Submission Date: April 30, 2014

Descriptive Title: North American Analysis and Synthesis on the Connectivity of "Geographically Isolated Wetlands" to Downstream Waters

Short Title: GIW Connectivity and Effects

PI Contact Information:

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Project Summary:

Two recent U.S. Supreme Court cases established that the extent to which geographically isolated wetlands (GIWs) are considered jurisdictional waters of the United States under the Clean Water Act hinges on the degree to which these systems have a quantifiable effect on downgradient waters. However, GIWs occur along gradients of hydrologic and ecological connectivity and isolation, even within wetland types and functional classes. Within a given watershed, the relative positions of wetlands and open-waters along these gradients influence the type and magnitude of their chemical, physical, and biological effects on downgradient waters. In addition, the ways in which GIWs connect to the broader hydrological landscape, and the effects of such connectivity on downgradient waters, depends largely upon climate, geology, and relief, the heterogeneity of which expands with increasing scale. Developing an understanding of connectivity between and among uplands, wetlands, and downgradient waters, as well as ascertaining the influence of climate, geology, relief, spatial distribution, and other phenomena on connectivity has thus emerged as an important focal research area for science with significant implications for the integrity of aquatic systems.

This macro-scale proposal will organize a comparison and synthesis of GIW connectivity across regional landscapes in North America. The two primary objectives of this Powell Center Working Group proposal are to: **(1)** *Quantify and model hydrological connectivity between GIWs, non-GIW systems, and downgradient surface waters across specific ecoregional, physiological, and/or physiographic provinces*, and **(2)** *Identify emergent properties of GIW connectivity across different landscape settings and scales to determine factors controlling connectivity, including climate, geology, and relief as well as the spatial distributions of GIWs*. To reach these objectives, our working group will develop an organizing conceptual framework for the research that accounts for multiple dimensions of possible connectivity (e.g., longitudinal, lateral, vertical, and temporal) as well as landscape, edaphic, climatic, and other factors controlling connectivity across focal regions. We will use existing spatial datasets to develop and quantify novel spatial indicators of GIW connectivity on the landscape across different regions. We will further develop and apply geostatistical and hydrological modeling approaches to discern the controls on GIW connectivity and effects of this connectivity on downgradient hydrology. The results from the Powell Center working group will provide unique insights on the connectivity of GIWs and identify areas where additional scientific insights are required to better understand these important components of the terrestrial and aquatic hydroscape.

Proposal State and End Dates: September 01, 2014 – September 30, 2016

Number and Duration of Working Group Meetings:
Two 4 day Powell Center Working Group meetings proposed (tentatively in January 2015, August 2015)

Total Requested Budget: $ 43,084

Proposed Data Release Date: December 1, 2016

Is this a resubmission? No

Conflicts of Interests with Reviews: David Mushet works closely with Martin Goldhaber on current research being conducted at the USGS's Cottonwood Lake Study Area in east-central North Dakota. Mushet and Goldhaber are also partners on an ongoing research effort evaluating effects of climate variation on 178 prairie lakes and wetlands of the region. Additionally, Mushet and Goldhaber have co-authored presentations and papers together as well as submitted several research proposals.

Keywords: Ecosystems, Water

NORTH AMERICAN ANALYSIS AND SYNTHESIS ON THE CONNECTIVITY OF "GEOGRAPHICALLY ISOLATED WETLANDS" TO DOWNSTREAM WATERS

Problem Statement:
Geographically isolated wetlands (GIWs) – defined as wetlands surrounded by uplands (e.g., Prairie Potholes, California vernal pools, cypress domes, woodland seasonal ponds, playas, etc.) and not adjacent to traditionally navigable waters – are distributed throughout North America (Figure 1). These wetlands and wetland systems include permanent open-water wetlands, intermittent and ephemeral wetlands with submergent or emergent vegetation, shrub wetlands, and mature forested wetlands. Up to 20% of the extant freshwater wetlands in the contiguous U.S. may be GIWs (~10 million hectares), though no national map yet exists (Likens et al. 2000). In the 2006 *Rapanos* decision, the U.S. Supreme Court determined that wetlands not adjacent to traditionally navigable waters (i.e., GIWs) could be considered protected or jurisdictional waters of the U.S. under the Clean Water Act (CWA) if those wetlands exhibited a *significant nexus* to a traditionally navigable water (Downing et al. 2007, Leibowitz et al. 2008). Specifically, the "Kennedy Test," named after Justice Anthony Kennedy's opinion in *Rapanos*, states that non-adjacent wetlands might be waters of the U.S. subject to regulation under the CWA if they "either alone or in combination with similarly situated lands in the region, significantly affect the chemical, physical, and biological integrity of other covered waters more readily understood as 'navigable'" (547 U.S. 715). CWA jurisdictional determination for millions of hectares across North America depends in part on evaluating how GIWs are both connected to and affect the chemical, physical, or biological properties of downgradient waters.

Hydrological flow paths form the basis of connectivity for the movement of water, energy, and material on the landscape, connecting uplands to wetlands, connecting between wetland systems and forming

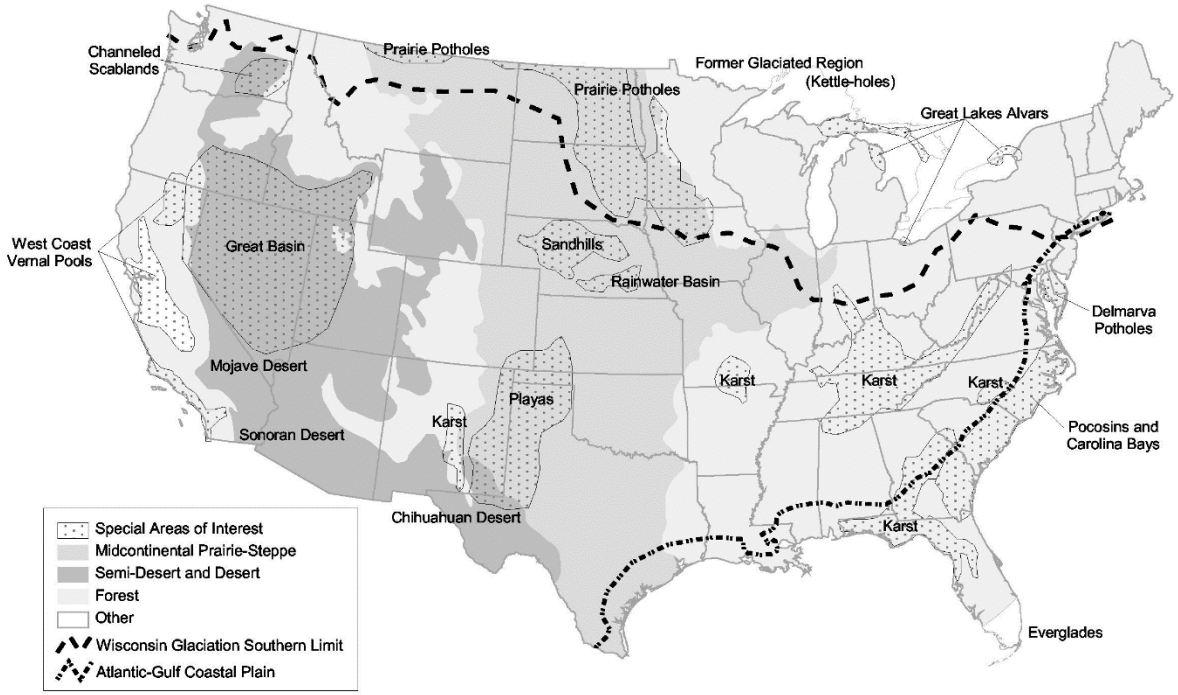

Figure 1. Regional distribution and areas of dense occurrence of geographically isolated wetlands across the US (Tiner 2003).

complexes, and connecting wetland systems to downgradient waters. Hydrological flow paths connect landscapes in four dimensions – longitudinally, laterally, vertically, and through time. This four-dimensional hydrological connectivity, operating at local to landscape scales, is a basic tenet of freshwater ecology (e.g., Ward 1989). GIWs as part of the landscape are therefore integrally connected to uplands, other wetlands, and downgradient waters. While an individual GIW can affect local-scale hydrology, the effects of a typical GIW on landscape-scale hydrology is probably negligible. However, the cumulative effect of all GIWs in a landscape can have important roles in regulating the frequency, magnitude, timing, duration, and rate of change of flows and entrained materials to downgradient waters (Ogawa and Male 1986; Hey and Philippi 1995; Creed et al. 2003). Therefore, GIWs can be thought of as being nodes in a flow path network. In such a network, each GIW is an actor, interacting with the broader hydrological landscape by receiving, storing, and sending water and water-borne materials and organisms. The ways in which GIWs connect to the broader hydrological landscape, and the effects of such connectivity on downgradient waters, depend largely upon climate, geology, and relief, an idea that is explicit in the concept of Hydrologic Landscape Regions, or HLRs (Wolock et al. 2004; Figure 2). The spatial distribution and landscape patterning of GIWs within a given region is further expected to affect multidimensional flow path connections, with novel hierarchical properties that may emerge at scale (e.g., Mandelbrot 1967, Rietkerk and van de Koppel 2008, van der Valk and Warner 2009). Therefore, connectivity and the effects thereof should be generalizable by region because the expressions of chemical, physical, and biological phenomena depend on environmental setting (e.g., climatic, geologic, topographic).

Developing an understanding of connectivity between and among uplands, wetlands, and downgradient waters, as well as ascertaining the influence of climate, geology, relief, spatial distribution, and other phenomena on connectivity has emerged as an important focal research area for science. The U.S. EPA (2013) recently conducted an extensive literature review on the connectivity of wetland systems and

downgradient waters and concluded that there was ample evidence that wetlands that exist within floodplains or riparian zones – and which had "bidirectional" hydrological exchanges between wetlands and rivers – were chemically, physically, and biologically connected with rivers through a number of flow paths. For wetlands located outside floodplains or riparian zones that lack these bidirectional exchanges (i.e., non-adjacent wetlands), the report found that these wetlands occur across North America on a continuum of connectivity, with a great deal of spatial and temporal variability. Furthermore, given this range of wetland types, the report concluded that it was difficult to generalize about the effects of non-adjacent GIWs on downgradient waters.

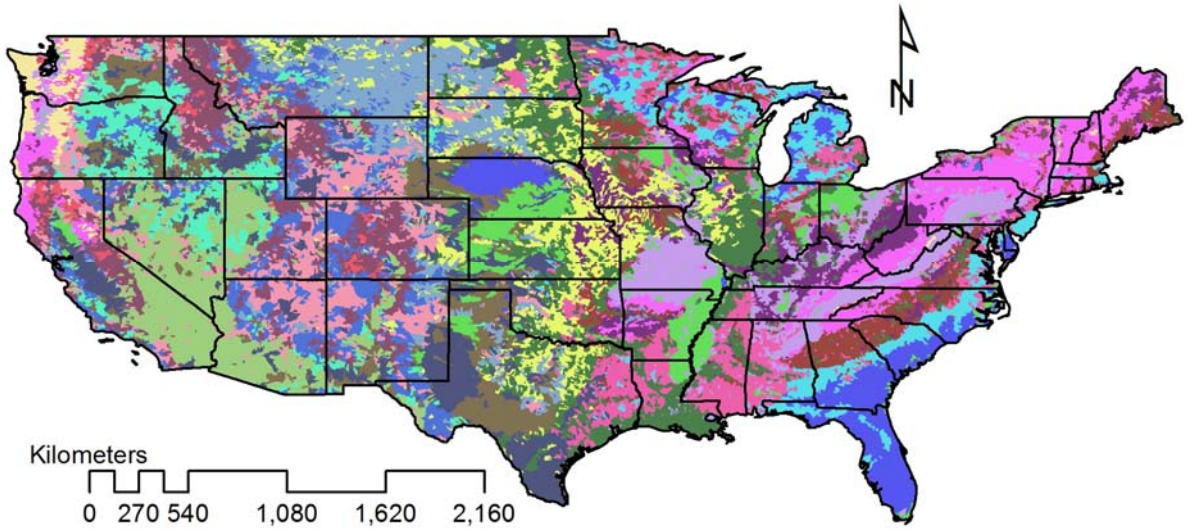

Figure 2. Spatial distribution of the 20 Hydrologic Landscape Regions of the United States (Wolock et al. 2004).

There is, therefore, a critical scientific need to provide sound science to assess and quantify hydrological connectivity between and among non-adjacent GIW systems and downgradient waters across North America. This includes analyzing and synthesizing the emergent properties of connectivity and effects at multiple spatial and temporal scales. This proposed macro-scale study will organize a comparison and synthesis of GIW hydrological connectivity across regional landscapes in North America. We will use existing GIS datasets to develop of a suite of spatial indicators and hydrological modeling components to determine relative connectivity and isolation gradients, in addition to the collective and individual effects of GIWs, as units, complexes, and systems within larger systems, at local to landscape scales.

The **two primary objectives** of the Powell Center Working Group are to:

(1) **Quantify and model hydrological connectivity between GIWs, non-GIW systems, and downgradient surface waters** across specific ecoregional, physiological, and/or physiographic provinces, and

(2) Identify emergent properties of GIW connectivity across different landscape settings and scales to **determine factors controlling connectivity**, including climate, geology, and relief as well as the spatial distributions of GIWs.

To reach these objectives, our working group will develop an organizing conceptual framework for the research that accounts for multiple dimensions of possible connectivity (e.g., longitudinal, lateral, vertical, and temporal) as well as landscape, edaphic, climatic, and other factors controlling connectivity across focal regions. We will use existing spatial datasets currently available to the selected working

group participants (including publically available spatial data) to develop and quantify novel spatial indicators of GIW connectivity on the landscape across different regions. We will further develop and apply geostatistical, graph theoretical, and hydrological modeling approaches to discern the controls on GIW connectivity and effects of this connectivity on downgradient hydrology.

Our efforts will result in the establishment of strong scientific underpinnings to effectively define and describe the connectivity and influence of a widely distributed landscape component affecting a broad range of wetland policy and management decisions across North America. The working group will encourage open communication and international collaboration among transdisciplinary scientists to conduct geospatial modeling and advanced hydrological and GIS/remote sensing analyses, establishing the state of the science on GIW hydrological connectivity and watershed-scale effects of connectivity across scales and regions. From these novel analyses we anticipate developing and communicating a broadly applicable synthesis through several manuscripts in high-ranking journals. The results from the Powell Center working group will provide sound science and unique insights on the connectivity of GIWs and identify areas where additional scientific efforts are required to better understand these critical components of the North American terrestrial and aquatic hydroscape.

Proposed Activities:

General approach

We have assembled an international team of research hydrologists, watershed and groundwater modelers, biogeochemists, geostatisticians and landscape and wetland ecologists from the USGS, U.S. EPA, and academia to analyze and synthesize large-scale datasets. Specifically, our efforts will focus on analyzing and synthesizing mature and existing spatial and temporally rich datasets from across North America focusing on gradients of wetland type, spatial distribution, climate, geology, relief, and land use-land cover. Potential system alterations at multiple spatial and temporal scales (e.g., drainage, sedimentation; climate change) will also be analyzed to identify the effects of landscape alterations on downstream connectivity. Data will include spatially explicit maps of wetland extent from both small scale studies (e.g., plot-scale wetland assessments; Winter 2003) to large-scale GIS and remote sensing analyses (e.g., state, provincial, and regional assessments; Bowen et al. 2010, Lane et al. 2012), USGS watershed hydrological and network features, and USGS stream flow data. Additional data, such as landscape parameters hypothesized to affect quantified connectivity between wetland and downstream systems will be developed specifically for this proposed work.

Analytical Approach

We plan to first conduct preliminary analyses (specified below) after the project is approved and funded. These analyses will occur over an approximately three month period ahead of the first Powell Center workshop and include development of a conceptual watershed-scale GIW connectivity framework, discussion and drafting of initial research questions and hypotheses, and identification and further refinement of spatial data sets for analyses. At the first workshop, the results of these preliminary steps will be discussed and refined, and – importantly – the geospatial modeling framework and analytical plan will be identified and initiated. We will then perform a secondary set of spatial and modeling analyses of connectivity over about a six month period after the first workshop. This secondary set of analyses will be followed by a second Powell Center workshop. At this second workshop, preliminary results of the spatial and modeling analyses that provide the greatest insight to study questions (as determined by the group) will be discussed and further refined, with the express aim of writing at least two to three peer-reviewed manuscripts. This writing process will occur during a four to six month period following the second workshop. The second Powell Center workshop will also focus on identifying

and communicating knowledge gaps to the broader scientific community and include the initial steps in writing papers and proposals to close gaps identified during this research effort. A summary follows.

I. Preliminary Analyses (before first workshop)
   a. Develop draft conceptual GIW watershed connectivity framework generalizable across all study regions
   b. Develop draft research questions and hypotheses for discussion around this conceptual framework at the workshop
   c. Compile North American spatial datasets that are readily available, develop criteria for selecting comparable data types (including the appropriate spatial scale and resolution), and refine spatial datasets for analysis across study regions
   d. Identify and develop a short-list of potential spatial metrics, geospatial/statistical analyses, and hydrological modeling approaches to test hypotheses about GIW connectivity and the integrated downgradient effects of GIWs at local to watershed scales

II. First Powell Center Workshop Activities
   a. Discuss and refine conceptual framework of GIW watershed connectivity across systems
   b. Further draft and finalize research questions and hypotheses
   c. Finalize spatial datasets that will be used in the analyses and modeling
   d. Prioritize, assign, and initiate geospatial and hydrological modeling research components to answer the refined set of research questions

III. Second Round of Analyses (to be conducted after first Powell Center Workshop)
   a. Conduct geospatial and hydrological modeling across North American study areas
   b. Initiate analyses and discussion of preliminary results (via project conference calls, webinars, and email communication)
   c. Adapt and revise geospatial and hydrological modeling as necessary based on the preliminary findings

IV. Second Powell Center Workshop Activities
   a. Analyze, discuss, and synthesize geospatial and hydrological modeling results
   b. Identify two to three (or more) themes around which review and synthesis manuscripts will be drafted, based results of analyses
   c. Discuss and prioritize knowledge gaps identified during the research effort
   d. Develop manuscript section “ownership” and a timeline for communication of research results and synthesis
   e. Develop ownership and a timeline for manuscript communication of identified knowledge gaps and potential opportunities for greater scientific community engagement in addressing GIW watershed connectivity

V. Final Round of Analyses and Manuscript Writing
   a. Conclude analyses and drafting of manuscripts
   b. Submit manuscripts to peer-reviewed journals
   c. Expand group effort and membership to include writing research proposals to close gaps identified during Powell Center workshops

VI. Encourage further development of collaboration among other, non-Powell Center Workshop scientists to conduct additional geospatial modeling, advanced hydrological and/or remote sensing analyses and monitoring to further explore and validate emerging scale-dependent assessments of spatial indicators of GIW connectivity.

Data to be Used for Proposed Activities:
Existing spatially explicit data from across North America will be used to discern the connectivity between and among GIWs, non-GIWs, and downgradient systems (Table 1). These will include but not be limited to listed layers of wetland extent, hydrographic data, remotely sensed data, and ancillary data layers of soil parameters, climate variables, topographic features, regionalization schema (e.g., HLRs, ecoregion and physiographic regionalization, etc.). Compiling of spatial data layers of potential GIWs has been initiated (Table 2). Proposed data layers will be discussed and finalized in advance of the initial Powell Center Workshop as a preliminary deliverable.

Table 1. Spatial data sets from across North America that will be considered for assessing GIW connectivity as part of this project

Data Layer Name	Spatial Extent for Analyses	Additional Information	Public Availability
National Wetlands Inventory (NWI)	Continental United States[1]		Yes
USGS National Hydrography Dataset (NHD)	Continental United States[1]		Yes
Soil Survey Geographic Database (SSURGO)	Continental United States[1]		Yes
State Soil Geographic Data Base (STATSGO)	Continental United States[1]		Yes
USGS National Elevation Dataset	Continental United States[1]		Yes
USGS Stream Gage Data	Continental United States[1]		Yes
Ancillary Elevation and Topographic Datasets	North America[1]	Typically LIDAR data	Frequently
USGS National Land Cover Database	Continental United States[1]	1992, 2001, and subsequent NLCD (2006, 2011) datasets	Yes
Omernik Level III Ecoregions	Continental United States[1]	Omernik 1987	Yes
Level III Ecoregions of North America	North America[1]	US – Canadian Committee for Environmental Cooperation	Yes
USDA Major Land Resource Area (MLRA)	Continental United States[1]		Yes
Hydrologic Landscape Regions (HLR)	Continental United States[1]	Wolock et al. 2004	Yes
USGS Landsat Data	North America[1]		
Ancillary Remotely Sensed Data Layers	North America[1]	Numerous remote sensing platforms exist	Varies
Canadian Wetland Inventory (CWI)	Partial Canada, primarily Ontario and Western Canada	Numerous data sources and resolutions	Yes
National Hydro Network	Canada		Yes

Soil Landscapes of Canada	Canada		Yes
Canadian Digital Elevation Dataset (CDED)	Canada		Yes
Water Survey of Canada Hydex Stations	Canada		Yes
Agriculture and Agri-Food Canada Landcover (2000)	Canada		Yes
National Ecological Framework for Canada Eco-regions	Canada		Yes
Study-site Specific Data Layer (See Table 2)	North America[1]	Scale and extent of data varies by Workshop Participant and/or data provider	Data layers will be made available to the public

[1] As appropriate for the selected data sets for the study regions

Table 2. Preliminary list of spatial data layers of geographically isolated wetlands.

Study Area	Approximate Area (km^2)	Researcher
Canadian Prairie Pothole Region Subwatershed (Unnamed)	260	Ali, Genevieve
Des Moines Lobe of the Prairie Pothole Region, Iowa	99,200	Basu, Nandita
High Plains Region, Kansas	103,920	Bowen, Mark
Big Cypress National Preserve, Florida	2900	Cohen, Matthew
Turkey Lakes Watershed, Ontario	11	Creed, Irena
DUC Project Sites, Ontario	2	Creed, Irena
Beaverhill Subwatershed, Alberta	1970	Creed, Irena
Utikuma Subwatershed, Alberta	2900	Creed, Irena
Prairie Pothole Region Parcels, Saskatchewan	1	Creed, Irena
Neuse River Basin in North Carolina	6570	Golden, Heather
Archbold Biological Station, Florida	35	Jenkins, David
MacArthur Agro-Ecology Research Center, Florida	42	Jenkins, David
Metropolitan Orlando Area, Florida	287	Jenkins, David
Dougherty Plain of Georgia[1]	6690	Kirkman, Kay

Alachua County, Florida	2600	Lane, Charles
Cuyahoga County, Ohio	1189	Lane, Charles
Southeastern US	886,362	Lane, Charles
Prairie Pothole Region (MT, ND, SD, MN, IA, NE)	325,000	Lane, Charles
Choptank River, Maryland[1]	1756	Lang, Megan
Calapooia Watershed, Oregon	963	Leibowitz, Scott
Prairie Pothole Region (ND, SD, MN, IA)	300,000	Mushet, David
Prairie Pothole Region (Stutsman County)	259	Mushet, David
Prairie Pothole Region (Cottonwood Lake Study Area	1	Mushet, David
St. Lucie County, Florida	1792	Rains, Mark
Tampa Bay Watershed, Florida	5908	Rains, Mark

[1] Researcher has expressed interest in participating in the analyses but will not be attending the Working Group meetings

Tentative Participants (Pending Confirmation):

Name, Expertise, and Role, add if confirmed	Affiliation
David Mushet, Wetland and Amphibian Ecology, Confirmed	U.S. Geological Survey, Northern Prairie Wildlife Research Center
Charles Lane, Wetland and Systems Ecology, Confirmed	U.S. Environmental Protection Agency, Office of Research and Development
Mark Rains, Ecohydrology and Hydrogeology, Confirmed	University of South Florida, Department of Geology
Scott Leibowitz, Wetland and Landscape Ecology, Confirmed	U.S. Environmental Protection Agency, Office of Research and Development
Heather Golden[†], Watershed Hydrology and Fate and Transport Modeling, Confirmed	U.S. Environmental Protection Agency, Office of Research and Development
Laurie Alexander, Aquatic Entomology and Population Ecology, Confirmed	U.S. Environmental Protection Agency, Office of Research and Development
Genevieve Ali, Hydrology, Confirmed	University of Manitoba, Faculty of Environment, Earth, and Resources
Nandita Basu, Hydrology and Biogeochemistry, Confirmed	University of Waterloo, Civil and Environmental Engineering, Earth and Environmental Sciences
Mark Bowen, Geomorphology and Wetland Ecology, Confirmed	University of Wisconsin-Oshkosh, Department of Geography and Urban Planning
Greg Bruland, Spatial Analyses and Wetland Ecology, Confirmed	Principia College, Biology and Natural Resource Department

Jay Christensen, Wetland Ecology and Hydrology, Confirmed	U.S. Environmental Protection Agency, Office of Research and Development
Matthew Cohen, Watershed Hydrology and Landscape Ecology, Confirmed	University of Florida, School of Forest Resources and Conservation
Irena Creed, Biogeochemistry, Hydrology, and Modelling, Confirmed	Western University, Department of Geography and Department of Earth Sciences
Grey Evenson, Spatial Analyses and Computational Ecology, Confirmed	Oak Ridge Institute for Science and Education Research Fellow at the U.S. Environmental Protection Agency, Office of Research and Development
Stephen Faulkner, Wetland Ecology and Biogeochemistry, Confirmed	U.S. Geological Survey, Leetown Science Center
David Jenkins, Wetlands Ecology and Biogeography, Confirmed	University of Central Florida, College of Science, Department of Biology
John Lindsay, Spatial Analyses and Hydrology, Pending, (or other Geospatial Statistician)	University of Guelph, Department of Geography
Daniel McLaughlin, Hydrology, Confirmed	Virginia Polytechnic Institute and State University, Department of Forest Resources and Environmental Conservation
Donald Rosenberry, Hydrologist, Confirmed	U.S. Geological Survey, National Research Program, Hydrogeology of Lakes, Wetlands, and Streams
Jennifer Rover, Remote Sensing and Landscape Ecology, Confirmed	U.S. Geological Survey, Earth Resources Observation and Science, Land Cover Applications and Global Change

† Will serve as Technical Liaison to the Powell Center and will be responsible for ensuring compliance with the Powell Center's Data and Information Policy.

Proposal Statement on Meeting Gender, Ethnicity, and Age Diversity Goals:
The proposal includes highly-qualified participants at multiple stages of their careers, including a postdoctoral researcher (Evenson) and six early-career/tenure-track scientists (Ali, Basu, Bowen, Christensen, Golden, McLaughlin). Our composition furthermore includes multiple ethnicities and an approximate 1:2 female:male ratio.

Timetable of Activities:
As detailed in the Analytical Activities (above), we will follow the following timetable, with additional and more specific milestones and deliverables to be inserted and attended to along the way.

I. Preliminary Analyses (before first workshop): September 01, 2014 – January 2015

II. First Powell Center Workshop: January 2015

III. Second Round of Analyses (after first Powell Center Workshop): February – August 2015

IV. Second Powell Center Workshop: August 2015

V. Final Round of Analyses and Manuscript Writing: September 2015 – September 2016

VI. Data Release: no later than December 2016

Anticipated Results and Benefits:

The project will facilitate the collaboration of transdisciplinary researchers who would otherwise not have the opportunity to work together to synthesize multi-scale datasets and quantify the hydrological connectivity of GIWs, important aquatic resources often not explicitly considered in scientific and management endeavors. The project, as envisioned, will advance the scientific understanding of connectivity between and among wetland systems and downgradient waters, quantifying the influence of GIWs and determining landscape-scale controls on their downgradient effects. This work is also expected to benefit policy and management communities that currently rely on case-by-case assessments of the influence and effect of GIWs on downgradient waters. We anticipate developing and communicating a broadly applicable synthesis through two to three manuscripts in high-ranking journals.

Literature Cited:

Bowen, M., W. Johnson, S. Egbert, and S. Klopfenstein. 2010. A GIS-based Approach to Identify and Map Playa Wetlands on the High Plains, Kansas, USA. Wetlands 30(4): 675-684.

Creed, I. F., S. E. Sanford, F. D. Beall, L. A. Molot, and P. J. Dillon. 2003. Cryptic wetlands: integrating hidden wetlands in regression models of the export of dissolved organic carbon from forested landscapes. Hydrological Processes 17(18): 3629-3648.

Downing, D. M., T. Nadeau, and R. Kwok. 2007. Technical and scientific challenges in implementing Rapanos' "Water of the United States". Natural Resources and Environment 42: 42-45+

Hey D. L and N. S. Philippi. 1995. Flood reduction through wetland restoration: the Upper Mississippi River Basin as a case history. Restoration Ecology 3:4-17

Lane, C. R., E. D'Amico, and B. Autrey. 2012. Isolated Wetlands of the Southeastern United States: Abundance and Expected Condition. Wetlands 32(4): 753-767.

Leibowitz, S. G., P. J. Wigington, M. C. Rains, and D. M. Downing. 2008. Non-navigable streams and adjacent wetlands: addressing science needs following the Supreme Court's Rapanos decision. Frontiers in Ecology and the Environment 6(7): 366-373.

Likens, G. E., J. Zedler, B. Mitsch, R. Sharitz, J. Larson, L. Fredrickson, S. Pimm, R. Semlitsch, C. Bohlen, C. Woltemade, M. Hirschfeld, J. Callaway, T. Huffman, T. Bancroft, K. Richter, J. Teal, and the Association of State Wetland Managers. 2000. Brief for Dr. Gene Likens et al., as Amici Curiae of Writ of Certiorari to the United States Court of Appeals for the Seventh Circuit., Solid Waste Agency of Northern Cook County v. U.S. Army Corps of Engineers, No. 99-1178: Submitted by T. D. Searchinger and M. J. Bean, attorneys for Amici Curiae.

Mandelbrot, B. 1967. How Long Is the Coast of Britain? Statistical Self-Similarity and Fractional Dimension. Science 156(3775): 636-638.

Ogawa, H. and J. Male. 1986. Simulating the Flood Mitigation Role of Wetlands. Journal of Water Resources Planning and Management 112(1): 114-128.

Omernik, J. M. 1987. Ecoregions of the Conterminous United States. Annals of the Association of American Geographers 77(1): 118-125.

Rietkerk, M. and J. van de Koppel. 2008. Regular pattern formation in real ecosystems. Trends in Ecology & Evolution 23(3): 169-175.

Tiner, R. 2003. Geographically isolated wetlands of the United States. Wetlands 23(3):494-516

U.S. EPA [Alexander, L.C., B.C. Autrey, J. DeMeester, K. M. Fritz, D. C. Goodrich, W. G. Kepner, C. R. Lane, S. D. LeDuc, S. G. Leibowitz, M. McManus, A. I. Pollard, H. Ranaan-Kipperwas, C. E. Ridley, K. Schofield, P. J. Wigington]. 2013. Connectivity of Streams and Wetlands to Downstream Waters: A Review and Synthesis of the Scientific Evidence. External Review Draft. EPA/600/R-11/098B, U.S. Environmental Protection Agency, Washington, DC

van der Valk, A. and B. Warner. 2009. The development of patterned mosaic landscapes: An overview. Plant Ecology 200(1): 1-7.

Ward, J. V. 1989. The four-dimensional nature of lotic ecosystems. Journal of the North American Benthological Society 8:2-8

Winter, T. C. 2003. Geohydrologic setting of the Cottonwood Lake area. In: Winter, T. C., (Ed.), Hydrological, chemical, and biological characteristics of a prairie pothole wetland complex under highly variable climate conditions -- the Cottonwood Lake area, east-central North Dakota, US Geological Survey Professional Paper 1675. pp. 1-24.

Wolock, D. M., T. C. Winter, and G. McMahon. 2004. Delineation and evaluation of hydrologic-landscape regions in the United States using geographic information system tools and multivariate statistical analyses. Environmental Management 34:S71-S88.

Curriculum Vitae: Attached below.

Data Management Plan: Attached below.

Budget: Attached below.

David Michael Mushet, Ph.D.

a. Professional Preparation

B.S., 1991, Wildlife Biology, Humboldt State University, Arcata, CA (1991)

Ph.D., 2010, Environmental and Conservation Sciences, North Dakota State University, Fargo, ND, Dissertation Title: From Earth observing space satellites to nuclear microsatellites: amphibian conservation in the northern Great Plains.

b. Appointments

Research Wildlife Biologist, 2011 to date, U.S. Geological Survey, Northern Prairie Wildlife Research Center, Jamestown, North Dakota

Wildlife Biologist, 1994 to 2011, U.S. Geological Survey, Northern Prairie Wildlife Research Center, Jamestown, North Dakota

Associate Editor, 2011 to date, *Wetlands*

Associate Editor, 2004 to 2011, *The Prairie Naturalist*

President Elect, 2013 to date, North Central Chapter – Society of Wetland Scientists

Treasurer, 2008 to 2013, North Central Chapter – Society of Wetland Scientists

c. Current Memberships in Professional Societies

Great Plains Natural Science Society
Society of Wetland Scientists
North Central Chapter, Society of Wetland Scientists
Society for Conservation Biology
North Dakota Chapter, The Wildlife Society

d. Publications

(i) Five Publications Most Closely Related to the Proposal

Mushet, D. M., J. L. Neau, N. H. Euliss, Jr. 2014. Modeling effects of conservation grassland losses on amphibian habitat. *Biological Conservation* 174:93-100

Euliss, N. H., Jr., D. M. Mushet, W. E. Newton, C. R. V. Otto, R. D. Nelson, J. W. LaBaugh, E. J. Scherff, and D. O. Rosenberry. 2014. Placing prairie pothole wetlands along spatial and temporal continua to improve integration of wetland function in ecological investigations. *Journal of Hydrology* 513:490-503

Mushet, D. M., N. H. Euliss, Jr., and C. A. Stockwell, 2013. Complex spatial dynamics maintain northern leopard frog genetic diversity in a temporally varying landscape. *Herpetological Conservation and Biology* 8:163-175

Rover, J., C. K. Wright, N. H. Euliss, Jr., D. M. Mushet, and B. K. Wylie. 2011. Classifying the hydrologic function of prairie potholes with remote sensing and GIS. *Wetlands* 31:319-327

Huang, S, C. Young, M. Feng, K. Heidemann, M. Cushing, D. M. Mushet, and S. Liu. 2011. Demonstration of a conceptual model for using LiDAR to improve the estimation of floodwater mitigation potential of Prairie Pothole Region wetlands. Journal of Hydrology 405:417-426

(ii) Five Additional Publications

Rover, J. and D. M. Mushet. In Press. Mapping wetlands and surface water in the Prairie Pothole Region. *In:* R. Tiner, and V. Klemas (eds) Advances in Wetlands Mapping. CRC Press, Boca Raton, FL

Mushet, D. M., N. H. Euliss, Jr., and C. A. Stockwell. 2012. A conceptual model to facilitate amphibian conservation in the northern Great Plains. *Great Plains Research* 22:45-58

Mushet, D. M., N. H. Euliss, Jr., and C. A. Stockwell. 2012. Mapping anuran habitat suitability to estimate effects of grassland and wetland conservation programs. *Copeia* 2012:322-331

Feng, M. S. Liu, N. H. Euliss, Jr., C. Young, and D. M. Mushet. 2011. Prototyping an online wetland ecosystem services model using open model sharing standards. *Environmental Modeling and Software* 26:458-468

Euliss, N. H., Jr., L. M. Smith, S. Liu, M. Feng, D. M. Mushet, R. F. Auch, and T. R. Loveland. 2010. The need for simultaneous evaluation of ecosystem services and land-use change. *Environmental Science and Technology* 44:7761-7763

e. Five Synergistic Activities

(i) PI on a USGS Climate and Land-use Change funded project developing systems models for studying potential effects of climate and land-use change on prairie pothole wetland ecosystems. This interdisciplinary effort is developing systems models that include hydrology and geochemical components that function as primary drivers of biotic communities, including plants, invertebrates, amphibians, and waterbirds.

(ii) PI on a USGS Climate and Land-use Change funded project studying the effects of climate dynamics on wetland hydrology and geochemistry and the combined effects of climate, hydrology, and geochemistry on wetland biotic communities. This interdisciplinary research effort includes the long-term monitoring of a wetland complex in North Dakota known as the Cottonwood Lake Study Area.

(iii) Regional Team Lead (Prairie Pothole Region) of a USGS/U.S. Department of Agriculture partnership developing methodologies to quantify services provided by wetland ecosystems. The goal of this research partnership is to quantify changes in multiple wetland ecosystem services resulting from USDA conservation programs, e.g., Conservation Reserve Program, Wetlands Reserve Program.

(iv) Co-PI on a USGS Energy and Minerals funded project studying the effects of land-use change resulting from the production of biofuel feed-stocks on the provisioning of ecosystem services provided by wetlands.

(v) P1 on a USGS Climate and Land-use Change funded project investigating the potential to mitigate climate change effects on prairie pothole wetlands ecosystems through the innovative use of upland management techniques including grazing, burning, and invasive species control.

f. Collaborators & Other Affiliations

(i) Collaborators in Past Five years

William Arnold, University of Minnesota; Yu-Ping Chin, Ohio State University; William Effland, USDA Natural Resources Conservation Service; Ned Euliss, Jr., U.S. Geological Survey; Min Feng, University of Maryland; Martin Goldhaber, U.S. Geological Survey; Shengli Huang, U.S. Geological Survey; James LaBaugh, Zeno Levy, Syracuse University; U.S. Geological Survey; Shuguang Liu, U.S. Geological Survey; Scott McMurry, Oklahoma State University; Christopher Mills, U.S. Geological Survey; Jordan Neau, U.S. Geological Survey; Wesley Newton, U.S. Geological Survey; Richard Nelson, U.S. Bureau of Reclamation; Clint Otto, U.S. Geological Survey; Donald Rosenberry, U.S. Geological Survey; Jennifer Rover, U.S. Geological Survey; Eric Scherff, U.S. Geological Survey; Neil Shook, U.S. Fish and Wildlife Service; Donald Siegel, Syracuse University; Loren Smith, Oklahoma State University; Bruce Wylie, U.S. Geological Survey; Claudia Young, U.S. Geological Survey

(ii) Graduate and Postdoctoral Advisors

Craig Stockwell, NDSU (PhD Advisor)

(iii) Graduate Students in Past Five Years

Justin Fisher (Continuing), Heather Inczauskis (Continuing), Kyle McLean (Continuing), David Renton (Continuing)

CHARLES RAYMOND LANE, PH.D.
U.S. Environmental Protection Agency, Office of Research and Development,
National Exposure Research Laboratory, Ecological Exposure Research Division
lane.charles@epa.gov | 513-569-7854

EDUCATION

2000 – 2003. Ph.D. Systems Ecology, H.T. Odum Center for Wetlands, Department of Environmental Engineering Sciences, University of Florida, Gainesville, Florida. Doctoral dissertation title: "Development of Biological Indicators of Wetland Condition for Isolated Depressional Herbaceous Wetlands in Florida"

1997 – 2000. MS. Systems Ecology, Department of Environmental Engineering Sciences, University of Florida, Gainesville, Florida. Master's thesis title: "Proposed Ecological Regions for Freshwater Wetlands of Florida"

1991 – 1995. B.A. Economics (Minor: Political Science), University of North Carolina at Chapel Hill, Chapel Hill, North Carolina.

APPOINTMENTS

2012 – current	Research Systems Ecologist and Senior Scientist, U.S. Environmental Protection Agency Office of Research and Development, Cincinnati, Ohio
2007 – 2012	Research Ecologist, U.S. Environmental Protection Agency Office of Research and Development, Cincinnati, Ohio
2003 – 2007	Postdoctoral Researcher, U.S. Environmental Protection Agency Office of Research and Development, Cincinnati, Ohio

SELECT PUBLICATIONS (†RESEARCH TEAM LEAD)

Golden†, H.E., C. R. Lane, D. Amatya, K. Bandilla, H. Raanan-Kiperwas, C. Knightes, and H. Ssegane. 2014. Modeling hydrologic connectivity between geographically isolated wetlands and surface water systems: A review of select methods. Environmental Modeling and Software 53:190-206.

U.S. EPA [Alexander†, L.C., B.C. Autrey, J. DeMeester, K. M. Fritz, D. C. Goodrich, W. G. Kepner, C. R. Lane, S. D. LeDuc, S. G. Leibowitz, M. McManus, A. I. Pollard, H. Ranaan-Kipperwas, C. E. Ridley, K. Schofield, P. J. Wigington]. 2013. Connectivity of Streams and Wetlands to Downstream Waters: A Review and Synthesis of the Scientific Evidence. External Review Draft. EPA/600/R-11/098B, U.S. Environmental Protection Agency, Washington, DC.

Lane, C.R. †, E. D'Amico, and B.C. Autrey. 2012. Isolated wetlands of the Southeastern United States: Abundance and expected condition. Wetlands 32(4): 753-767.

Murray-Hudson, M., C.R. Lane†, S. North, and M.T. Brown. 2012. Macrophyte species distribution, indices of biotic integrity and sampling intensity in isolated Florida marshes. Wetlands 32:449-460.

Frohn, R.C., E. D'Amico, C.R. Lane†, B. Autrey, J. Rhodus, and H. Liu. 2012. Multi-temporal sub-pixel Landsat ETM+ classification of isolated wetlands in Cuyahoga County, Ohio, USA. Wetlands 32:289-299.

Frohn, R.C., B.C. Autrey, C.R. Lane†, and M. Reif. 2011. Segmentation and object-oriented classification of wetlands in a karst Florida landscape using multi-season Landsat-7 ETM+ imagery. International Journal of Remote Sensing 32(5):1471-1489

Lane†, C.R. and E. D'Amico. 2010. Calculating the ecosystem service of water storage in isolated wetlands using LIDAR in north central Florida, USA. Wetlands 30(5):964-977

Reiss†, C.R., M.T. Brown, and C.R. Lane. 2010. Characteristic community structure of Florida's subtropical wetlands: the Florida Wetland Condition Index for depressional marshes, depressional forested, and flowing water forested wetlands. Wetlands Ecology and Management 18(5):543-556

Lane†, C.R., K.C. Reiss†, S. DeCelles, and M.T. Brown. 2009. Benthic diatom composition in isolated forested wetlands subject to drying: Implications for monitoring and assessment. Ecological Indicators 9:1121-1128

Reif, M., R.C. Frohn, C.R. Lane†, and B. Autrey. 2009. Mapping isolated wetlands in a karst landscape: GIS and remote sensing methods. GIScience and Remote Sensing 46(2):187-211

Frohn, R.C., M. Reif, C.R. Lane†, and B. Autrey. 2009. Satellite remote sensing of isolated wetlands using object-oriented classification of Landsat-7 data. Wetlands 29(3):931-941

Lane, C. R., B. C. Autrey, T. Jicha, L. Lehto, C. Elonen, and L. Seifert-Monson. *In Journal Review*. Denitrification potential in select

geographically isolated wetlands of North Carolina and Florida, USA. Freshwater Science.

Golden, H.E., H. A. Sander, C. R. Lane, C. Zhao, K. Price, E. D'Amico, and J. R. Christensen. *In Journal Review*. Relative effects of geographically isolated wetlands on streamflow: A watershed-scale analysis. Ecohydrology.

ADDITIONAL PUBLICATIONS

Douglas†, M.R., Y.V. Slyn'ko, S. Kohl, C.R. Lane, and E.E. Slyn'ko. 2011. Crossroad blues: An intersection of rivers, wetlands, and public policy. Fisheries 36(7):337-339

Lane, C.R. 2007. Assessment of isolated wetland condition in Florida using epiphytic diatoms as genus, species, and subspecies taxonomic resolution. EcoHealth 4(2):219-230. [Invited Contribution to Special Issue on Wetland Condition Assessment]

Lane, C.R. and M.T. Brown†. 2007. Diatoms as indicators of isolated herbaceous wetland condition in Florida, USA. Ecological Indicators 7:521-540

Lane, C.R., J.E. Flotemersch†, K.A. Blocksom, and S. DeCelles. 2007. Effect of sampling method on diatom composition for use in monitoring and assessing large river condition. River Research and Application 23:1126-1146

Lane, C. R., H. Liu, B. C. Autrey, O. A. Anenkhonov, and V. V. Chepinoga. *In Journal Review*. A hybrid classification method for wetland habitat mapping using 8-band Worldview-2 imagery. International Journal of Remote Sensing.

Liu, H., O. Anenkhonov, C. R. Lane, B. C. Autrey, and V. V. Chepinoga. *In Journal Review*. Classification and inventory of freshwater wetlands and aquatic habitats in the Selenga River Delta of Lake Baikal, Russia, using high-resolution satellite imagery. Wetlands Ecology and Management.

SYNERGISTIC ACTIVITIES AND LEADERSHIP ROLES

- Co-Organizer, Geographically Isolated Wetlands Research Workshop. November 18 – 21, 2013. Joseph W. Jones Ecological Research Center, Newton, GA. Organized and led four-day research workgroup of federal, academic, and non-profit scientists to define state of the science and identify research needs associated with geographically isolated wetland functions and connectivity across biogeochemical, biological, and hydrological fields. Six manuscripts from group in prep and on-time for June – December 2014 submission (Targets: Nature, Frontiers in Ecology and the Environment, BioScience, Hydrological Processes, Wetlands). Identification of international researchers and development of Powell Center Working Group proposal for quantifying hydrological and spatial connectivity and determinants an outcome of this workshop.

- Co-Lead, U.S. EPA Office of Research and Development, Wetland Ecosystems Services Research Program. 2009 – 2012. Organize, focus, facilitate, and communicate wetland research of >50 scientists from U.S. EPA/ORD national laboratories.

- Co-Organizer and Scientific Lead, Third International Symposium on Ecology and Biodiversity in Large Rivers of Northeast Asia and North America. September 20-24, 2009. Memphis, TN. Organized and led international conference of >150 Russian, Chinese, and American scientist.

SYMPOSIA ORGANIZED

Golden, H.E., N. Basu, C. Knightes, C. R. Lane. Session Co-Organizer. Linking Watershed Processes with Aquatic Ecosystem Functions and Services. Proposed. American Geophysical Union, December 15-19, 2014. San Francisco, California.

Lane, C. R., E. Gordov, E. Dyukarev, B. Autrey. Session Co-Organizer. Western Siberian Peatlands: Sources, Sinks, and Processes Affecting Carbon Effluxes. Proposed. American Geophysical Union, December 15-19, 2014. San Francisco, California.

Golden, H.E. C. Knightes, and C. R. Lane. Session Co-Organizer. Connecting the Landscape to Aquatic Ecosystem Endpoints: Linking Watershed Processes with Ecosystem Services and Sustainability. American Geophysical Union, December 09 – 13, 2013. San Francisco, CA.

Lane, C. R., H. E. Golden, K. Kirkman, L. Smith. Session Co-Organizer. Benefits and Services of Isolated Wetlands: State of Our Knowledge. Society of Wetland Scientists Annual Meeting, June 03-07, 2013. Duluth, Minnesota.

Golden, H. E., C. Knightes, and C. R. Lane. Session Co-Organizer. Connecting the Landscape to Aquatic Ecosystem Endpoints: Linking Watershed Processes with Ecosystem Services and Sustainability. American Geophysical Union, December 03 – 07, 2012. San Francisco, CA.

MAJOR AWARDS

US EPA ORD Statesmanship Award. 2010. "For Enhanced International Wetlands Research and Advanced Communication with Foreign Diplomats, Environmental Managers, and Scientists." Washington, DC.

MEMBERSHIPS IN PROFESSIONAL SOCIETIES

Society of Wetland Scientists (Life Member) | American Geophysical Union | Society for Freshwater Science

Mark Cable Rains, Ph.D.

a. Professional Preparation

UC San Diego	Ecology, Behavior, & Evolution	BA, 1990
University of Washington	Forestry	MS, 1994
UC Davis	Hydrologic Sciences	PhD, 2002
UC Davis	Ecohydrology	Postdoctoral, 2002-2003

b. Appointments

Associate Professor& Assistant Professor, 2003 to date, School of Geosciences, University of South Florida

Associate Editor for Aquatic Ecology, 2011 to date, Journal of the American Water Resources Association

Interim Associate Director, 2013-2014, School of Geosciences, University of South Florida

Fellow, 2008, Dr. Kiran C. Patel Center for Global Solutions, University of South Florida

Postgraduate Researcher, 2002-2003, Department of Land, Air, and Water Resources, UC Davis

Research Assistant, 1997-2002, Department of Geology, UC Davis

Staff Scientist, 1997-2002, David Magney Environmental Consulting, Ojai, California

Senior Associate, Associate, & Technical Assistant, 1993-1997, L.C. Lee & Associates, Inc., Seattle, Washington

Research Associate, 1995-1996, Smithsonian Environmental Research Center, Edgewater, Maryland

c. Publications

(i) Five Publications Most Closely Related to the Proposal

Rains, M.C. 2011. Water sources and hydrodynamics of closed-basin depressions, Cook Inlet Region, Alaska. *Wetlands* 31:377-387.

Leibowitz, S.G., P.J. Wigington, Jr., M.C. Rains, and D.M. Downing. 2008. Non-navigable streams and adjacent wetlands: Addressing science needs following the Supreme Court's Rapanos decision. *Frontiers in Ecology and Environment* 6:364-371.

Rains, M.C., R.A. Dahlgren, R.J. Williamson, G.E. Fogg, and T. Harter. 2008. Geological control of physical and chemical hydrology in vernal pools, Central Valley, California. *Wetlands* 28:347-362.

Nadeau, T.-L., and M.C. Rains. 2007. Hydrological connectivity of headwaters to downstream waters: State-of-the-science and future directions. *Journal of the American Water Resources Association* 43:118-133.

Rains, M.C., G.E. Fogg, T. Harter, R.A. Dahlgren, and R.J. Williamson. 2006. The role of perched aquifers in hydrological connectivity and biogeochemical processes in vernal pool landscapes, Central Valley, California. *Hydrological Processes* 20:1157-1175.

(ii) Five Additional Publications

Rains, M.C., S. Landry, K.C. Rains, V. Seidel, and T.C. Crisman. 2013. Using net wetland loss, current wetland condition, and planned future watershed condition for wetland conservation planning and prioritization, Tampa Bay Watershed, Florida. *Wetlands* 33:949-963.

Nilsson, K.A., M.C. Rains, D.B. Lewis, and K.E. Trout. 2013. Hydrologic characterization of 56 geographically isolated wetlands in west-central Florida using a probabilistic method. *Wetland Ecology and Management* 21:1-14.

Rains, M.C., K.C. Rains, W.J. Kleindl, S. Landry, T.L. Crisman, A. Brown, and L. van Maurik. 2011. Wetland Inventory and Evaluation, St. Lucie County, Florida. St. Lucie County, Florida.

Stringer, C.E., M.C. Rains, S. Kruse, and D. Whigham. 2010. Controls on water levels and salinity in a barrier island mangrove, Indian River Lagoon, Florida. *Wetlands* 30:725-734.

Murphy, K.E., M.C. Rains, M.G. Kittridge, M. Stewart, and M.A. Ross. 2008. Hydrological connectivity between clay settling areas and surrounding hydrological landscapes in the phosphate mining district, peninsular Florida, USA. *Journal of the American Water Resources Association* 44:980-995.

d. Five Synergistic Activities

(i) Co-PI on the NSF-funded Urban Development, Power Relations and Water Redistribution as Drivers of Wetland Change in the Tampa Bay Urban Ecosystem Urban Long-Term Research Area (Tampa ULTRA-Ex), which is an interdisciplinary effort designed to investigate how social organization and distribution of power in a socioecosystem drive resource redistribution, and thus modify social and ecological structures and functions at scales beyond that of the built city.

(ii) Co-PI on the NSF-funded Geology of National Parks: Spreadsheets, Quantitative Literacy, and Natural Resources, which seeks to develop and test spreadsheet modules to enhance students' quantitative literacy skills in the context of routine coursework in a course titled “Geology of National Parks”.

(iii) Co-Leader of the Scenarios and Modeling Cross-Cutting Theme of the NSF-Funded Florida Coastal Everglades Long-Term Ecological Research (FCE LTER) Program, which seeks an understanding of how climate, hydrology, and human activities affect ecosystem and population dynamics in the Florida Coastal Everglades.

(iv) Co-edited a Featured Collection of the Journal of the American Water Resources Association addressing the roles played by headwater streams in maintaining the integrity of downstream navigable-in-fact waters, which the US Environmental Protection Agency now includes as one of 11 products listed under the “Relevant Information About Water” tab on the website that provides information regarding the "Clean Water Act Definition of ‘Waters of the United States’".

(v) Assisted in the development and implementation of the Hydrogeomorphic Approach to Functional Assessment (HGM), now a standard methodology for functional assessment of waters of the U.S., including wetlands, in numerous federal and state regulatory programs.

e. Collaborators & Other Affiliations

(i) Collaborators in Past Five years

Fenda Akiwumi, University of South Florida; Susan Bell, University of South Florida; Tom Crisman, University of South Florida; Solomon Dobrowski, University of Montana; Chris Hammersmark, cbec, inc., eco engineering; Ric Hauer, University of Montana; Tom Juster, University of South Florida; Ryan King, Baylor University; George Kish, US Geological Survey; Bill Kleindl, University of Montana; Sarah Kruse, University of South Florida; Riks Laanbroek, Netherlands Institute of Ecology; Shawn Landry, University of South Florida; Scott Leibowitz, US Environmental Protection Agency; David Lewis, University of South Florida; Judy McIlrath, University of South Florida; Eric Stein, Southern California Coastal Water Research Project; Mark Stewart, University of South Florida; Arturo Torres, US Geological Survey; Len Vacher, University of South Florida; Coowe Walker, Kachemak Bay Research Reserve; Dennis Whigham, Smithsonian Environmental Research Center; Becky Zarger, University of South Florida; Jos Verhoeven, University of Utrecht

(ii) Graduate and Postdoctoral Advisors

Kern Ewing, University of Washington (MS Advisor); Jeffrey Mount, UC Davis (PhD Advisor); Graham Fogg, UC Davis (Postdoctoral Advisor); Thomas Harter, UC Davis (Postdoctoral Advisor)

(iii) Graduate Students in Past Five Years

Jason Bellino (MS, 2009); Mike Callahan (Continuing), Hunter Clasen (Continuing); Gregg Jones (Continuing); Mike Kittridge (MS, 2007), Hilary Flower (Continuing), Bruce LaFrenz (Continuing), Kathryn Murphy (MS, 2007), ReNae Nowicki (Continuing), Natalie Pechenik (MS, 2009), Vickie Spence (MS, 2011); Christina Stringer (PhD, 2010), Amie West (co-Advised with Len Vacher, MS, 2012)

Scott G. Leibowitz, Ph.D.

a. Professional Preparation

B.S. – Agriculture and Life Sciences (with honors), Cornell University, May 1978
M.S. – Environmental Engineering Sciences, University of Florida, Dec. 1980
Ph.D. – Marine Sciences (Electrical and Computer Engineering minor), Louisiana State University, May 1989. Dissertation title: The Pattern and Process of Land Loss in Coastal Louisiana: A Landscape Ecological Analysis

b. Appointments

8/12 – present – Task Leader (GS-14), US EPA National Health and Environmental Effects Research Laboratory, Western Ecology Division (Lead for two tasks under the Air, Climate, and Energy [ACE] and Safe and Sustainable Water Resources [SSWR] Programs)

3/06 – 7/12 – Principal Investigator (GS-14), Non-navigable Streams and Wetlands Project, US EPA National Health and Environmental Effects Research Laboratory, Western Ecology Division

1/01 – 9/07 – Principal Investigator (GS-13), Freshwater Habitat Project, US EPA National Health and Environmental Effects Research Laboratory, Western Ecology Division

8/89 – 12/00 – Project Leader (GS-13), Landscape Function Project, US EPA National Health and Environmental Effects Research Laboratory, Western Ecology Division

1/89 – 8/89 – Research Ecologist (GS-13), Wetlands Research Program, US EPA Environmental Research Laboratory – Corvallis

10/87 – 11/88 – Research Associate, Remote Sensing and Image Processing Laboratory, Louisiana State University

2/81 – 9/87 – Research Associate, Center for Wetland Resources, Louisiana State University

6/79 – 9/79 – Intern, President's Council on Environmental Quality, Washington, DC

c. Current Memberships in Professional Societies

Society of Wetland Scientists, American Geophysical Union

d. Publications

(i) Five Publications Most Closely Related to the Proposal

US EPA. 2013. Connectivity of streams and wetlands to downstream waters: a review and synthesis of the scientific evidence. External Review Draft. US Environmental Protection Agency, Office of Research and Development, EPA/600/R-11/098B. [Co-lead on Chapter 3 (conceptual framework) and lead on Chapter 5 (wetlands)]

Leibowitz, S.G., P.J. Wigington, Jr., M.C. Rains, and D.M. Downing. 2008. Non-navigable streams and adjacent wetlands: addressing science needs following the Supreme Court's Rapanos decision. Frontiers in Ecology and the Environment 6(7):364-371.

Leibowitz, S.G. 2003. Isolated wetlands and their functions: An ecological perspective. Wetlands 23(3):517-531.

Leibowitz, S.G. and T.-L. Nadeau. 2003. Isolated wetlands: State-of-the-science and future directions. Wetlands 23(3):663-684.

Leibowitz, S.G. and K.C. Vining. 2003. Temporal connectivity in a prairie pothole complex. Wetlands 23(1):13-25.

(ii) Five Additional Publications

Ebersole J.L., P.J. Wigington, Jr., S.G. Leibowitz, R.L. Comeleo, and J. Van Sickle. Predicting the occurrence of cold water patches at intermittent and ephemeral tributary confluences with warm rivers. Freshwater Science (accepted).

Patil, S, P.J. Wigington, Jr., S.G. Leibowitz, and R.L. Comeleo. 2013. Use of hydrologic landscape classification to diagnose streamflow predictability in Oregon. Journal of American Water Resources Association 1-15. DOI: 10.1111/jawr.12143.

Leibowitz, S.G., P.J. Wigington, Jr, R.L. Comeleo, and J.L. Ebersole. 2012. A temperature-precipitation based model of thirty-year mean snowpack accumulation and melt in Oregon, USA. Hydrological Processes 26:741-759.

Wigington, P.J., Jr, S.G. Leibowitz, R.L. Comeleo, and J.L. Ebersole. 2013. Oregon hydrologic landscapes: a classification framework. Journal of the American Water Resources Association 49:163-182.

Leibowitz, S.G., C. Loehle, B. L. Li, and E.M. Preston. 2000. Modeling landscape functions and effects: A network approach. Ecological Modelling 132(1 2):77 94.

e. Major Awards, Professional Service and Recognition

Served as co-lead of the Hydrology Subgroup at the Isolated Wetlands Research Workshop, Joseph W. Jones Ecological Research Center, Newton, GA, November 18-21, 2013

Associate editor for Wetlands, Jan. 2009 – present

Served on steering committee to develop a technical support document on relationships between tributaries and wetlands and Waters of the United States for EPA's Office of Water; technical lead for two of the document's chapters (conceptual framework and wetlands) (Aug. 2010 – Sept. 2013)

EPA Bronze Medal "for establishing how the configuration of stream habitats in stream networks including intermittent streams impact the productivity and survivability of coho salmon in coastal watersheds" (with Salmon Freshwater Habitat Team). July 8, 2010

EPA's 2009 Level 2 Scientific and Technological Achievement Award for "Advancing the scientific basis for assessing functional interactions and flow duration in integrated hydrologic systems." May 7, 2010

Invited participant, Coho Modeling Workshop, US Forest Service Forestry Science Laboratory, Corvallis, OR, Apr. 27, 2010

EPA's 2007 Level 2 Scientific and Technological Achievement Award for "Outstanding research quantifying the influence of intermittent streams on the biological integrity of navigable waters." Mar. 31, 2008

Paper on isolated wetlands by Leibowitz and Nadeau was cited by Justice Anthony Kennedy in the June 19, 2006 U.S. Supreme Court decision on Rapanos v. United States

EPA's 2004 Level 1 Scientific and Technological Achievement Award, "For your research publication advancing the scientific understanding of isolated wetlands following the U.S. Supreme Court's SWANCC decision." May 16, 2005

Participant in National Center for Ecological Analysis and Synthesis working group on Conservation Planning in Coastal Environments. Santa Barbara, CA, June 14-16, 2004

Guest co-editor of special issue of Wetlands (vol 23, no. 3, 2003) containing 15 papers on the subject of isolated wetlands

Member of Society of Wetland Society's Publications Committee (Jan. 2002 – Dec., 2003)

Served as a peer review panel member for the terrestrial aspects of the Biological Resources Program of the Grand Canyon Monitoring and Research Center (2000)

EPA Bronze Medal "in recognition of the outstanding achievement of the Wetlands Research Team for its contribution to the Agency's wetlands protection strategy and to the science of wetlands ecology." Feb. 14, 1992

Powell Center Data Management Plan

Data Management Plan for Approved Working Groups

(Repeat table for each data input, provide information for each element, submit with proposal.)

Data Inputs	
Title	*National Wetlands Inventory*
Description	*Inventory of wetlands and aquatic systems across USA*
Format	*ArcGIS*
Source	*U.S. Fish and Wildlife Service*
Access/sharing	*ArcGIS geodatabase*
Restrictions	*None*
Data Volume Estimate	*<10 gb for our purposes*
Purpose	*Base layer of wetland extent*
Metadata	*http://www.fws.gov/wetlands/Data/Metadata.html*
Link or identifier	*http://www.fws.gov/wetlands/Data/Mapper.html*
Data Inputs	
Title	*USGS National Hydrography Dataset*
Description	*Inventory of surface waters of the US*
Format	*ArcGIS*
Source	*USGS*
Access/sharing	*ArcGIS geodatabase*
Restrictions	*None*
Data Volume Estimate	*<10 gb for our purposes*
Purpose	*Base layer of lentic and lotic systems in the US*
Metadata	*Available for each state: ftp://nhdftp.usgs.gov/DataSets/Staged/States/FileGDB/HighResolution/*
Link or identifier	*http://nhd.usgs.gov/index.html*
Data Inputs	
Title	*Soil Survey Geographic Database (SSURGO)*
Description	*Database of soil types and characteristics*
Format	*ArcGIS*
Source	*USDA*
Access/sharing	*ArcGIS geodatabase*
Restrictions	*None*
Data Volume Estimate	*<5 gb for our purposes*
Purpose	*Inventory of soils and soil components for the US*

Metadata	*http://www.nrcs.usda.gov/wps/PA_NRCSConsumption/download?cid=stelprdb1241114&ext=pdf*
Link or identifier	*http://www.nrcs.usda.gov/wps/portal/nrcs/soilsurvey/soils/survey/state/*
Data Inputs	
Title	*State Soil Geographic Database (STATSGO)*
Description	*Broad-based inventory of soils and non-soil areas*
Format	*ArcGIS*
Source	*USDA*
Access/sharing	*ArcGIS geodatabase*
Restrictions	*None*
Data Volume Estimate	*<5 gb for our purposes*
Purpose	*Broader inventory of soils and soil components for larger-scale analyses*
Metadata	*http://www.nrcs.usda.gov/wps/PA_NRCSConsumption/download?cid=stelprdb1241114&ext=pdf*
Link or identifier	*http://www.nrcs.usda.gov/wps/portal/nrcs/detail/soils/survey/?cid=nrcs142p2_053629*
Data Inputs	
Title	*USGS National Elevation Dataset*
Description	*Elevation datalayer*
Format	*ArcGIS*
Source	*USGS*
Access/sharing	*ArcGIS geodatabase*
Restrictions	*None*
Data Volume Estimate	*<100 gb for our purposes*
Purpose	*Useful for determining flow path characteristics*
Metadata	*http://ned.usgs.gov/metadata.html*
Link or identifier	*http://ned.usgs.gov/*
Data Inputs	
Title	*USGS Stream Gauge Data*
Description	*Surface water data*
Format	*Tabular and spatial*
Source	*USGS*
Access/sharing	*ArcGIS geodatabase*
Restrictions	*None*
Data Volume Estimate	*<10 gb for our purposes*
Purpose	*Used in hydrological modeling*
Metadata	*See:http://www.wateratlas.usf.edu/shared/metadata.asp?id=USGS_NWIS; site-specific metadata and QA/QC data available*

Link or identifier	*http://waterdata.usgs.gov/nwis*
Data Inputs	
Title	*National Land Cover Database*
Description	*Land cover classification*
Format	*ArcGIS*
Source	*Multi-Resolution Land Characteristics Consortium*
Access/sharing	*ArcGIS geodatabase*
Restrictions	*None*
Data Volume Estimate	*<2 gb for our purposes*
Purpose	*Land cover characteristics to inform hydrologic modeling and time-series analyses of change and quantify effect on extent/hydrographs*
Metadata	*http://extract.cr.usgs.gov/distmeta/servlet/gov.usgs.edc.MetaBuilder ?TYPE=HTML&DATASET=NLCD06LANC; other metadata available depending on NLCD Product*
Link or identifier	*http://www.mrlc.gov/; http://www.mrlc.gov/finddata.php*
Data Inputs	
Title	*Level III Ecoregions of the United States*
Description	*Ecoregional classification of the US*
Format	*ArcGIS*
Source	*US EPA*
Access/sharing	*ArcGIS geodatabase*
Restrictions	*None*
Data Volume Estimate	*<1 gb for our purposes*
Purpose	*Provides classification based on analysis of patterns in biotic and abiotic phenomena*
Metadata	*ftp://ftp.epa.gov/wed/ecoregions/us/Eco_Level_III_US.htm*
Link or identifier	*http://www.epa.gov/wed/pages/ecoregions/level_iii_iv.htm*
Data Inputs	
Title	*Level III Ecoregions of North America*
Description	*Short description of the data as it relates to the proposal*
Format	*ArcGIS*
Source	*Commission for Environmental Cooperation*
Access/sharing	*ArcGIS geodatabase*
Restrictions	*None*
Data Volume Estimate	*<1 gb for our purposes*
Purpose	*Provides classification based on analysis of patterns in biotic and abiotic phenomena*
Metadata	*ftp://ftp.epa.gov/wed/ecoregions/cec_na/NA_CEC_Eco_Level3.htm*

Link or identifier	*http://www.epa.gov/wed/pages/ecoregions/na_eco.htm*
Data Inputs	
Title	*Major Land Resource Areas (MLRA)*
Description	*Geographic areas characterized by patterns of soils, climate, water resources, and land uses*
Format	*ArcGIS*
Source	*USDA*
Access/sharing	*ArcGIS geodatabase*
Restrictions	*None*
Data Volume Estimate	*<1 gb for our purposes*
Purpose	*Provides classification based on analysis of patterns in biotic and abiotic phenomena*
Metadata	*http://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb1043520.pdf*
Link or identifier	*http://www.nrcs.usda.gov/wps/portal/nrcs/detail/soils/survey/?cid=nrcs142p2_053624*
Data Inputs	
Title	*Hydrologic Landscape Regions of the United States*
Description	*Patterning of land-surface form, geologic texture, and climate variables*
Format	*ArcGIS*
Source	*USGS*
Access/sharing	*ArcGIS geodatabase*
Restrictions	*None*
Data Volume Estimate	*<1 gb for our purposes*
Purpose	*Classification of landscapes based on patterning of land-surface form, geologic texture, and climate variables*
Metadata	*http://water.usgs.gov/GIS/metadata/usgswrd/XML/hlrus.xml*
Link or identifier	*http://ks.water.usgs.gov/pubs/abstracts/of.03-145.htm*
Data Inputs	
Title	*Landsat*
Description	*Multispectral satellite imagery*
Format	*Spatially explicit TIF*
Source	*USGS*
Access/sharing	*ArcGIS / ERDAS Platforms*
Restrictions	*None*
Data Volume Estimate	*<100 gb for our purposes*
Purpose	*Used in flow path analyses, time series changes in land cover, wetland complex determination*
Metadata	*http://landsat.usgs.gov/consumer.php; varies by sensor*

Link or identifier	*http://landsat.usgs.gov/*
Data Inputs	
Title	*Canadian Wetland Inventory*
Description	*Inventory of wetland areas in Canada*
Format	*ArcGIS*
Source	*Environment Canada, Canadian Space Agency, Ducks Unlimited Canada, and the North American Wetlands Conservation Council (Canada)*
Access/sharing	*ArcGIS geodatabase*
Restrictions	*Are there limitations for data re-use, access, sharing?*
Data Volume Estimate	*<20 gb for our purposes*
Purpose	*Partial inventory of wetlands in Canada*
Metadata	*Availability depends on source*
Link or identifier	*http://maps.ducks.ca/cwi/*
Data Inputs	
Title	*National Hydro Network*
Description	*Inventory of hydrographic features in Canada*
Format	*ArcGIS*
Source	*Natural Resources Canada, Geobase*
Access/sharing	*ArcGIS geodatabase*
Restrictions	*None*
Data Volume Estimate	*<10 gb for our purposes*
Purpose	*Inventory of aquatic features in Canada*
Metadata	*http://www.geobase.ca/geobase/en/metadata.do;jsessionid=9AA12AC0F7958A8066624AD9B6826EF3?id=87066E9A-94EE-680A-B1BA-591F4688DB7D*
Link or identifier	*http://www.geobase.ca/geobase/en/data/nhn/description.html;jsessionid=4E39513DAF955D39822FC8B0E34804E1.geobase2*
Data Inputs	
Title	*Soil Landscapes of Canada*
Description	*Database of soil features and characteristics in Canada*
Format	*ArcGIS*
Source	*Canadian Soil Information System, Agricultural and Agri-Food Canada*
Access/sharing	*ArcGIS geodatabase*
Restrictions	*None*
Data Volume Estimate	*<5 gb for our purposes*
Purpose	*Soil features and characteristics affecting flow paths and connectivity*
Metadata	*http://sis.agr.gc.ca/cansis/nsdb/slc/v3.1/slcv3shp_metadata.htm*
Link or identifier	*http://sis.agr.gc.ca/cansis/nsdb/slc/v3.2/index.html*

Data Inputs	
Title	*Canadian Digital Elevation Dataset*
Description	*Elevation datalayer*
Format	*ArcGIS*
Source	*Natural Resources Canada, Geobase*
Access/sharing	*ArcGIS geodatabase*
Restrictions	*None*
Data Volume Estimate	*<100 gb for our purposes*
Purpose	*Useful for determining flow path characteristics*
Metadata	*http://www.geobase.ca/geobase/en/metadata.do?id=3A537B2D-7058-FCED-8D0B-76452EC9D01F*
Link or identifier	*http://www.geobase.ca/geobase/en/data/cded/description.html*
Data Inputs	
Title	*Water Survey of Canada National Water Data Archive*
Description	*Surface water data*
Format	*Tabular and spatial*
Source	*Environment Canada*
Access/sharing	*ArcGIS geodatabase*
Restrictions	*None*
Data Volume Estimate	*<10 gb for our purposes*
Purpose	*Used in hydrological modeling*
Metadata	*Site-specific metadata and QA/QC data available*
Link or identifier	*http://www.ec.gc.ca/rhc-wsc/default.asp?lang=En&n=9018B5EC-1*
Data Inputs	
Title	*Land Cover, Circa 2000*
Description	*Land cover in Canada*
Format	*ArcGIS*
Source	*Natural Resources Canada*
Access/sharing	*ArcGIS geodatabase*
Restrictions	*None*
Data Volume Estimate	*<10 gb for our purposes*
Purpose	*Land cover characteristics to inform hydrologic modeling and time-series analyses of change and quantify effect on extent/hydrographs*
Metadata	*http://www.geobase.ca/geobase/en/metadata.do?id=673E0D20-F2FB-F14C-E119-584EB3CF2B15*
Link or identifier	*http://geobase.ca/geobase/en/data/landcover/csc2000v/description.html*
Data Inputs	
Title	*Data name or reference*

Description	*National Ecological Framework for Canada Ecoregions*
Format	*ArcGIS*
Source	*Environment Canada and Agriculture and Agri-Food Canada*
Access/sharing	*ArcGIS geodatabase*
Restrictions	*None*
Data Volume Estimate	*<5 gb for our purposes*
Purpose	*Provides classification based on analysis of patterns in biotic and abiotic phenomena*
Metadata	*http://www.agr.gc.ca/atlas/supportdocument_documentdesupport/ aafcEcostratification/en/ISO_19131_National_Ecological_ Framework_for_Canada_Data_Product_Specification.pdf*
Link or identifier	*http://sis.agr.gc.ca/cansis/nsdb/ecostrat/index.html*
Data Inputs	
Title	*Site-Specific Data Layers*
Description	*Spatially explicit inventories of wetland features*
Format	*ArcGIS*
Source	*Varies by source*
Access/sharing	*ArcGIS geodatabase*
Restrictions	*Data layers will be made available to the public*
Data Volume Estimate	*<1 gb for our purposes*
Purpose	*Identification of wetland features on landscape to be used in spatial analyses and hydrological modeling*
Metadata	*Metadata of site-specific layers in Federal Geographic Data Committee (FGDC) format will be developed for funded proposal*
Link or identifier	*Examples of publications using existing data layers:* *Bowen, Kansas Playas: http://link.springer.com/article/10.1007/s13157-010-0077-z;* *Lane, Southeastern USA: http://link.springer.com/article/10.1007/s13157-012-0308-6;* *Lane, Northeastern Ohio: http://link.springer.com/article/10.1007/s13157-011-0254-8;* *Basu, Des Moines Lobe, Iowa: http://onlinelibrary.wiley.com/doi/10.1002/hyp.9967/full;* *Jenkins, Orlando, Florida: http://link.springer.com/article/10.1007%2Fs13157-012-0357-x*
Data Processing (will occur during the course of Working Group activities)	
Transformation and processing workflow	*As this is a large team, we will appoint a single researcher (currently Golden, with support from Lane and Evenson) to serve as the data manager and QA/QC principal. Analyses will focus on hydrological modeling and spatial analyses, and will include the derivation of a single geodatabase for the team as well as multiple processing steps. Processing for spatial analyses and hydrological modeling base layers (including derivation of spatial*

	indicators of connectivity, application of graph theoretic analyses, and geostatistical examination of relationships between local and landscape features and wetland-aquatic system connectivity) will include multiple steps outlined in the Analytical Approach, above. Specific processes to achieve goals of proposal will be conducted as necessary and documented. Synthesis actions involve the interim reporting and discussion of results at multiple scales and through multiple analytical processes (e.g., modeling, spatial analyses) to distill and identify emerging properties of connectivity and controls on connectivity that vary by local and landscape characteristics. The Powell Center Working Group team will focus on synthesizing the results of these analyses.
Technology needs	*High-performance computing and data storage will be required for portions of the research (in particular, certain modeling and graph theoretic analyses require multiple high-end CPUs for parallel processing and extensive storage space (though estimated at <10 GB)). The specific computing needs will be refined in the discussions in advance of first the Powell Center work group meeting, though of course US EPA high-performance computers as well as additional team resources will be expended in these efforts.*
Data Publishing	
Title	*Downstream Connectivity of Geographically Isolated Wetlands*
Description	*Derived data will identify study GIWs and quantify linkages to downgradient systems based on multiple hypothesized connectivity pathways (e.g., hydrological models, spatial analyses).*
Format	*ArcGIS geodatabase*
Data Volume Estimate	*<5 gb*
Metadata	*Metadata for output data will be developed using the standardized method of each base publically-available spatial data set.*
Restrictions	*None are anticipated, though in the happenstance that threatened or endangered species are known to occur in specific geographically isolated wetland systems, the locational information for these wetlands will not be shared with the public.*

POWELL CENTER BUDGET SHEET

Working Group Name: GIW Connectivity and Effects

A. Travel	**Year 1**			**Year 2**		
Names of Working Group members	Name of Departure City	Roundtrip Economy Airfare	Other transportation expenses (maximum; parking + shuttle)	Roundtrip Economy Airfare	Other transportation expenses (maximum; parking + shuttle)	**TOTAL TRANSPORTATION**
1 Mushet, David	Fargo, ND	$ 295	$ 111.00	$ 295	$ 111.00	$ 812
2 Lane, Charles	Cincinnati, OH	$ 304	$ 111.00	$ 304	$ 111.00	$ 830
3 Rains, Mark	Tampa, FL	$ 304	$ 111.00	$ 304	$ 111.00	$ 830
4 Leibowitz, Scott	Corvallis, OR	$ 224	$ 111.00	$ 224	$ 111.00	$ 670
5 Golden, Heather	Cincinnati, OH	$ 304	$ 111.00	$ 304	$ 111.00	$ 830
6 Alexander, Laurie	Washington, DC	$ 345	$ 111.00	$ 345	$ 111.00	$ 912
7 Ali, Genevieve	Winnipeg, Ontario	$ 407	$ 111.00	$ 407	$ 111.00	$ 1,036
8 Basu, Nandita	Toronto, Ontario	$ 575	$ 111.00	$ 575	$ 111.00	$ 1,372
9 Bowen, Mark	Milwaukee, WI	$ 214	$ 111.00	$ 214	$ 111.00	$ 650
10 Bruland, Greg	St. Louis, MO	$ 194	$ 111.00	$ 194	$ 111.00	$ 610
11 Christensen, Jay	Las Vegas, NV	$ 114	$ 111.00	$ 114	$ 111.00	$ 450
12 Cohen, Matthew	Gainesville, FL	$ 458	$ 111.00	$ 458	$ 111.00	$ 1,138
13 Creed, Irena	London, Ontario	$ 649	$ 111.00	$ 649	$ 111.00	$ 1,520
14 Evenson, Grey	Cincinnati, OH	$ 304	$ 111.00	$ 304	$ 111.00	$ 830
15 Faulkner, Stephen	Washington, DC	$ 392	$ 111.00	$ 392	$ 111.00	$ 1,006
16 Jenkins, David	Orlando, FL	$ 345	$ 111.00	$ 345	$ 111.00	$ 912
17 Lindsay, John	Guelph, Ontario	$ 575	$ 111.00	$ 575	$ 111.00	$ 1,372
18 McLaughlin, Danie	Roankoke, VA	$ 524	$ 111.00	$ 524	$ 111.00	$ 1,270
19 Rosenberry, Donald	Longmont, CO	n/a	$ 46.00	n/a	$ 46.00	$ 92
20 Rover, Jennifer	Sioux Falls, SD	$ 200	$ 111.00	$ 200	$ 111.00	$ 622

B. Per Diem	**Year 1 Per Diem**		**Year 2 Per Diem**	**TOTAL PER DIEM**
Number of participants * number of days (4 day minimum) * $147/day	11760		11760	23520
TOTAL	**YEAR 1 TRAVEL AND PER DIEM**	$ 20,642	**YEAR 2 TRAVEL AND PER DIEM**	$ 20,642

C. Fellow Support	**Year 1 Fellow Support**	**Year 2 Fellow Support**	**TOTAL FELLOW SUPPORT**
Fellow salary			
Indirect/Overhead Costs (@17.5%)			
Total, not to exceed $100,000	**YEAR 1 FELLOW SUPPORT** $	**YEAR 2 FELLOW SUPPORT**	

D. Page Charges					
Total, not to exceed $1800					1800

E. Salary support for Water Science Center Particpants during Working Group meetings ONLY	**Year 1 WSC salary**	**Year 2 WSC salary**	**TOTAL WSC SALARY SUPPORT**
n/a			
	YEAR 1 WSC SALARY $	**YEAR 2 WSC SALARY**	$

F. WORKING GROUP TOTAL EXPENSES	**Year 1 Total**		**Year 2 Total**		**WORKING GROUP TOTAL**
	Year 1 Travel & Per Diem	$ 20,642	Travel & Per Diem, also includes $1800 page charges	$ 22,442	$ 43,084

Notes

Travel Expense Details: The John Wesley Powell Center will reimburse for the following;

* Shuttle from the Denver International Airport to hotel
* Shuttle from hotel back to the Denver International Airport
* Parking at home airport (up to $70.00)
* Taxi (to home airport/back to residence. Up to $70.00)
* Hotel ($91.00 per night plus taxes); Meals ($56 per day) = $147 per Working Group participant per day

All receipts must be submitted for the items listed above. There is no need to submit meal