

Water Resource Sustainability
Peer Review Proposal to the LCCMR

2007

Submitted by

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I. Abstract.

This research will address the key science question: how landscape heterogeneity controls spatial and temporal variability of stream runoff, recharge/discharge flux and vadoze zone flux across the scales. To study this intimate relationship between these components of the terrestrial hydrologic system we propose *a novel and improved regionalization model* that integrates two parts: water balance characteristics quantification and hierarchical organization of landscape components. In this research we propose to build on previous research (Shmagin and Kanivetsky, 2002; Ruhl et al., 2002; Kanivetsky and Shmagin, 2005) by adding the *vadose zone* to existing hydrologic–hydrogeologic (surface water–ground water) regionalization. The hydrologic–hydrogeologic regionalization previously completed for Minnesota identifies hydrological units for stream runoff that are closely associated with ecological subdivisions, and hydrogeological units for ground water recharge/discharge that are closely associated with low-flow streamflow characteristics. By adding *vadose zone regionalization* the method will be *significantly improved* as we will make the regionalization of units more refined as well as the boundaries of units better defined.

The proposed research will test the following hypothesis: *The flux for surface–vadoze zone–ground water can be quantified using appropriate watershed characteristics (quantitative analysis) by subdividing landscapes into similarly functioning hierarchical structures (descriptive analysis) at multiple spatial scales.* Our method of analysis, known as *regionalization*, is based on the statistically significant differences in water balance characteristics distribution for hierarchical layers of flow fields for surface water–vadoze zone–ground water systems. We will test the variants in generalization for each layer of flow fields that provides three-dimensional watershed characteristics.

II. Background and Hypothesis.

Current State of Knowledge

Regionalization of hydrologic systems

The regionalization (the division of the whole into parts) as a research method is widely used in many branches of natural sciences. Surprisingly however, this research methodology is not widely used in hydrologic science. The fundamental concept of the regionalization method when applied to the hydrologic sciences is the systematization of the laws governing the spatial distribution and processes controlling hydrologic characteristics. The process of regionalization consists of: (1) the choice of characteristics by which land area is to be subdivided, and (2) the mapping of the boundaries of these characteristics (Pinneker, 1983). This is achieved by summarizing the regional data in hydrology, putting it in order, and mapping the hydrologically different land areas. That part of the Earth's landscape (surface and interior) which is distinguished by unity of characteristics of occurrence, or formation is described as an hydrological unit for regionalization. In hydrology the regionalization term is the isolation of land area units which differ from each other in hydrological features and characteristics. *The natural approach with a multi-scale quantification must be regarded as the key principle of hydrological regionalization and a guaranty of objectivity* (Pinneker, 1983).

The division of the territory into units depends upon the scale and the purpose for which the regionalization is being carried out, and also the methodology which the tasks of hydrological research require. Hydrological regionalization provides a comprehensive knowledge of the

hydrological laws for the territory under study as well as delivers the practical tools. The scale of regionalization is determined by the size of territory under study, the availability of information, as well as by imposed practical considerations. The most important method in regionalization is quantification of hierarchical structures of hydrological systems (Pinneker, 1983; Lin et al., 2006), because it reveals the hydrological laws of the territory under study.

For example, Pinneker (1983) suggests an elegant and properly ordered classification of the regions for ground-water systems that is founded on scientific information of hierarchical hydrogeological systems from global to local levels. Each region corresponds to a defined ground-water system. From the largest to the smallest the regions are placed in the following taxonomic order: province, subprovince, region, area, and district. Thus the hydrological unit is land area representing a ground water system. The result of distinguishing hydrogeological units in that manner is that the nomenclature of hydrogeological regions now becomes applicable for multi-scale regionalization at multiple scales, from global to local. Such nomenclature provides a much fuller characterization of a ground water system, than traditional descriptions of aquifers and confining beds. It can be used for quantification of water balance characteristics at multi-scale levels and in addition, such nomenclature provides a linkage to the landscape perspective. Such synergistic knowledge ideas as those developed by Pinneker (1983) for hydrogeological systems will be implemented in our project for the entire terrestrial system.

In contrast to scientific principles developed by Pinneker (1983) other researchers (e.g., Winter, 2001; Woolock et al., 2004; Vogel et al., 2005) do not use such scientific principles for regionalization described above and as a result their methods lack the scientific rigor and objectivity contained in the proposed approach. For example, Winter (2001) proposed the concept of hydrologic landscapes as a framework for objectively (author's word) conceptualizing the processes in ground water, surface water, and atmospheric water in different types of terrain. He defines the hydrologic landscape unit as land-surface form of upland adjacent to lowland separated by a steeper slope together with geologic framework and its climatic setting. His regionalization framework is based on 1) land-surface form; 2) geologic framework based on hydraulic properties; and 3) climatic setting based on difference between precipitation and evaporation. Such regionalization is based on matrices for measures of landforms, geology and a climate. For landform metrics his approach utilizes land slopes and offers six generalized Hydrologic Landscapes units including Mountain Valley, Playa, Plateau and High Plains, Riverine Valley, Coastal Terrain and Hummocky Terrain.

However, such a regionalization approach does not take into consideration the recognition of the similarity between land-surface forms (Strahler, 1958) and hydrology (Freeze and Cherry, 1979) of a watershed, and that the watershed (this term is also used for basin, catchments) should be a unit for regionalization of hydrologic system. His regionalization approach does not address an important hierarchical interrelationship between landscape and hydrologic system as presented above (Pinneker, 1983). In addition, using the matrix for hydraulic properties of geologic units does not acknowledge the hierarchical spatial organization of subsurface flow (local, intermediate, and regional) (Toth, 1963) as well as landscape system. Lastly, the use of the climate matrix is subjective, because the data on evaporation is estimated and not measured. Besides, the metrics use for such regionalization requires an enormous amount of data.

This concept of hydrologic landscapes has been embraced by other researchers (Wollock et al., 2004 and Vogel et al., 2005). Wollock et al. (2004) regionalized 20 hydrologic-landscape regions in the United States using geographic information system (GIS) tools combined with principal components (land-surface form, geologic texture, and climate variables) and cluster

analyses. These authors acknowledge that the regionalization is “objective in the sense that it is based on statistical methods applied to digital geospatial data”. According to these authors, the method used to regionalize hydrologic-landscape units is very sensitive to the spatial scale and such regionalization does not provide a bridge for multi-scale organization and quantification of hierarchical structures of hydrologic system. Vogel et al. (2005), have done the regionalization using digital network of streamflow, climate and watershed boundary. Although these authors adapt the watershed-based methodology for regionalization of water balance their model is not adequate because it does not address the hierarchical structures and spatio-temporal organization of the system and therefore their approach does not account for hydrological regionalization across the scales and also is not readily transferable elsewhere. Many researchers (Kroll et al., 2004; Vogel et al., 2005) point to the need for better characterization of landscape components of watersheds. This could be achieved by adapting science principles for regionalization as described by Pinneker (1983) and recognition of hierarchical structures for landscape components expressed in various maps and classifications.

CUAHSI (Maidment, 2005) is developing the hydrologic information system as a combination of hydrological data, tools and simulation models. Some of the important goals of this program are digital description of hydrologic regions such as river basin or an aquifer and an enhancement of our understanding of hydrological processes. While this geospatial information has an enormous value for studying processes over various scales and time, this program is lacking hydrological regionalization across spatial scales. A deeper insight into functioning of hydrological processes requires the recognition of the hydrologic similarity concept with the landscape perspective as well as hierarchical organization of all components of the terrestrial hydrologic system. In this respect the watershed as a unit with its soils, topography, geology, climate, hydrology and vegetation, and not some other subdivision of hydrologic scale classification (Maidment, 2002) or traditional aquifer classification allows an integrated research approach of different disciplines and their components to acquire better insights into the functioning of hydrologic processes with practical application. Combining the national geospatial databases for hydrology developed by CUAHSI with regionalization the method proposed by this project will make the hydrologic information system a powerful tool to address a wide array of emerging societal issues (e.g., sustainability of water resources).

The proposed research is *innovative* in that we will use an integrative systems approach by combining knowledge not only in different aspects of hydrology such as surface water, vadose zone and ground water, but also soils, topography, geology, climate and vegetation. We propose to use a regionalization technique with which we have quite some experience, but which has not been widely used by others for hydrologic analysis. We will focus on the *improvement of the regionalization method for hydrologic analysis by inclusion of the vadose zone*. While there is common knowledge (Smakhtin, 2001; Popov, 1968) for water balance characteristics for stream runoff and baseflow (as proxy for recharge/discharge flux), there is no present knowledge base on how to connect the vadose zone flux to stream runoff and baseflow characteristics. In particular, we will focus on this issue in order to determine the influence of the vadose zone on surface water – ground water interaction. Our proposed research activities will be the multi-scale quantification of surface water, vadose zone and ground water systems. Specifically, we will investigate linkages between these systems as well as association of water balance characteristics of these systems with soils, topography, geology, climate and vegetation. Because the regionalization method will be tested in Minnesota it is instructive to compare the

regionalization approaches available today for Minnesota. These alternative approaches are outlined in Table 1, and will be described briefly in the following text.

The regionalization map created by the Minnesota Department of Natural Resources (MN DNR) and used by other agencies (for instance, the Land Management Information Center and the Minnesota Pollution Control Agency) was compiled from pre-existing hydrogeological maps developed by Kanivetsky (1978, 1979). Those hydrogeologic maps pre-dated the application of the proposed regionalization method and therefore the MN DNR regionalization does not have a scientific basis. That is, the mapped units are not quantified by any hydrologic characteristics, and the boundaries of units are not defined by hydrologic characteristics, only hydrogeologic boundaries. Furthermore, the MN DNR maps do not reflect the connection between surface and ground waters and therefore cannot be used for a scientifically based multi-scale quantitative regionalization.

The Winona State University regionalization model frivolously uses the term “ground water provinces” by using bedrock aquifers nomenclature in Minnesota from State hydrogeologic maps (Kanivetsky, 1978).

The USGS study for Minnesota does not have regionalization at all and treats surface water and ground water as separate entities. For surface waters the USGS uses annual runoff rate from nationwide data and for ground water classification it uses the nomenclature of aquifer systems for glacial aquifers and aquifers for bedrock aquifers. Such description of hydrologic characteristics is inadequate to understand the processes and quantification of hydrological system and does not provide the knowledge to bridge multiple scales.

In summary, the present alternative regionalization approaches of hydrologic systems in Minnesota (Table 1) used by practitioners are not based on fundamentals of regionalization and are not adequate for addressing emerging issues in water resource sustainability.

In contrast, our hydrologic regionalization approach in Minnesota (Figures 1 and 2) shows functional patterns of hydrologic units for stream runoff and recharge/discharge as a proxy of minimal monthly stream runoff (Shmagin and Kanivetsky, 2002; Kanivetsky and Shmagin, 2005). Our method of regionalization bridges spatial scale and provides quantification of water fluxes because the more detailed levels are derived from more general levels (from global, to national, to state, to regional, to local scales; for example of several scales see Figures 1,2 and 3) (Shmagin and Kanivetsky, 2002; Ruhl et al., 2002).

Table 2 shows the units of regionalization and ranges in values for surface and ground water systems. There is no quantification of vadose zone systems as no quantification currently exists. Such quantification is an objective of the proposed research wherein a similar regionalization for agroecoregions representing the vadose system will be performed and this will then provide the basis for a linkage between the surface water, ground water and vadose zone systems.

We expect that the proposed research will result in new fundamental knowledge for any landscape regionalization by quantifying hierarchical structures, functional patterns and scale dependency of water balance characteristics for surface water-vadose zone-ground water systems. **The outcome of this research will be a regionalization model that is three dimensional and applicable across spatial scale: from global, to national, to regional, to local.**

Table 1. Regionalization methods of hydrologic systems in Minnesota

Agency	Regionalization method	Units	Location
Minnesota Geological Survey	Watershed Characteristics	Ecohydrologic (see Figures 1, 2, 3 and Table 2)	(Shmagin and Kanivetsky, 2002; Ruhl et al., 2002; Kanivetsky and Shmagin, 2005)
Minnesota Department of Natural Resources (MN DNR)	Ground water provinces	Geographic Nomenclature	http://www.dnr.state.mn.us/groundwater/provinces/index.html
Land Management Information Center (LMIC)	Same	Same	http://www.lmic.state.mn.us/chouse/metadata/gwprovs.html
Minnesota Pollution Control Agency (MPCA)	Same	Same	http://www.geo.umn.edu/mgs/gwig/index.html
Winona State University	Ground water provinces	Aquifers Nomenclature	http://www.winona.edu/geology/2629.htm
USGS	No system for regionalization, but depiction of runoff and aquifer systems	Average annual runoff rate and nomenclature of aquifer systems and aquifers	http://capp.water.usgs.gov/gwa/ch_j/index.html

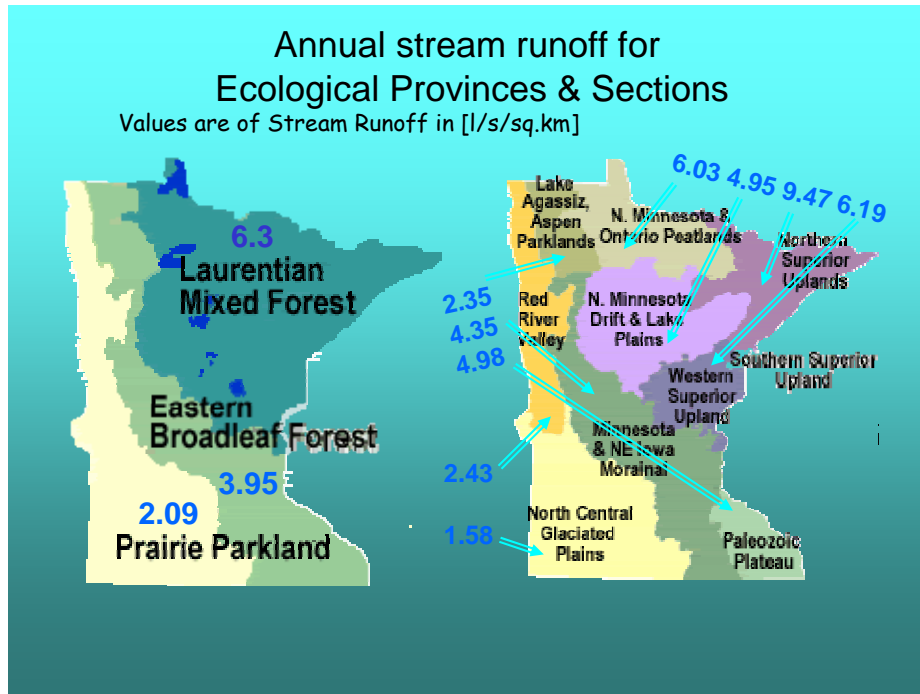


Figure 1. Regionalization of surface water systems in Minnesota (Shmagin and Kanivetsky, 2002; Kanivetsky and Shmagin, 2005)

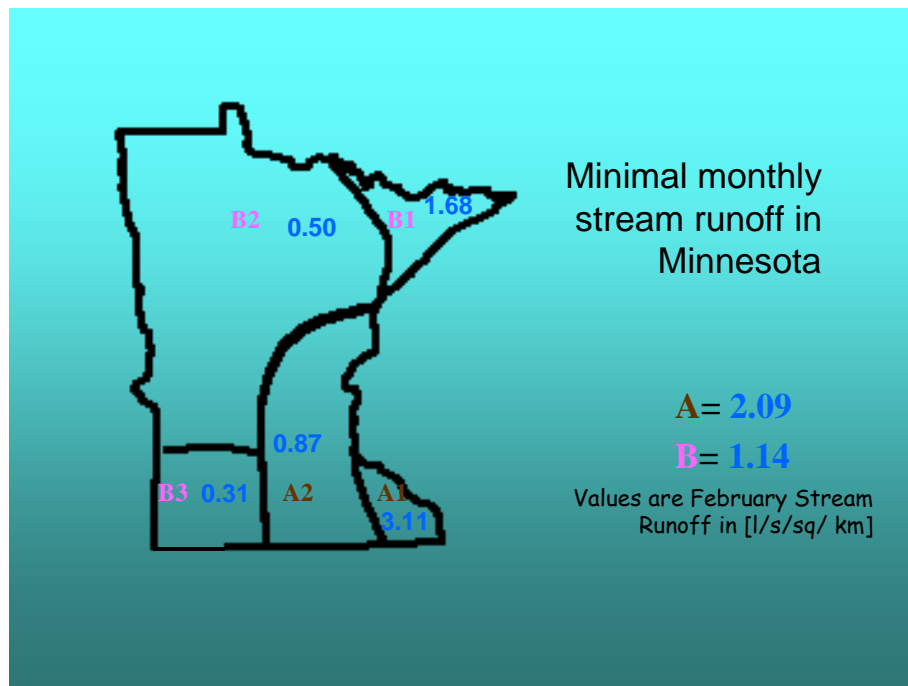


Figure 2. Regionalization of ground water systems in Minnesota (Shmagin and Kanivetsky, 2002; Kanivetsky and Shmagin, 2005). A- Artesian Basin; B – Precambrian Basement

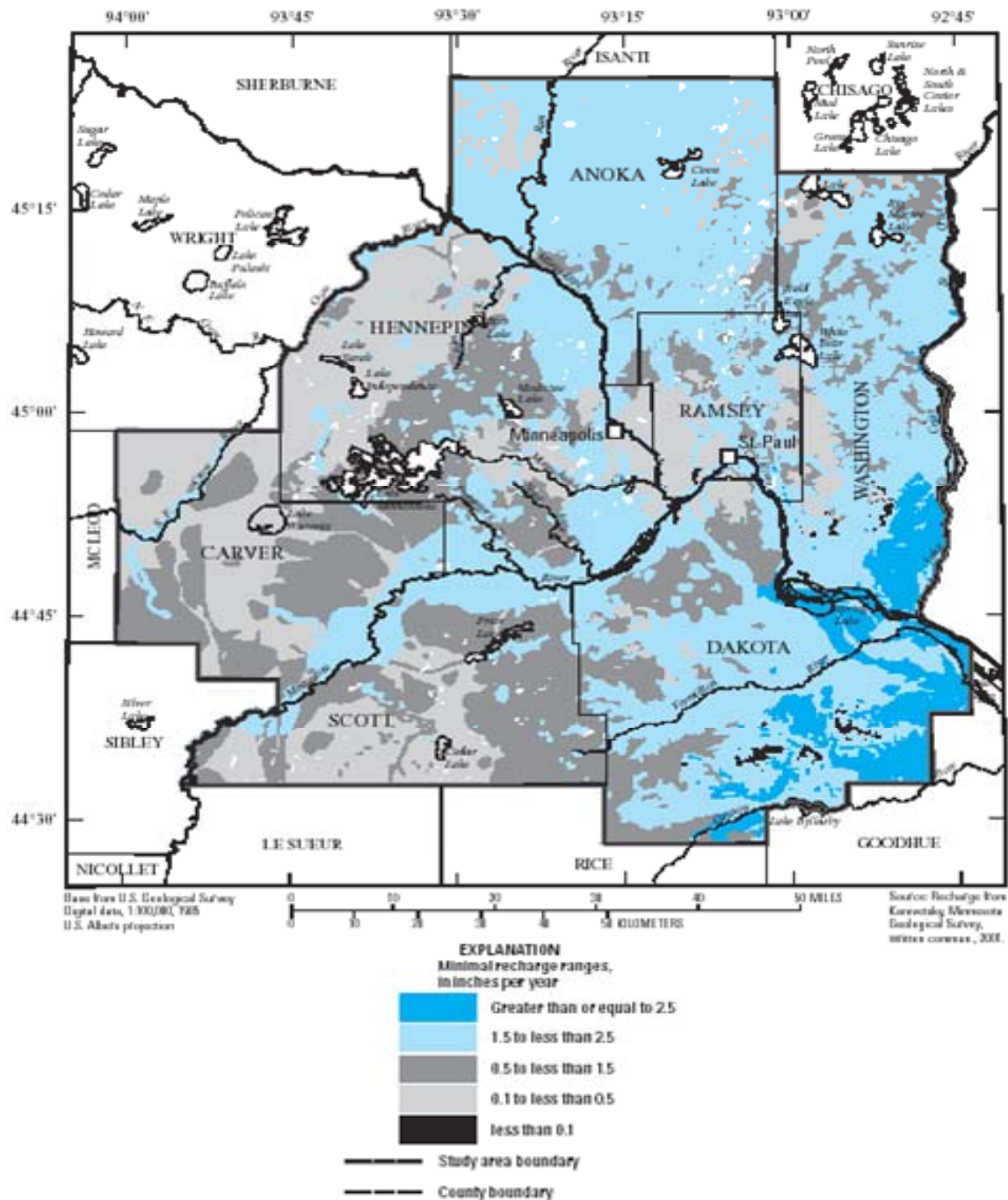


Figure 3. Regionalization of ground water systems in the Twin Cities Metro area, Minnesota (Shmagin and Kanivetsky, 2002; Kanivetsky and Shmagin, 2005)

Table 2. Units of regionalization and their quantification for surface and ground water systems derived from *watershed characteristics method*, and agroecological classification for the vadose zone without quantification.

Hydrologic regionalization (surface water)	Units Value Range l/s/sq.km	Hydrogeologic regionalization (ground water)	Units Value Range l/s/sq.km	Agroecologic classification (vadose zone)	Units Value Range l/s/sq.km
Ecological provinces state (4 units)	2.09 – 6.3	Hydrogeologic regions state (5 units)	0.31 – 3.11	Agroecoregions units state (39 units)	<i>No estimation</i>
Ecological Sections more detail (9 units)	1.58 – 9.47	Hydrogeologic subregions East Central Minnesota (22 units)	0.59 – 3.11	Agroecoregions units Minnesota River basin (13 units)	<i>No estimation</i>
Not Applicable	Not Applicable	Hydrogeologic Districts and subdistricts, Twin Cities (based on units of hierarchical units on map)	Less than 0.1 to greater than 2.5 (see Figure 3)	Not Applicable	Not Applicable

Hypothesis

Based on the above discussion and recognizing the enormous knowledge gap in hydrologic regionalization, we suggest the following hypothesis: **The flux of water at the surface, in the vadose zone, and in the saturated zone can be quantified using appropriate watershed characteristics to subdivide the landscape into similarly functioning hierarchical structures at multiple scales.** By adding the vadose zone into our model we hypothesize that our regionalization method will be improved by refinement in quantification of runoff characteristics and better definition of boundaries for units of regionalization.

III. Description of the methodology to be employed to carry out the proposed research.

Research Approach

The method will be tested for landscapes in the State of Minnesota as follows (Figure 4):

- 1) State of Minnesota at a scale 1:3,000,000.
- 2) Areas where the method will be tested at greater level of detail will include:
 - a) The area of intensive ground water use in the Twin Cities-St. Cloud (TCSC) urban corridor;
 - b) The area of the Karst region in southeast Minnesota;
 - c) The area of the counties for Olmsted (Karst), Lac Qui Parle and Pope (sand plains) counties.

The principles of regionalization and tasks are the same for any scale, but the process of regionalization proceeds from large scale such as the State of Minnesota (1:3,000,000) to regional scale of 1:500,000 and finally to detail 1:200,000. We will test our hypothesis with outcome (results) by applying first to the state and then to regional scales for the TCSC by adding vadose classification, where the rigorous analysis has been performed previously. The result will be enhanced characterization of water balance characteristics and better statistical quantification of the boundary definition for the units of regionalization.

After testing the hypothesis at the state and the regional (TCSC) levels we will test the method for landscapes in the test areas specified above. The objectives listed for the proposed research will be achieved by carrying out the following tasks.

Task 1: Compilation of the hierarchy of flow fields within the landscape based on ecological (surface water system), agroecological (vadose zone) and hydrogeological units (ground water system). Computation and analysis of runoff rates and ground water recharge/discharge rates and preparation of atlases of stream runoff and ground water recharge/discharge. Prepare state-wide maps of flow fields at the 1:3,000,000 scale, and similar maps for Southeastern Minnesota and the Twin Cities – St. Cloud Corridor at the 1:500,000 scale, and for Olmsted, Pope and Lac Qui Parle counties at the 1:100 000 to 1:200 000 scales. Using these flow field results we will develop estimates of surface runoff and ground water recharge/discharge at the same spatial scales. From these estimates we will develop atlases of stream runoff and ground water recharge/discharge at the same spatial scales. The developed atlases will be basic information for assessment of water resource sustainability. Note that detailed maps and atlases for other regions and counties of the state cannot be produced within the scope of the proposed budget. The study areas selected for analysis in the present work will be used to demonstrate that the proposed approach does work as expected. It will require additional follow-up work (and funding) to complete maps and atlases for other counties and other regions of the state.

Task 2: Develop materials needed in a quantitative information system (QIS) for surface and ground water sustainability. It is desirable to develop a QIS which will be an expert information and decision support system to compare sustainable supply with water use. To support the future development of this QIS, the water resources sustainability atlases for study areas within the project will be converted as overlays onto GIS databases that will also include the spatial distribution of water use/demand.

Task 3: County level test of the sustainable supply estimation methodology. The water use and the estimated sustainable supply of water in Olmsted, Pope and Lac Qui Parle counties will be compared as case study tests of the methodology used here to estimate sustainable supply. Data from various agencies will be collated related to water use within the borders of these counties by municipalities, private residences, agriculture, and industries. Those data will be compared to the estimates of sustainable supply developed with the method proposed in this project. The data base developed for the QIS for water resource sustainability for each of these counties will be applied in this analysis and this will provide a test of the QIS materials developed within the project.

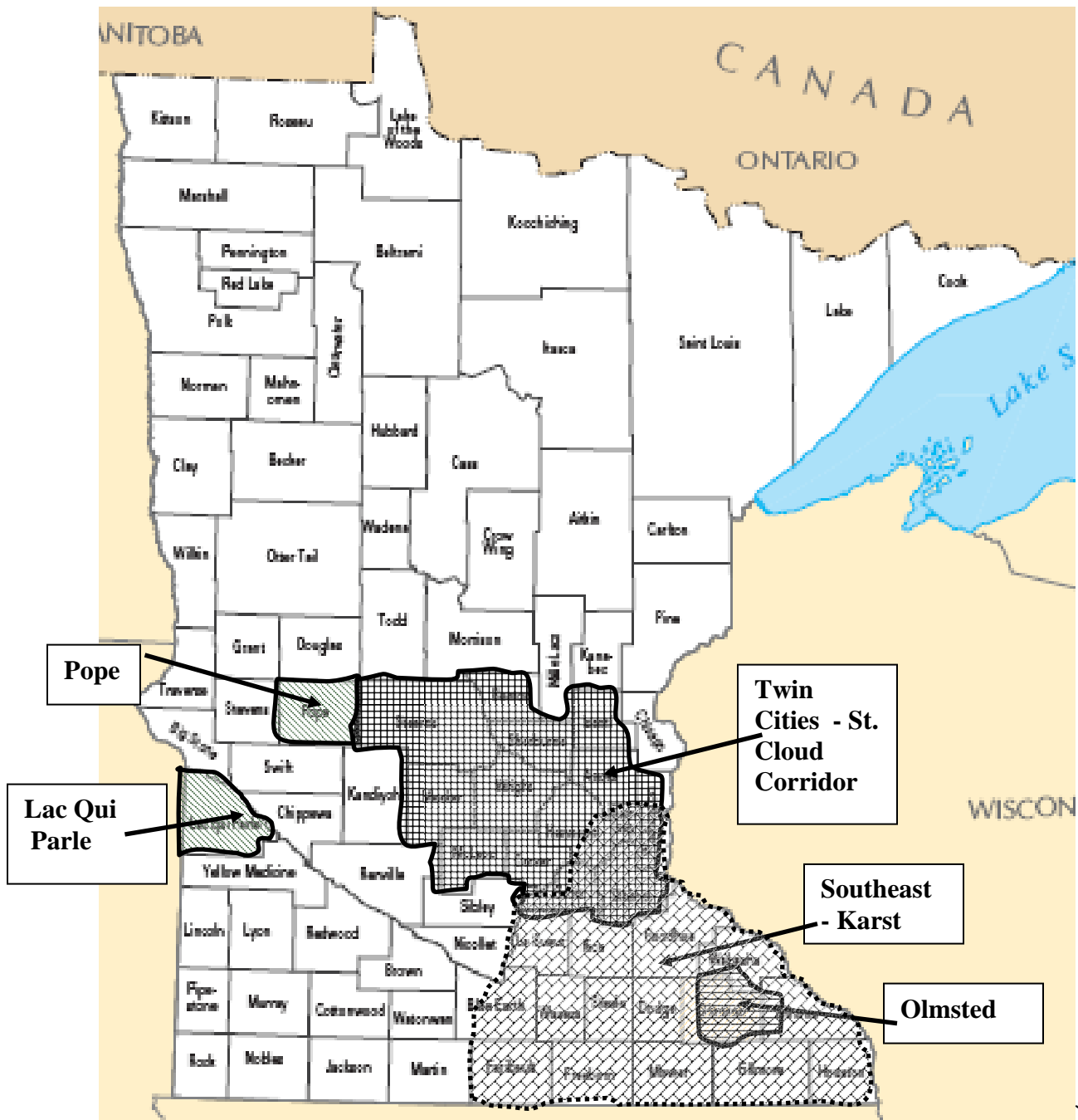


Figure 4. Location: Statewide; Southeastern Minnesota (Karst region); Twin Cities – St. Cloud Corridor; and Olmsted, Pope and Lac Qui Parle counties. There is an overlap of the Twin Cities – St. Cloud Corridor region with the Karst (Southeast) region.

Limitations of the Proposed Research

While our proposed research will develop a method for regionalization at any scale, it must be recognized that because of paucity of streamflow data the scale cannot be more detailed than 1:100,000 – 1:200,000. However, because of ever increasing availability of geospatial data in hydrology (CUAHSI effort) and related to landscape water flux fields it appears that results at refined scales will be feasible in the future.

The accuracy of the method depends on correct selection of the benchmark series of runoff characteristics as well as correct maps reflecting landscape components. The work done in Minnesota (Shmagin and Kanivetsky, 2002, Ruhl et al., 2002; Kanivetsky and Shmagin, 2005) is a confirmation that both features are selected correctly. We expect that the vadose zone characteristics will be correctly selected from the benchmark series and then associated with the agroecoregions using the regionalization principles described above.

IV. Deliverables

Task 1. Detailed maps and associated statistics of the distribution and hierarchy of flow fields will be prepared for various spatial scales including the entire State of Minnesota, selected regions (Twin Cities Metro-St. Cloud corridor and for the southeast Karst area), and selected counties (three).

Task 2. GIS data bases and associated maps and hydrologic parameters will be developed for the State of Minnesota, selected regions and for three counties. These data bases will be developed for use in the quantitative information system (QIS) for comparison of actual water use with sustainable supply.

Task 3. A report that provides a clear demonstration of the comparison of actual water use with sustainable supply for the three counties. The report will provide a summary of actual and projected water use in those counties, and will show how the water supply is either allocated correctly or overallocated.

V. Time table for completing the proposed research.

Project Schedule

A timeline for the progress for activities in the project is presented in Table 3.

Table 3. Timeline for progress on the various task activities of the proposed research. Month 1 is July 2007.

Tasks	Month in project																							
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
1	X	X	X	X	X	X	X	X	X	X	X	X	X	X	*									
2									X	X	X	X	X	X	X	X	X	*						
3																X	X	X	X	X	X	X	X	X*

* Indicates the date for completion of task deliverables.

VI. Deliverable products.

The deliverable products for the project are outlined in section IV. The final delivery dates for these products are listed in Table 3. The cost for the product outlined for the first task is \$204,000, while the cost for the products of the second two tasks are \$44,000 for each task. This comes to a total of \$292,000 for the project.

VII. Budget

Salaries:

Dr. John L. Nieber, UofM, \$12,180
 Dr. Bruce N. Wilson, UofM, \$12,180
 Dr. David Mulla, UofM, \$12,180
 Dr. Roman Kanivetsky, UofM, \$67,666
 Dr. Boris Shmagin, SDSU, \$17,763
 Graduate Research Assistants, \$82,824
 Undergrad Research Assistant, \$8,877

Fringe Benefits:

32.8% of salary for Nieber, Wilson, Mulla, \$11,985
 13.4% of salary for Kanivetsky, \$9,068
 70% of salary for Graduate Research Assistants, \$52,593
 7.7% of salary for Undergrad Research Assistant, \$684

Travel:

For visits between UofM and SDSU, \$4,000

Total budget: \$292,000

VIII. References Cited

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IX. Curriculum Vitae of Investigators

CURRICULUM VITAE

Dr. John L. Nieber
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Academic Background:

B. S. Forest Engineering, Syracuse Univ., 1972
M. S. Civil and Envir. Eng., Cornell Univ., 1974
Ph.D. Agricultural Engineering, Cornell Univ., 1979

Professional Experience:

1995-present Professor Agr. Eng. Dept., Univ. of MN.
1985-1995 Assoc. Professor Agr. Eng. Dept., Univ. of MN.
1979-1985 Asst Professor, Agr. Eng. Dept., Texas A&M Univ.
1975-1979 Graduate Res. & Teaching Asst. Agr. Eng. Dept., Cornell University
1973-1975 Res. Tech. Agr. Eng. Dept., Cornell Univ.
1972-1973 Teaching Asst. Civil & Envir. Eng., Cornell Univ.

Courses Taught:

Finite Element Method; Fundamentals and Applications. Basic theory and implementation of the finite element method for a number of fundamental engineering areas.
Water Management Engineering. Applying engineering principles to managing water for production and environmental protection in agricultural systems.
Mechanics of Flow in the Unsaturated Zone. Fluid retention and transmission properties of porous media for single and multiphase systems. Analytical and numerical solution of the equations for single and multiphase flow in porous media.
Coupled heat, moisture and solute transport in porous media. Modeling of coupled heat, moisture and solute transport in porous media, including geological materials and biological materials.
Small Watershed Hydrology. Theory underlying concepts of water movement in the land phase of the hydrologic cycle. Special applications to modeling surface runoff and subsurface flow processes in the small scale.
Soil and Water Conservation Engineering. Principles of water control to prevent soil erosion and flooding.
Transport in Biological Systems. Principles of heat and mass transport in biological materials and systems.

Research Experience:

Mathematical models describing multiphase fluid flow, and mass and energy transport in the unsaturated zone including phase change, chemical reactions and biodegradation. Hydrologic modeling and monitoring of watershed physical and biogeochemical processes. Assessment of TMDLs and evaluation of TMDL assessment tools.

Publications List: (30+ publications)

Last 4 years and earlier relevant publications:

- Allaire, S.E., S.C. Gupta, J. NIEBER, and J.F. Moncrief. 2002. Role of macropore continuity on solute transport in soil: 1. Effects of initial and boundary conditions. *J. Cont. Hydrol.* 58: 299-321.
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- Cohen, D., M. Person, R. Daanen, S. Locke, D. Dahlstrom, V. Zabielski, T.C. Winter, D.O. Rosenberry, H. Wright, E. Ito, J.L. NIEBER and W.J. Gutowski, Jr., 2006. Groundwater-supported evapotranspiration within glaciated watersheds under conditions of climate change, *J. Hydrol.*, 320(3-4):484-500.
- Egorov, A., R. Dautov, J.L. NIEBER, and A. Sheshukov, 2003. Stability analysis of gravity-driven infiltrating flow, *Water Resour. Res.* 39: doi:10. 1029/2002WR001886
- Filby, S.K., S.M. Locke, M.A. Person, T.C. Winter, D.O. Rosenberry, J.L. NIEBER, W.J. Gutowski and E. Ito, 2002. Mid-Holocene hydrologic model of the Shingobee Watershed, Minnesota, *Quaternary Res.*, 58:246-254.
- NIEBER, J.L., R. Dautov, A. Egorov, and A. Shehsukov, 2005. Dynamic capillary pressure mechanism for gravity-driven flows; review and extension to dry conditions, *Transport in Porous Media*, 58: 147-172.
- NIEBER, J.L., T.S. Steenhuis, T. Walter, and M. Bakker, 2006. Enhancement of seepage and lateral preferential flow by biopores on hillslopes, *Biologia*, 61: S225-S228 Suppl. 19, 2006
- van den Eertwegh, G.A.P.H., J.L. NIEBER, P.G.B. de Louw, H.A. van Hardeveld, and R. Bakkum, 2006. Impacts of drainage activities for clay soils on hydrology and solute loads to surface water, *Irrig. and Drainage*, 55: 235-245

VITAE
Bruce N. Wilson, Professor
Department of Bioproducts and Biosystems Engineering
University of Minnesota

Expertise:

Modeling and experimental analyses of erosion mechanics and hydrologic/water quality processes of watersheds. Special emphasis on processes related to agricultural watershed and site disturbed by construction and urbanization.

Education

Ph.D University of Kentucky, Agricultural Engineering (1984)
M.Sc. University of Minnesota, Agricultural Engineering (1979)
B.Sc University of Minnesota, Agricultural Engineering (1976)

Professional Experience

1983-1991: Assistant and Associate Professor
 Agricultural Engineering Department
 Oklahoma State University
1991- present: Assistant, Associate and Full Professor
 Bioproducts/Biosystems/Agricultural Engineering Department
 University of Minnesota

Professional Registration

Registered Professional Engineer: Oklahoma
Registered Professional Hydrologist

Summary of Activities

Publications:

Books/Manuals:	4
Referred Journal Articles:	40
Published Symposium/Meeting Papers:	66
Technical Reports:	16
Total	126

Invited Presentations:

Out-Of-State Presentations:	3
In-State Presentations:	19

Graduate Student Advising

Different Courses Taught:	12	
Graduate Advisor:	22 M.S.	8 Ph.D.
Non-advisor Graduate Committee Member:	53 M.S.	48 Ph. D.

External Grants

Lead Investigator	22 projects	\$4,500,00
Co-Investigator	18 projects	\$4,000,000
Total:		
Lead/Co-Investigator	40 projects	\$8,500,000

Selected Awards

Semi-finalist for Oklahoma State University's Outstanding Graduate Teaching Award (1988).

Technical Paper Award by the American Society of Agricultural Engineering (1989).
 Honorable Mention Technical Paper Award by the American Society of Agricultural Engineering (1986, 1987, 1991).
 Outstanding Technical Reviewer for the American Society of Agricultural Engineering (1990, 1991, 1994, 2002)
 Distinguished Contribution to Undergraduate Education, ASAE Student Branch (1997).
 Outstanding Contribution Advancing the State of the Art of Controlling Erosion. Minnesota Erosion Control Association (1998).
 Research Partnership Award, Center for Transportation Studies (2000).
 Professor of the Year, Department of Biosystems and Agricultural Engineering, The Institute of Technology Student Board (2002).

Selected Publications:

- Thompson, A.M. and B.N. Wilson. 2003. Drag on elements representative of vegetation in overland flow. *Transactions of the ASAE*, Vol. 46(2): 295-302.
- Burt, E.A. and B.N. Wilson. 2003. Sediment control practices for surface tile inlets. *Applied Engineering in Agriculture*, Vol. 19(1): 161-169.
- Benik, S.R., B. N. Wilson, D. D. Biesboer, B. Hansen, and D. Stenlund. 2003. Evaluation of erosion control products using natural rainfall events. *Journal of Soil and Water Conservation*, Vol. 58(2): 98-104.
- Benik, S.R., B. N. Wilson, D. D. Biesboer, B. Hansen, and D. Stenlund. 2003. Performance of erosion control products on a highway embankment. *Transactions of the ASAE*. Vol. 46(4): 1113-1119.
- Wilson, B.N. and P. Oduro. 2004. Sensitivity coefficients for the GAML infiltration model. *Transactions of the ASAE*, Vol. 47(2): 479-484.
- Thompson, A.M. and B.N. Wilson. 2004. Calibration accuracy for a constant temperature thermal anemometer. *Journal of Hydraulic Engineering*, ASCE, Vol. 130(8):833-836..
- Thompson, A.M., B.N. Wilson, and B.J. Hansen. 2004. Shear stress partitioning for idealized vegetated surfaces. *Transactions of the ASAE*, Vol. 47(3): 701-709.
- Lindley, M.R., Barfield, B.J., Ascough, J.C., Wilson, B.N., and Stevens, E.W. 1998. Hydraulic Simulation Techniques Incorporated in the Surface Impoundment Element of WEPP. *Applied Engineering in Agriculture*, Vol. 14(3): 249-256.
- Wilson, B.N., R. Leaf, and B. Hansen. 2001. Microrelief meter for field topography measurements. *Transactions of the ASAE*, Vol. 44(2): 289-295.
- Thompson, A.M. and B.N. Wilson. 2003. Drag on elements representative of vegetation in overland flow. *Transactions of the ASAE*, Vol. 46(2): 295-302.
- Wilson, B.N. and Aleksey Y. Sheshukov. 2006. A Process Based Erosion and Sediment Model for Construction Sites. Conference of World Environmental and Water Resources Congress. Omaha, NE.
- Wilson, B.N. and J.C. Hayes. 2004. Modeling Erosion and Transport of Sediment from Urbanizing Landscapes. Proceedings of the 6th International Conference on Hydro-Science and -Engineering, Brisbane, Australia.
- Singh, Udai, M. Kocian, B.N. Wilson, A. Bolton, J. L. Nieber, B. Vondracek, J.Perry, and J. Magner. 2005. Analyzing Indicators of Stream Health for Minnesota Streams. Watershed management to meet water quality standards and emerging TMDL, Proceedings of the 5-9 March 2005 conference, American Society of Agricultural Engineers, 2950 Niles Road, St. Joseph, Michigan 49085-9659. pp. 570-577.

Dr. David Mulla

David Mulla, Ph.D.

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Education

B.S., Geophysics, University of California at Riverside, 1979
M.S., Soil Chemistry, Purdue University, 1981
Ph.D., Soil Physics, Purdue University, 1983

Experience

Assistant Professor, Dept. of Crop and Soil Sciences, Washington State University, 1983-1988
Associate Professor, Dept. of Crop and Soil Sciences, Washington State University, 1988-1993
Professor, Dept. of Crop and Soil Sciences, Washington State University, 1993-1995
W.E. Larson Chair for Soil and Water Resources, Dept. of Soil, Water and Climate, University of Minnesota, 1995-present

Professional Associations

Fellow of the Soil Science Society of American and Agronomy Society of America
Associate Editor for Journal of Precision Agriculture
Past Chair of the Soil Physics Division of SSSA
Technical Editor for the SSSA in Soil Physics
Past member of the Gulf of Mexico Hypoxia Work Group for the White House Committee on Environment and Natural Resources
Member of the Lake Pepin TMDL Scientific Advisory

International Activities

Consultant to the United Nations for Water Resource Protection in Lebanon
USAID projects for soil erosion control or water conservation in Morocco, Jordan and Sri Lanka.
Taught short courses at universities in Paris, France, Wageningen, Holland, and Berlin, Germany
Invited to present findings from his research in Switzerland, Sweden, France, Italy, Japan, Mexico, England, Brazil, India and Holland.

Selected Publications (out of 140+)

- Davis, D. M., P. H. Gowda, D. J. Mulla, and G. W. Randall. 2000. Modeling nitrate nitrogen leaching in response to nitrogen fertilizer rate and tile drain depth or spacing for southern Minnesota, USA. *J. Environ. Qual.* 29:1568-1581.
- Randall, G. W. and D. J. Mulla. 2001. Nitrate-N in surface waters as influenced by climatic conditions and agricultural practices. *J. Environ. Qual.* 30:337-344.
- Gowda, P. H., B. J. Dalzell, D. J. Mulla, and F. Kollman. 2001. Mapping tillage practices with Landsat Thematic Mapper based logistic regression models. *J. Soil Water Conservation* 56:14-19.
- Hatch, L. K., A. P. Mallawatantri, D. Wheeler, A. Gleason, D. J. Mulla, J. A. Perry, K. W. Easter, P. Brezonik, R. Smith, and L. Gerlach. 2001. Land management at the major watershed - agroecoregion intersection. *J. Soil Water Conservation* 56:44-51.
- Birr, A. S. and D. J. Mulla. 2001. Evaluation of phosphorus site index in watersheds at the regional scale. *J. Environ. Quality.* 30:2018-2025.
- Sekely, A. C., D. J. Mulla, and D. W. Bauer. 2002. Streambank slumping and its contribution to the phosphorus and suspended sediment loads of the Blue Earth River, Minnesota. *J. Soil Water Conservation.* 57(5):243-250.
- Birr, A. S. and D. J. Mulla. 2002. Relationship between lake and ground water quality patterns and Minnesota agroecoregions. *Hydrological Sci. Tech.* 18(1-4):31-41.
- Fang, F., P. L. Brezonik, D. J. Mulla, and L. K. Hatch. 2002. Estimating runoff phosphorus losses from calcareous soils in the Minnesota River Basin. *J. Environ. Quality* 31(6):1918-1929.
- Gowda, P. H., D. J. Mulla, and B. J. Dalzell. 2003. Examining the targeting of conservation tillage to steep vs. flat landscapes in the Minnesota River Basin. *J. Soil Water Conservation* 58:53-57.
- Johansson, R. C., P. H. Gowda, D. J. Mulla, and B. J. Dalzell. 2004. Metamodeling phosphorus best management practices for policy use: A frontier approach. *Am. J. Agricultural Economics* 30(1):63-74.
- Updegraff, K., P. Gowda, and D. J. Mulla. 2004. Watershed scale modeling of the water quality effects of cropland conversion to short rotation woody crops. *Renewable Agric. Food Systems* 19(2):1-11.
- Dalzell, B. J., P. H. Gowda, and D. J. Mulla. 2004. Modeling sediment and phosphorus losses in an agricultural watershed to meet TMDLs. *J. Am. Water Resources Assoc.* 40(2):533-543.
- Fang, F., P. L. Brezonik, D. J. Mulla, and L. K. Hatch. 2005. Characterization of soil bioavailable phosphorus in the Minnesota River basin. *Soil Sci. Soc. Am. J.* 69:1016-1025. <http://soil.scijournals.org/cgi/content/full/69/4/1016>
- J.S. Strock, D. Bruening, J.D. Apland, and D.J. Mulla, 2005. Farm nutrient management practices in two geographically diverse watersheds in the Cottonwood River Watershed of Minnesota. *J. Water Air Soil Pollution* 165:211-231.
- Rolf, K., J. Strock and D. Mulla. 2006. Influence of alternative and conventional management practices on soil physical and hydraulic properties. *Vadose Zone J.* Accepted.

CURRICULUM VITAE

Roman Kanivetsky, Adjunct Professor

Department of Bioproducts and Biosystems Engineering, University of Minnesota

A. Professional Preparation

B.S., Mining Technology, 1958, Mining College, Tallinn, Estonia

M.S. Hydrogeology and Engineering, 1967, Leningrad Mining Institute, Leningrad, USSR

Sc.D. Hydrogeology, 1989, Leningrad Mining Institute, Leningrad, USSR

B. Appointments

January, 2006 – Present, Dept. of Bioproducts and Biosystems Engineering, University of Minnesota, Adjunct Professor

June 2003 – December 2005, Minnesota Geological Survey, Research Associate.

April, 78 – June 2003, Minnesota Geological Survey, Senior Scientist-Hydrogeologist.

April-August, 82, Geological Survey of Finland, Kuopio, Finland, Research Hydrogeologist.

July, 77 - March, 78, Department of Natural Resources, St. Paul, MN, Principal Hydrologist.

August, 76 - June, 77, Minnesota Geological Survey, Senior Hydrogeologist.

April, 76 - July, 76, Minnesota Department of Natural Resources, St. Paul, MN, Hydrogeologist.

1974 – 1975, Northwestern Territory Geological Survey, Leningrad, USSR, Hydrogeologist.

1968 – 1971, Northwestern Territory Geological Survey, Leningrad, USSR, Hydrogeologist.

1971 – 1974, USSR Mission to Mongolia, Barun-Urt, Mongolia, Engineer in Charge.

C. Publications

Closely related publications:

Kanivetsky, R., 1978, Hydrogeologic map of Minnesota, bedrock hydrogeology: Minnesota Geological Survey, State Map Series S-2, scale 1:500,000.

Kanivetsky, R., 1979, Hydrogeologic map of Minnesota, Quaternary hydrogeology: Minnesota Geological Survey, State Map Series S-3, scale 1:500,000.

Kanivetsky, R., 1979, Regional approach to estimating the ground-water resources of Minnesota: Report of Investigations 22, Minnesota Geological Survey, Univ. of Minnesota, 13 p.

Kanivetsky, R., and Palen, B., 1986, Ground-Water Recharge rates in Minnesota as related to precipitation: University of Minnesota Water Resources Res. Center Bulletin 114, 37 p.

Shmagin and **Kanivetsky, R.**, 2000, Systems approach for assessment of renewable ground and surface water resources – Minnesota example, Hydrological Science and Technology, vol.16, no. 1-4, pp.25-34.

Kanivetsky, R., and B.A. Shmagin, 2001, Watershed hydrogeologic characteristics method (a supplement to the map: Minimal annual ground-water recharge in the Twin Cities Seven-County Metropolitan area): unpublished report, 8 p., will be included in USGS Report “Ground-Water Recharge in the Seven-County Metropolitan area of Minneapolis-St. Paul, Minnesota” in 2002.

Ruhl, J. F, **Kanivetsky, R.**, and Shmagin, B., 2002, Estimates of recharge to unconfined aquifers and leakage to confining aquifers in the seven-county metropolitan area of Minneapolis-St. Paul, Minnesota: U.S. Geological Survey Water-Resources Investigations Report 02-4092, 32 p.

Shmagin, B., A., and **Kanivetsky, R.**, 2002, System analysis to estimate subsurface flow: from global level to the State of Minnesota: Environmental Geology, Springer-Verlag, v. 42, no.203, pp. 259-269.

Kanivetsky, R., and Shmagin, B., 2005, Quantifying Freshwater Sustainability Through Multi-Scale Mapping: EOS, AGU, Volume 86 number 50, 13 December 2005, pp. 521, 524

Shmagin, B., and **Kanivetsky, R.**, 2006, Regional Hydrology: Tools vs. Ideas, Published in Coastal Hydrology and Processes (ed. by V. P. Singh & Y. J. Xu), 183-196, © 2006 Water Resources Publications, LLC, Highlands Ranch, CO 80163-0026, USA

D. Synergistic Research Activities

System approach to quantify stream runoff and base flow from global to local scale.

Ecohydrologic Approach to Multi-Scale Quantification of Regional Recharge/Discharge.

Down-scaling and up-scaling of hydrologic characteristics for quantification of water sustainability.

Mapping of hydrogeologic parameters and hydrologic characteristics across the scales.

Serving on task forces and on water boards for sustainable management of water resources.

E. Collaborators

Boris Shmagin, South Dakota State University

Vincent Gorokhovski, University of Georgia

John Nieber, University of Minnesota

Olaf Pfannkuch, University of Minnesota

Otto Strack, University of Minnesota

Randal Barnes, University of Minnesota

John Wells, Environmental Quality Board

Chin Fu Tsang, Lawrence Livermore Lab

Bruce Olsen, Minnesota Geological Survey

Matt Walton, Minnesota Geological Survey

James Stark, USGS

Geoff Delin, USGS

Janes Ruhl, USGS

Alex Zaporozec, University of Wisconsin

Sandor Scallany, SCENECO

Kinshiro Nakao, University of Hokkaido, Japan

Eiji Tokunaga, University of Chuo, Japan

Valery Mironenko, University of St. Petersburg, Russia

Vyacheslav Rumynin, University of St. Petersburg, Russia

Igor Zektser, Russian Academy of Science

Roald Dzhmalov, Russian Academy of Science

BORIS A. SHMAGIN

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Fax: (605) 688-6764
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PROFESSIONAL PREPARATION

Moscow State University, Russia	Hydrogeology	M.S., 1970
Moscow State University, Russia	Geology and Hydrogeology	Ph. D., 1979
Komensky University, Bratislava, Charles University, Prague, Czechoslovakia	Mathematical Geology	Postdoctoral 1981-82

APPOINTMENTS

2004- present	Research Associate Professor , Water Resources Institute, South Dakota State University, Brookings, SD.
2003-2004	Research Associate , Water Resources Institute, South Dakota State University, Brookings, SD.
2003-2002	Research Associate , Department of Geological Sciences, University of Minnesota, Duluth MN
2002	Expert , National Science Foundation, Geosciences Directorate, Hydrology Program, Arlington VA
1999-2001	Research Associate , Department of Geological Sciences, University of Minnesota, Duluth MN
1996-1999	Visiting Researcher, Adjunct Associate Professor , Department of Geological Sciences, University of Minnesota, Duluth MN
1970-1996	Junior - Senior Research Associate , Department of Hydrogeology, Moscow State University, Russia

SCIENTIFIC AND PROFESSIONAL ORGANIZATIONS

Membership:

American Institute of Hydrology
American Geophysical Union

GRANTS:

2002-2006 U.S. Environmental Protection Agency (Grant No. R829643). "Interactive Effects of Climate Change, Wetlands, and Dissolved Organic Matter on UV Damage to Aquatic Foodwebs." \$897,307. Co-Principal Investigator.

FIVE PUBLICATIONS MOST RELATED TO PROJECT:

Ruhl, James F., Roman Kanivetsky, and Boris Shmagin. 2002. Estimation of Recharge to Unconfined Aquifers and Leakage to Confined Aquifers in the Seven-County Metropolitan Area of Minneapolis-St. Paul, Minnesota. Water-Resources Investigation Report 02-4092. U.S. Geological Survey, Mound View, Minnesota.

Shmagin, B. A., and R. Kanivetsky. 2002. System analysis to estimate subsurface flow: from global level to the State of Minnesota. *Environmental Geology* 42:259-269.

Shmagin B. and R. Kanivetsky. 2000. Systems Approach for Assessment of Renewable Ground and Surface Water Resources: Minnesota Example. *Hydrological Science and Technology*, v. 16, No 1-4, p. 25-34.

- Shmagin, B.A. 2000. Seasonal river discharge in Minnesota, U. S. and its multidimensional statistical analysis base (in Russian). Journal "Geography and natural resources" (Geografiya i prirodnye resursy) Siberian Branch Russian Academy of Science: No. 2, pp. 123-130.
- Shmagin, B.A. 1997. The use of a runoff hydrosphere system's structure model as a basis of monitoring water resources. Third USA/CIS Joint Conference on Environmental Hydrology and Hydrogeology - Water: Sustaining a Critical Resource. A selection of papers presented at the Conference held in Tashkent, Uzbekistan, September 22-27, 1996, (ed. J. D. Powell), p. 107-111.

FIVE OTHER SIGNIFICANT PUBLICATIONS:

- Carol A. Johnston and Boris Shmagin. 2006. Scale issues in lake-watershed interaction: Assessing shoreline development, impacts on water clarity. In "Scaling and Uncertainty Analysis in Ecology Methods and Applications". Springer, Wu, J.; Jones, K.B.; Li, H.; Loucks, O.L. (Eds.)
- Shmagin B. A. and Johnston, C. A. 2004. The Hydroclimatology of the Central territory of conterminous U.S. and stream flow regime in Upper Missouri River Basin. Proceedings of the South Dakota Academy of Science, v. 83, p. 355-356.
- Shmagin, B.A., C.A. Johnston, H. Mooers. 1998. The systemic model of a hydrosphere of the Earth and temporal-spatial variability of the river runoff in headwaters of the Mississippi. Pp. 484-489. In: A. Buccianti, A., G. Nardi, R. Potenza (eds.) Proceedings of IAMG'98, Fourth Annual Conference of the International Association for Mathematical Geology. Universita di Firenze, Italy.
- Pashkovsky, I. S., E.Yu. Potapova and B.A. Shmagin. 1996. Dynamic-stochastic model of ground water balance for river basins. Proceedings of the Third International Conference/ Workshop on Integrating Geographic Information, Santa Fe, NM (CD and WWW). National Center for Geographic Information and Analysis, Santa Barbara, CA.
- Boris Shmagin and Milan Trizna. 1992. A Long-Term Prognosis of Average Annual Flows of Danube River in Orsova Station. Acta Facultatis Rerum Naturalium Universitatis Comenianae. Geographica No 33, Bratislava. 233-243 pp.

COLLABORATORS & OTHER AFFILIATIONS

Collaborators and Co-Authors:

Bridgham, S., University of Oregon; *Kanivetsky, R.*, University of Minnesota; *Lamberti, G.*, University of Notre Dame; *Lodge, D.*, University of Notre Dame, *Maurice, P.*, University of Notre Dame, *Mooers, H.*, University of Minnesota-Duluth;