five criteria identified by CUAHSI, PRIVHO would be an ideal type locality to investigate questions related to interstate and intrastate conflicts over water use, evolution of water policy and water law in the wake of advancing science, and societal and economic changes that are driven by water use, availability and management, and human impacts on climate and land use changes.

The large area of PRIVHO will allow investigators to make regional scale measurements across the entire basin for use in continental climate models, regional scale groundwater models or ecosystem models for example, while more detailed, smaller scaled measurements can be carried out within smaller sub-basins.

B. Site Characteristics

The Platte River Basin, located in the U.S. central Great Plains region, covers approximately 86,000 square miles and spans several important environmental gradients, including temperature and the precipitation-to-evaporation ratio, thus making it an ideal natural observatory for conducting long-term hydrologic as well as climatologically, ecosystem, landscape-evolution, and sociological research related to the dynamics of the hydrologic cycle. The Platte River system, about 1,400 miles in length, flows across the Colorado Piedmont and High Plains provinces and encompasses a variety of physiological zones including; alpine, sand plain grassland prairie, and glaciated terrains. The basin is underlain by varied geologic and hydrogeologic regimes including the High Plains Aquifer under much of its reach. The Basin crosses six Level III Terrestrial Ecoregions and in central Nebraska, serves as a vital link in the Central Flyway, providing habitat for 300 species of migratory birds, including 80% of the continental population of Sandhill cranes and many threatened or endangered species such as whooping cranes, piping plovers, interior least terns and bald eagles. In addition the basin is home to a number of other federally listed species such as Preble's meadow jumping mouse, the Wyoming toad, the Colorado butterfly plant, and the Western prairie fringed orchid. Finally, the river itself provides critical habitat for many threatened fish species such as the pallid sturgeon, and the greenback cutthroat trout.

Both the North and South Platte Rivers have their headwaters in Colorado's Rocky Mountains (Figure 1). The North Platte flows north into Wyoming before turning southeast across the Nebraska panhandle. The South Platte flows northward through the Denver metropolitan area and then turns northeastward across Colorado and into Nebraska. These two main stems flow across the High Plains region until reaching their confluence near North Platte. From here, the Platte River flows across Nebraska, south of the Sandhills region and through the eastern dissected plains until it reaches its confluence with the

Missouri River south of the city of Omaha.

C. Proposed Field Facilities

Because the proposed Basin is so large, it will be subdivided into three smaller subbasins for more focused study; North Platte, South Platte, and Central/Lower Platte Basins, with each basin's research and monitoring being managed by one of the PIs. There are three field headquarters proposed for PRIVHO. The main coordinating station will be located in North Platte, Nebraska at the University of Nebraska West Central Research and Extension Center <http://westcentral.unl.edu/>. The two remaining stations are yet to be determined but could possibly be located along the North Platte River in Scottsbluff, Nebraska at the University of Nebraska Panhandle Research and Extension Center <http://www.panhandle.unl.edu/> and in Colorado near the South Platte River at Colorado State University.

III. Existing Data Infrastructure

A. GIS / Remotely Sensed Data:

(i). ***Center for Advanced Land Management Information Technologies (CALMIT)*****:** <http://calmit.unl.edu/calmit/> CALMIT serves to focus the significant interdisciplinary expertise in advanced land management information technologies that exists on campus and in the region. CALMIT has outstanding digital-processing facilities, including the necessary software for image analysis and GIS and more than a terabyte of online disk storage. Especially relevant to this proposal are the following components of the CALMIT research infrastructure: (1) a 20-hectare Field Research Facility located on UNL's Agricultural Research and Development Center (ARDC) near Mead, NE. This site has controlled wetlands and vegetation plots, indoor lab and storage facilities, and a seminal facility for calibration of airborne and field-based remote sensing instruments; (2) a complete field spectroscopy capability, including vehicles with boom-mounted sensor packages that allow measurements to be acquired from the ultraviolet through the microwave region of the electromagnetic spectrum. Included are two all-terrain motorized platforms (Goliath and Hercules) for deploying spectroradiometers and other systems above targets; (3) a pontoon boat equipped for rapid, automated data collection in freshwater environments; (4) an indoor spectroscopy/water quality lab at UNL that allows for controlled measurements and calibrations; and (5) the CALMIT Hyperspectral Airborne Monitoring Program (CHAMP) which features a specially modified Piper Saratoga that carries as the AISA as its principal sensor. The AISA is a hyperspectral pushbroom-type imaging spectrometer system with programmable spectral and spatial resolution. CHAMP has been operational since the 2002 growing season and has made acquisitions over a variety of terrestrial and aquatic targets at sites across the US, from Washington to Florida and throughout the Great Plains. CALMIT serves as the Nebraska node of the USGS AmericaView program and hosts deep archives of Landsat TM and ETM+ images of Nebraska as well as AVHRR and SeaWIFS imagery of the Platte River Basin and the Great Plains. CALMIT is currently collecting twice-daily AMSR-E soil moisture and vegetation wetness data products to composite and process them into weekly land surface status products for use in regional ecological modeling. In addition to the data holding and data acquisition capabilities, CALMIT scientists have expertise in remote water quality assessment, remote estimation of vegetation status and biophysical

characteristics, development and application of advanced spectral indices, land cover classification, statistical modeling of land use land cover change, and advanced spatio-temporal change analysis techniques.

(ii). *Nebraska Conservation and Survey Division (CSD)*: CSD is engaged in assembling a set of statewide spatial databases including; average annual Nebraska river discharge, bedrock geology, center pivot irrigation systems, configuration of the base of the principal aquifer, configuration of the water table, deep oil/gas exploration wells, depth to water, ecological regions, groundwater level changes since predevelopment, lakes, land use/land cover, wetlands inventory, registered wells, soils, streams, aquifer thickness, vegetation, vegetation greenness and elevation. All statewide GIS data bases are in a common map projection. In addition CSD provides county DEM data, National Elevation Dataset information, and Nebraska Elevation Dataset metadata.

(**iii). *Wyoming Geographic Information Science Center*:** <http://www.sdvc.uwyo.edu/> This Center hosts a variety of watershed oriented online spatial and biological data and is a clearinghouse for coal bed methane information.

B. Climate Data

(i). *High Plains Regional Climate Center (HPRCC)*: <http://hprcc.unl.edu/index.html>, The HPRCC, located on the UNL campus, maintains 60 automated weather stations within Nebraska, Colorado and Wyoming that collect hourly and daily weather data including air temperature, precipitation, relative humidity, soil temperature, solar radiation, wind speed, and wind direction. The HPRCC also provides access to National Weather Service data from 956 stations across the three states that collect daily evaporation, high and low temperature, precipitation, and snowfall data. HPRCC also provides estimates of potential ET at each of its automated stations.

(ii). *Wyoming Water Resource Center Data System*: <http://www.wrds.uwyo.edu/>. Online hydrological and climatological data bases for the state and region.

(iii). *Community Collaborative Rain and Hail Study* (*CoCoRaHS)*: The CoCoRaHS, located at CSU <http://www.atmos.colostate.edu/>, records rain, snow and hail fall.

(iv). *National Drought Mitigation Center (NDMC)*: <http://drought.unl.edu/>, The NDMC also located on the UNL campus, helps people and institutions develop and implement measures to reduce societal vulnerability to drought, stressing preparedness and risk management rather than crisis management. The NDMC's activities include maintaining an information clearinghouse; drought monitoring, including participation in the preparation of the U.S. Drought Monitor; drought planning and mitigation; and drought policy.

(v). *Great Plains Regional Center – National Institute for Global Environmental Change (GPRC-NIGEC)*: <http://gprcnigec.unl.edu/> GPRC is one of the six regional centers of NIGEC. GPRC is devoted to supporting research that develops quantitative information on the role of key ecosystems as a source or sink of carbon dioxide. Through understanding gained by the research it supports, the GPRC provides scientific information required to assess the consequences of climate change on social, physical, and biological resources within the region.

(vi). *National Atmospheric Deposition Program (NADP)*: <http://nadp.sws.uiuc.edu/> NADP operates 11 stations in the region that compile water quality concentration (mg/L) and deposition (kg/ha) data for precipitation including the constituents; pH, SO_4, NO_3, NH_4,

Ca, Mg, K, Na, Cl, and N.

(vii). ***University of Nebraska, School of Natural Resources*****:** The Groundwater Chemistry Laboratory has measured weekly stable oxygen and hydrogen isotope composition of precipitation over a period of 5 to 9 years at three sites along the Platte River (North Platte & Mead, Nebraska and Pawnee Grasslands, Colorado). In addition, short-term precipitation isotope records are available for a site near Brooklyn Lake Wyoming and at several other research sites across the basin.

(viii). ***Solar and Meteorological Surface Observation Network (SAMSON)*****:** Long-term mean annual evapotranspiration data has been calculated using the WREVAP model for 22 stations across the region. SAMSON is a compilation of National Renewable Energy Laboratory solar data and National Weather service hourly surface observations for the period 1961-1990.

C. Soil and Geologic Data

The Nebraska Conservation and Survey Division <http://csd.unl.edu/default.asp> has, since 1930, compiled a stratigraphic database from over 4,700 test holes and more than 17,000 oil and gas wells. The CSD also maintains a large core lab which in addition to test hole cuttings also contains oil and gas exploration well rock cores.

D. Soil Moisture Data

The High Plains Regional Climate Center (HPRCC) <http://hprcc.unl.edu/index.html> has established 34 long-term monitoring stations across Nebraska to collect soil moisture data using vital and theta probes. Measurements are taking hourly (reported daily at midnight on the website) at 10, 25, 50 and 100 cm. In addition, these stations also collect root zone water data.

E. Surface Water Data

(i*). Stream discharge***:** A large network of stations within the basin measure real-time and/or daily stream flow (ft/s) and stage (ft). These include; 32 USGS <http://waterdata.usgs.gov/nwis/rt>, 21 Nebraska Department of Natural Resources <http://dnrdata.dnr.state.ne.us/shifts/stream.asp> and 27 Colorado Division of Water Resources < http://www.dwr.state.co.us/Hydrology/flow_search.asp> along the various reaches of the North, South, Central and Lower Platte River. In addition, numerous other gages provide this information for headwater streams and tributaries.

(ii). ***Stream water quality*****:** The USGS's National Water Quality Assessment Program (NAWQA) <http://water.usgs.gov/nawqa/> monitors two basins within the region (the South Platte, River (CO, WY, NE), and the Central Nebraska Basin) for various water quality parameters.

F. Groundwater Data

(i). ***Registered Groundwater Wells*****:** The Nebraska Department of Natural Resources, and the Nebraska Conservation and Survey Division (CSD) maintain a database <http://nrcnt3.dnr.state.ne.us/wellssql/default.asp> of registered groundwater wells across the state.

(ii). ***Groundwater Levels*****:** The UNL Conservation and Survey Division Groundwater-Level Monitoring Program (GLMP) collects, evaluates and manages water-level data from

monitoring agencies in Nebraska and disseminates spatial-temporal water level data in multiple platforms that enable responsible management of Nebraska's ground water resources. GLMP monitors 5,200 wells annually, manages approximately 300 continuous recorder wells and provides real-time groundwater-level data from 13 sites.

(iii). *Groundwater Recharge Map*: The Nebraska CSD has published a groundwater recharge maps of Nebraska <http://snr.unl.edu:6006/surveyareas/rechargemaps.asp>.

(iv). *Groundwater Level Change Maps*: The Nebraska CSD publishes groundwater level change maps of Nebraska <http://csd.unl.edu/general/newpub-gwmaps.asp>

(v). *The USGS High Plains Regional Groundwater Study*: This study encompasses much of the Platte River Basin in all three states <http://webserver.cr.usgs.gov/nawqa/hpgw/HPGW_home.html>.

(vi). *Cooperative Hydrology Study (COHYST)*: <http://cohyst.dnr.state.ne.us/> COHYST has developed a regional groundwater model for a portion of the Platte River Basin.

G. Other Datasets

(i). *COHYST*: <http://cohyst.dnr.state.ne.us/cohyst_data.html> COHYST has assembled a number of data sets and reports including; bedrock, parent material, soil classification, stream coring, stream permeability, aquifer property, transmissivity, historic stream location and gains/losses, land use, irrigation, groundwater pumping, and recharge.

(ii). *US Bureau of Reclamation (BR)*: USBR has compiled water records on surface water diversion and delivery for irrigation projects and cropping patterns.

(iii). *Nebraska Department of Natural Resources (DNR)*: DNR maintains records of surface water rights and diversions.

(vi). *Nebraska Natural Resource Districts (NRDs)*: NRDs record and compile annual irrigation well pumpage records.

(vii). *Modeling*: There have been numerous groundwater and surface water modeling studies of the Platte sponsored by the state, NRD, USGS and many local agencies.

H. Other Infrastructure and Support

(i*). UNL Water Resources Research Initiative*: < http://wrri.unl.edu/>. The Initiative promotes greater collaboration among research faculty in UNL water science disciplines of great strength such as groundwater hydrology, water quality, climate change, irrigation, remote sensing and geographical information systems. It includes outside organizations such as the Nebraska Department of Natural Resources, the state's network of Natural Resources Districts and irrigation districts.

(ii). *Great Plains Cooperative Ecosystem Studies Unit(GP-CESU)*: <http://greatplains.cesu.unl.edu/>. The GP-CESU, established at UNL in October, 2000, is a network of faculty and staff from 13 academic institutions, and agency managers and resource professionals from five federal agencies. The unit encompasses a broad geographical portion of the Great Plains and offers an outstanding group of scientists in grasslands, ecosystems studies, and natural and cultural resources management for collaborative research, technical assistance and educational opportunities in the CESU.

(iii). *Center for Great Plains Studies*: <http://www.unl.edu/plains/index.html>. The Center encourages and sponsors interdisciplinary studies, research, teaching, service, and extension activities that are directed toward exploring the biological and physical environments, the

people, the institutions, the economy, and the cultures characteristic of the Great Plains and comparable regions.

(iv). *Center for Grassland Studies*: <http://www.grassland.unl.edu/>. The Center's mission is to implement focused, interdisciplinary research, educational and service programs and activities that emphasize the role of grasslands as a natural resource and conservation measure and that enhance the efficiency, profitability, sustainability, and aesthetic value of grasslands, wetlands and turfs.

(v). *Platte River Whooping Crain Maintenance Trust*: The Platte River Trust is a non-profit organization dedicated to conserving habitat for migratory birds on the Platte River in central Nebraska <http://www.whoopingcrane.org/index2.html>. The Trust's activities include acquiring and protecting habitat, maintaining and managing habitat, and conducting research about the habitat needs of migratory birds. They also oversee a number of monitoring well nests along the river in Nebraska.

(vi). *Ducks Unlimited*: DU has initiated a Platte River and Rainwater Basin Initiative designed to preserve water foul habitat along the river <http://prairie.ducks.org/>.

(vii). *Nebraska Earth Science Education Network (NESEN)*: NESEN networks with teachers to improve science education in schools and would be well suited to assist with the education component of the HO <http://nesen.unl.edu/index.asp>.

(viii). *Platte Watershed*: < http://ianrwww.unl.edu/ianr/pwp/pwp.html> Located at UNL, the Platte Watershed is a watershed-based Cooperative Extension program designed to address the information, education and research needs of stakeholders in the watershed and link the applicable resources of the University of Nebraska to those needs.

(iv). *Nebraska LB 962*: <http://www.dnr.state.ne.us/LB962/LB962Implementation.html> LB 962 is a law enacted in April, 2004 aimed at making the Department of Natural Resources and the states 23 Natural Resource Districts more proactive in anticipating and preventing conflicts between groundwater users and surface water users. The law also established a fund to be used to identify priority subbasins for development and implementation of Integrated Management Provisions (IMPs).

(x). *Cooperative Agreement for Endangered Species Habitat Along the Central Platte River*: <http://ianrpubs.unl.edu/wildlife/nf375.htm> The governors of Nebraska, Colorado and Wyoming and the Secretary of the Interior signed a historic agreement on July 1, 1997. This agreement addresses endangered species issues affecting the Platte River Basin upstream of its confluence with the Loup River. *The Cooperative Agreement for Platte River Research and Other Efforts Relating to Endangered Species Habitats Along the Central Platte River, Nebraska* provides funding and an administrative structure to allow the states and the federal government to work together in enhancing water and land resources for endangered species. The agreement has two main objectives: (1) To develop and implement a "recovery implementation program" to improve and conserve habitat for four threatened and endangered species: whooping crane, piping plover, least tern and pallid sturgeon, and (2) To enable existing and new water uses in the Platte River Watershed to proceed without actions beyond the Program for the four species under the Endangered Species Act.

(xi). *Platte River Endangered Species Partnership*: <http://www.platteriver.org/> The partnership was formed to implement the *Cooperative Agreement for Endangered Species Habitat Along the Central Platte River* (see III.H.x.)

(xii). *USGS Bibliography of Platte River Resources*: The USGS maintains a website listing

various water resources and water quality publications related to the Platte River <http://mcmcweb.er.usgs.gov/platte/bib.html>.

IV. Proposed Core Data

PRIVHO would collect the following core data within each sub-basin:

A. Remote Sensing Data/GIS

(i) ***Water quality*****:** Secchi disc depth, turbidity, chlorophyll concentration, total suspended matter.

(ii) ***Vegetation cover and status***: Fraction of green vegetation, vegetation density (green LAI), fractional absorbed photosynthetic radiation, NEE retrieved from MODIS and ETM+ sensors.

(iii) ***Surficial soil moisture and vegetation wetness*****:** Derived from AMSR-E passive microwave radiometry data products from NSIDC. These data are acquired twice daily at a spatial resolution of 25 km. Further processing by CALMIT will provide composited, smoothed image time series better suited for hydrological monitoring and modeling.

(iv) ***Land cover classification*****:** Derived from MODIS image time series and supplemented by NLCD and more current high resolution imagery.

B. Climate Data

Tipping bucket precipitation, Nexrad rainfall distribution, snow amonts, forested stemflow & through-fall, surface water evaporation, pan evaporation, transpiration, air and soil temperature, solar radiation, humidity, wind speed and direction, and CO_2, water, and energy fluxes using the eddy covariance technique. Precipitation isotope data would continue to be collected at the NADP weather stations.

C. Vadose Zone / Soil Moisture Data

Soil moisture data would be collected using various methods (theta probes, TDR, matric potential sensors) to a depth of at least 100 cm at various sites across the basin in addition to those operated by HPRCC. Vadose zone hydraulic conductivity and moisture movement measurements will be made as selected sites within each subbasin.

D. Surface Water Data

To augment the existing USGS and state agency stream gages, stream discharge and stage would be collected at several additional stations along each major stem of the river. Stream water temperature, ion concentrations and stable oxygen and hydrogen isotope samples would be collected monthly at selected existing sites and at several additional new sites. In addition, stream bottom sediment hydraulic conductivity will be determined as selected, representative sites along the channels.

E. Groundwater Data

A groundwater levels monitoring network will be installed (or retrofitted where existing wells are in place) and instrumented with sensors to record daily water levels and temperature. Selected wells will be fitted with sensors to measure conductivity. In addition, irrigation and municipal well withdrawals will be compiled by the various state agencies. Selected wells will be samples to monitor monthly or seasonal concentrations of major ions, and selected contaminants and to determine stable oxygen and hydrogen isotope composition

of the groundwater. Selected wells will also be sampled for age dating using tritium and/or carbon-14 as appropriate. Recharge measurements will be made as selected sites within each basin.

F. Ecological Data

Migratory waterfowl and terrestrial animals and aquatic organisms and their relationships to the physical and chemical habitat conditions where they live are being sampled by a number of federal, state, and university projects across the basin. Coordination of these activities and the development of a basin-wide data base will provide a way to evaluate how species are responding to changes in surface and subsurface water resources. Also, the USGS Gap Analysis Program collects species distribution and land stewardship data for Nebraska, Colorado, and Wyoming.

VI. Example Science Questions

A. What are the impacts of groundwater extraction for irrigation on stream flow and species habitat within the context of high interannual climatic variability?

B. What is the impact of evaporative losses from center pivot and canal irrigation on local and regional weather?

C. What are the impacts of hyporheic flow dynamics within braided channels on transport and natural attenuation of non-point source contamination in agricultural regions?

D. What are the impacts of long-term droughts on riparian and lacustrine wetlands in the region and their subsequent impact on water fowl migratory patterns?

E. How do water conservation practices affect flows in streams and groundwater levels?

F. How can surface water diversion and groundwater withdrawals be managed to augment habitat for fish and wildlife while providing resources for municipal, industrial and agricultural uses of water?

G. What are the amounts and timing of instream flows that are needed to protect habitat for viable aquatic ecosystems that support the endangered species within the Platte basin?

H. What are the influences of climate modes (e.g., ENSO, NAO, PDO, etc.) on Platte River hydrological dynamics? How can this information be used in water resource planning to mitigate risks to ecosystem goods and services?

I. How do upland rangeland and forest management practices influence the amount and quality of water yield, especially within the context of mitigating recurring, albeit unpredictable, floods and droughts that historically have been especially pronounced in the Platte River drainage?

J. What are the tradeoffs of maintaining upstream dams and historical flood irrigation practices to moderating seasonal flow patterns and the ecology of the Platte River drainage?

K. What are the tradeoffs of adopting irrigation practices that promote increased water use efficiency at the cost of modulating seasonal flow in the Platte River via return flow from flood irrigation systems?