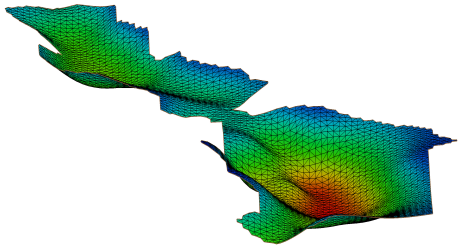
San Marcos Observing System

American Recovery and Reinvestment Act of 2009



River Systems Institute - Texas State University

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The Honorable, Patrick Rose
The Honorable Jeff Wentworth, Texas Senate
The Honorable Kip Averitt, former Chairman of Senate Committee on Natural Resources
The Honorable Alan Ritter, Chairman of House Committee on Natural Resources
The Honorable Joe Strauss, Speaker of the Texas House of Representatives
Dr. Denise Trauth, President, Texas State University
Dr. Bill Covington, Vice President for Research, Texas State University
City of San Marcos
Edwards Aquifer Authority
Edwards Aquifer Recovery Implementation Program (EARIP)
San Marcos National Fish Hatchery, U.S. Fish and Wildlife Service
River Studies Center, Texas Parks and Wildlife Department (TPWD)

San Marcos Observing System Co-Principal Investigators

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Dr. Michael Abbott – Associate Director, River Systems Institute
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Dr. Benjamin Schwartz, Department of Biology, Texas State University
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Dr. Timothy Bonner, Department of Biology, Texas State University
Mrs. Emily Warren, Assistant Director, River Systems Institute

San Marcos Observing System Contributing Investigators

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Ms. Kristy Kollaus, Grant Specialist, River Systems Institute
Mr. Philip Ramirez, Grant Specialist, Department of Biology, Texas State University
Mr. Thomas Heard, Grant Specialist, River Systems Institute
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Ms. Gabrielle Timmins, Grant Specialist, Department of Biology, Texas State University

Executive Summary

The Rivers Systems Institute (RSI) at Texas State University – San Marcos was tasked with the development of the San Marcos Observing System (SMOS) for Spring Lake and the upper San Marcos River basin. Located in Central Texas, the San Marcos River originates from the Edwards Aquifer through the second largest artesian spring system in the United States and flows through the campus of Texas State University and the City of San Marcos. The entire system faces increased threats from land use and land cover changes due to urbanization within the watershed as well as increased pressure from groundwater pumping within the Edwards Aquifer System where the City of San Antonio, the 7th largest city in the U.S., relies on groundwater pumping from the Edwards Aquifer for more than 80 percent of its municipal needs.

RSI has been tasked with stewardship of Spring Lake and the upper San Marcos River to protect its unique ecosystem and guide restoration efforts for a number of unique and endangered aquatic plant and animal resources. This includes protection and investigation of its unique cultural resources and archeological evidence has confirmed that the area may be the longest continuously inhabited location in North America dating back over 12,000 years. Spring Lake and the San Marcos River maintains a very diverse aquatic ecosystem including a number of endangered aquatic and plant species and is visited by over 150,000 school children every year as part of the State of Texas core curriculum activities involving field based experiences. These factors made the characterization of the ecological, hydrogeological, cultural, archeological, and historical significance of the spring and river system an ideal candidate for development of an ecological based observing system.

The principle goal of SMOS was to collect, compile, and maintain data regarding the physical, chemical, and ecological characteristics of the San Marcos River and upper San Marcos watershed necessary to support research and policy decisions regarding Spring Lake, the San Marcos River, and the upper San Marcos watershed. In addition, this effort focused on the development of a comprehensive management plan for Spring Lake and the San Marcos River at Texas State University to address the linkages between water quality and quantity entering Spring Lake and the San Marcos River, and future sustainability of the upper San Marcos River basin. SMOS also strove to undertake critical research, data collection, and analyses that would support RSI's stewardship responsibilities, the development of the Edwards Aquifer Recovery Implementation Program Habitat Conservation Plan (EARIP HCP), and provide a basis to support the development of the upper San Marcos Watershed Protection Plan (SMWPP).

The San Marcos Observing System and related projects are making immediate contributions to planning and management of the San Marcos River and its watershed. Renovation efforts in Spring Lake, invasive vegetation removal, sediment dredging, and construction of culverts and bridges in the San Marcos River watershed are using information directly generated from SMOS and its associated studies. These projects have also received recognition at regional, national, and international conferences for the novel approach of combining multi-metric monitoring of a surface watershed, groundwater, water bodies, and aquatic communities, suggesting that the approach used in SMOS will serve as a template for other systems at the state and national level.

Finally, future planning and management of the river (ERIP, Spring Lake Management Plan) will be dependent on baseline information established by SMOS, which will serve as an essential data source for decades. Likewise, the research infrastructure and results from SMOS will continue to support public outreach, K-12 education, university education, and academic research at the local, state, regional, and national levels.

Objectives

The broad objectives for SMOS were to:

- Design a long-term monitoring program for surface water and groundwater affecting the upper San Marcos watershed;
- Determine nutrient and sediment inputs to the system;
- Characterize the quality, quantity, source, and susceptibility of water resources to changes in climate and land use;
- Compile relevant physical, chemical, and biological data for the San Marcos River and upper San Marcos watershed into a functional GIS framework for analysis and communication with stakeholders;
- Characterize the effects of interactions between surface water, groundwater, and land use on the ecologic health of the San Marcos River;
- Develop a comprehensive management plan for Spring Lake and the upper San Marcos River; and
- Provide support to researchers and resource managers throughout the Edwards Aquifer, Spring Lake, and the upper San Marcos River system.

Given these goals and objectives identified for the SMOS, the project team adopted a strategic implementation plan that focused on the overlapping needs and priorities of existing management efforts within the San Marcos River watershed. The existing efforts included the Edwards Aquifer Recovery Implementation Program, the associated development of a Habitat Conservation Plan, the nascent upper San Marcos Watershed Protection Planning process, the City of San Marcos/Army Corp of Engineers river restoration project, and the Texas State University Spring Lake restoration project. Given these on-going management and restoration efforts, the project team developed the following project specific implementation priorities for the SMOS:

1. Meet time critical data or analysis needs in support of EARIP, HCP, San Marcos River restoration project and the Spring Lake restoration project;
2. Provide value added data and analysis for existing research projects in the system;
3. Fill known and suspected data gaps in terms of short term (HCP) and long term (WPP) needs;
4. Develop the highest quality base line conditions to benchmark all proposed restoration research;
5. Provide opportunities for undergraduate and graduate students for research and education;
6. Provide opportunities for the public over a range of information, educational, and professional levels;

7. Develop a strong public education and outreach program centered on Spring Lake and the Upper San Marcos River watershed that is sustainable into the future; and
8. Leverage SMOS funds to establish long term funding opportunities in support of ongoing programs in the watershed and in particular the stewardship responsibilities of RSI for Spring Lake and the upper San Marcos River

Outcome/Output Measures

As originally proposed, the primary outcome and output measures for the SMOS were:

1. The establishment of an integrated sensor system for discharge, sediment, and water quality parameters within the upper San Marcos River system. The specific performance measure for this element was the deployment of the sensor array and a web based portal for accessing the data.
2. The establishment of an integrated biological monitoring program that focused on the federally listed species within the upper San Marcos River as well as other native and non-native aquatic species and linking this data to the web portal.
3. The development of a web based watershed characterization module for economic, cultural, land use, land cover, etc. using georeferenced spatial data.
4. The development of the Spring Lake Management Plan.
5. The creation of journal articles, technical reports, and other media suitable for scientific and public outreach programs.

SMOS Outcome/Output Measures Accomplished

Access to SMOS data and reports can be found at: http://www.smos-rsi.org/. Detailed technical reporting covering all aspects of the SMOS are provided on the web. SMOS met or exceeded all Outcome/Output measures and a brief synopsis of each accomplished Outcome/Output Measure is provided below. Future data reporting will be accomplished through the publication of peer-reviewed manuscripts in scientific journals.

<u>Outcome 1</u> – Lead Investigators: Dr. Benjamin Schwartz, Dr. Weston Nowlin, Ms. Gabrielle Timmins, and Mr. Philip Ramirez.

SMOS accomplished a preliminary hydrogeochemical characterization of groundwater and surface waters contributing to discharge in the Upper San Marcos watershed. In addition, the project successfully completed the installation of a sensor array that supports long-term high frequency monitoring of hydrogeochemical parameters at various locations throughout the upper portion of the river. Specifically, the sensor array includes:

- Tributary storm flow monitoring and estimation of nutrient and sediment Loads
- Long-Term instrumentation and monitoring - continuous water quality and discharge at multiple sites in the upper San Marcos River watershed
- Hydrogeochemical Characterization - Continuous data collection

- Hydrogeochemical Characterization - Periodic sampling of springs

<u>Outcome 2</u> – Lead Investigators: Dr. Timothy Bonner and Ms. Kristy Kollaus

SMOS developed and implemented a long term and cost effective monitoring plan to assess changes in the upper San Marcos River aquatic habitats and fish community. The monitoring program was specifically designed to quantify community structure, available aquatic habitats, and fish-habitat associations in deep and wadeable habitats in lentic and lotic areas in the upper San Marcos River. The monitoring program was also designed to compare community structure and fish-habitat associations between areas with minimal recreation use and high recreational use to detect possible influences of anthropogenic effects on the upper San Marcos River biota.

<u>Outcome 3</u> – Lead Investigators: Dr. Thomas Hardy, Dr. Benjamin Schwartz, Dr. Weston Nowlin, Mrs. Meredith Blount-Miller, Mrs. Emily Warren, and Mr. Philip Ramirez

SMOS developed a high spatial and temporal resolution monitoring program over the entire ninekilometers of the San Marcos River. The characterization integrates LIDAR, 0.25 meter resolution multispectral imagery, 3-dimensional channel topography mapping, subsurface sediment characterization using ground penetrating radar, vegetation mapping at 1 meter resolution, and a complete riparian community delineation. These data have been integrated with 2-dimensional hydrodynamic models of the system and 10 meter longitudinal water temperature models to develop predictive habitat models for two key sentinel species, fountain darter (*Etheostoma fonticola*), and Texas wild rice (*Zizania texana*). SMOS completed an analysis of existing geospatial and landuse data, including land use and land cover, digital elevation data, and various cultural data such as roadways and municipal boundaries. In addition to characterizing land use as it exists today in the watershed, we quantified changes in land use over a 14-year period in order to investigate how changes in land use are occurring. These data also served as the basis to develop a distributed rainfall-runoff model for the watershed that was used to examine changes in runoff and water quality under two historical conditions of land use and land cover and under projected changes in land use and land cover in 2025 and 2050.

<u>Outcome 4</u> – Lead Investigators: Mr. Michael Abbott, Mr. Andrew Sansom, Mrs. Emily Warren, Dr. Thomas Hardy

The Spring Lake Management Plan was successfully developed and submitted to the Texas State University President's Council for approval. The Spring Lake Management Plan is now a central feature of the on-going Spring Lake restoration project, provides guidance for the City of San Marcos river restoration project, and a critical component of the Edwards Aquifer Recovery Implementation Program Habitat Conservation Plan.

<u>Outcome 5</u> – Lead Investigators: Full Project Team

As noted below, SMOS supported a number of Master Thesis efforts and disseminated project related research at a number of conferences and symposiums. As of the writing of this report, several journal articles were currently under review and several more were in preparation for submittal. SMOS also produced a number of technical reports in support of integrated research

and management activities as noted below. Finally, a comprehensive public outreach and education plan was developed as a sustainable program that integrates with existing Spring Lake and San Marcos River education programs at the River Systems Institute as well as identifying a number of achievable programs that would be revenue generating programs for Texas State University.

SMOS Supported Existing Resource Management Actions

The SMOS directly supported a number of activities within the San Marcos River and the upper San Marcos watershed. The project team was able to meet the stated goals and objectives of the project and in many instances, clearly exceeded expectations as defined by the outcome/output measures for the project. In particular, SMOS provided data, analyses, and technical support to the following ongoing resource management efforts within the upper San Marcos River and watershed:

- Edwards Aquifer Recovery Implementation Program
- Edwards Aquifer Habitat Conservation Plan (HCP)
- HCP between the City of San Marcos and Texas State University
- USACOE and City of San Marcos Restoration Project
- USFWS Alternative Dam Configuration Assessment in the San Marcos River
- USFWS/TPWD/City of San Marcos/Texas State non-native vegetation removal
- City of San Marcos fine sediment removal
- USEPA/TCEQ 319 grant
- Upper San Marcos Watershed Protection Planning process
- Archeological investigations of Spring Lake
- Spring Lake Restoration Project

SMOS Leveraged Funding

SMOS was able to leverage project data and results to support a number of additional research grants either directly or indirectly in excess of $ 1,250,000 at Texas State University. As of the writing of this report, SMOS derived products were serving as the basis for a number of proposals to the National Science Foundation, Department of Agriculture, and Foundations. A partial list of projects at Texas State University that were supported through SMOS generated data, analysis, or modeling is provided below.

City of San Marcos	Fine Sediment Mapping - $ 25,000.00
USFWS	Capes and Cummings Dam Removal Evaluation - $ 25,000.00
EARIP	Recovery Implementation Plan - $ 254,940.00
EARIP	San Marcos River Environmental Flow Regime Analysis - $ 165,940.00
EARIP	Mitigation Modeling - $ 40,070.00
TCEQ	Spring Lake Nutrient Sources Identification and Nutrient Management Plan- $489,481.70
EPA	Geomorphic and Water Resource Characterization of the Upper Blanco Watershed - $ $261,314.00

In addition, SMOS generated data and analyses were the primary technical basis for the development of EARIP HCP baseline conditions. The HCP identified a required funding base of over $ 20,000,000 per year over the next seven years for research and adaptive management activities. Texas State University was not only a signatory to the Implementation Agreement, but the HCP explicitly identified several key research and monitoring activities to be conducted at Texas State University based on data, analyses, and modeling supported by SMOS.

SMOS Supported MS and PhD Students

Benjamin Hutchins (PhD) - Effects of Hydrogeologic and Biogeochemical Processes on Organic Matter and Food Web Structure in a Phreatic Karst Aquifer

Kertin Hoesel (MS) - Effects of non-native vegetation on nutrient cycling in a spring-fed ecosystem

Kristina Tower (MS) – Modeling Texas Wild rice habitat in the San Marcos River

Casey Williams (MS) – Distribution and Physical Habitat Characteristics of *Hygrophila polysperma* along the San Marcos River, Hays County, TX. MS Thesis, Texas State University (in progress).

Ryan Spencer (MS) – Recreation impacts on aquatic resources in the San Marcos River (in progress)

Kenneth Behen (MS) - Spatial and temporal trends in habitat associations of the fish community in Spring Lake and the headwaters of the San Marcos River

SMOS Supported People

As noted previously, SMOS supported research for five Master of Science, one PhD, and two Post Doctoral positions. Six grant specialists who were hired in support of SMOS are now being supported through ongoing extramural research grants based on their acquired expertise directly related to SMOS activities. SMOS provided direct support for more than 30 individuals that ranged from undergraduate, graduate, professional staff, and faculty.

- Michael Abbott
- Joseph Angermeier
- Meredith Blount-Miller
- Stephen Curtis
- Christopher Douthit
- Brett Gerard
- Sharla Gutierrez
- Dittmar Hahn
- Thomas Heard
- Kerstin Hoesel
- Benjamin Hutchins
- Kristy Kollaus
- AshleyLewis
- Danielle Livingston
- Laura Parchman
- Hayat Qurunful
- Philip Ramirez
- Thomas Ryan
- Robert Sams
- Andrew Sansom
- Ryan Spencer
- James Tennant
- Chad Thomas
- Gabrielle Timmins
- Ben Tobin
- Kristina Tower
- Sarah Wardlow
- Emily Warren
- Kathryn Wilcox
- Kelly Wilkinson
- Casey Williams
- Janet Wisian

SMOS Based Presentations at Conference and Symposium

Research findings from efforts supported by SMOS have been disseminated at the following state, regional, national, and international forums.

Hardy, T.B., W.H. Nowlin, B. Schwartz, and T. Bonner. 2011. San Marcos Observing System: Integrating Physical, Chemical, and Biological Data at High Resolution Spatial and Temporal Scales. American Fisheries Society 141st Annual Meeting. Seattle, Washington, September 4-8, 2011.

Kollaus, K.K., T.B. Hardy, T. Heard, J. Tennant, and A. Jensen. 2011. Deployment and Flight Training Procedures Associated with Using Small, Autonomous Unmanned Aerial Vehicles for Capturing Multispectral Aerial Imagery. American Fisheries Society 141st Annual Meeting. Seattle, Washington, September 4-8, 2011.

Behen, K., K.K. Kallaus, T.B. Hardy, and T.H. Bonner. 2011. Spatial and Temporal Trends in Habitat Associations of the Fish Community in Spring Lake and the Headwaters of the San Marcos River. American Fisheries Society 141st Annual Meeting. Seattle, Washington, September 4-8, 2011.

Williams, C.R., T.B. Hardy, and K. Tower. 2010. Spring Lake aquatic vegetation mapping project. Student oral presentation, 2nd Place. Texas Aquatic Plant Management Society, Bandera, Texas. October 25-27, 2010.

Williams, C.R., T.B. Hardy, and K. Tower. 2010. Distribution and habitat of *Hygrophila polysperma* along the San Marcos River. 2010. Student Poster, 1st Place. Texas Aquatic Plant Management Society, Bandera, Texas. October 25-27, 2010.

Mock, L. B.F., Schwartz, W.H. Nowlin, B.T. Hutchins, T.B. Hardy, T. H. Bonner, A. Lockwood, and A. Steinback. 2011. The Role of Metrology in Monitoring and Preserving the Water Quality in the Edwards Aquifer in Central Texas. 2011 National Conference of Standards Laboratories International Workshop and Symposium. August 21-25, 2011, Gaylord National Convention Center, National Harbor, Maryland.