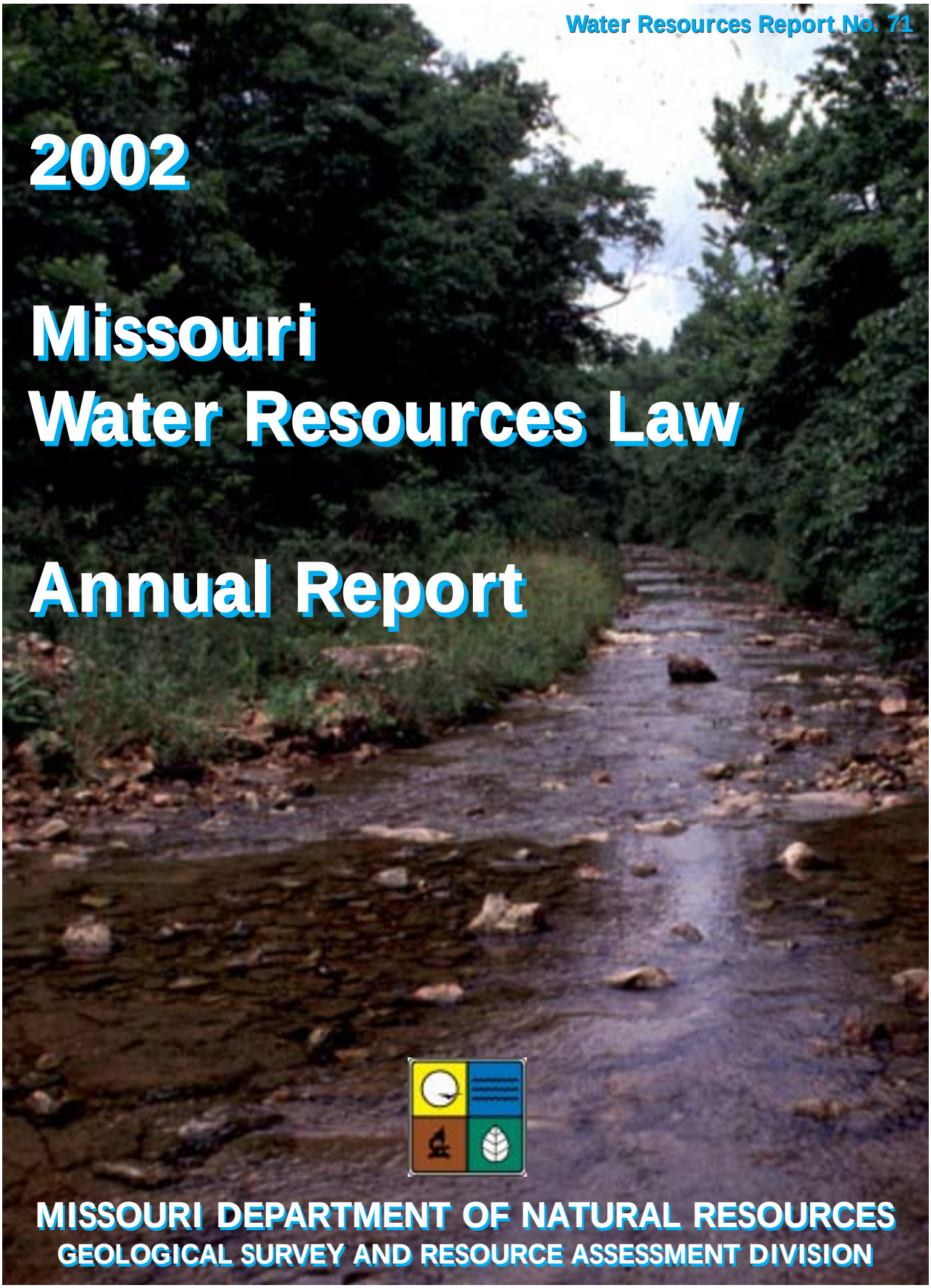

Water Resources Report No. 71

2002

Missouri Water Resources Law

Annual Report

MISSOURI DEPARTMENT OF NATURAL RESOURCES
GEOLOGICAL SURVEY AND RESOURCE ASSESSMENT DIVISION

Water Resources Report Number 71

Missouri Water Resources Law

2002

Annual Report

INTEGRITY AND EXCELLENCE IN ALL WE DO

MISSOURI DEPARTMENT OF NATURAL RESOURCES
GEOLOGICAL SURVEY AND RESOURCE ASSESSMENT DIVISION
P.O. BOX 250, ROLLA, MO 65402-0250
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Cover Photo: Limestone Creek, Cherryville, Missouri. Missouri Department of Natural Resources' Geological Survey and Resource Assessment Division file photo.

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MISSOURI WATER RESOURCE LAW

Sections 640.400 to 640.435 shall be known and may be cited as the "Missouri Water Resources Law," in recognition of the significance of the conservation, development and appropriate use of water resources of Missouri. The law, in its entirety, is located in Appendix 1.

2002 MISSOURI WATER LAW ANNUAL REPORT

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2002 MISSOURI WATER LAW ANNUAL REPORT

INTRODUCTION

The 2002 Missouri Water Resources Law Annual Report provides an overview of the activities in the Missouri Department of Natural Resources to meet the objectives of the Missouri Water Resources Law in section 640.426 RSMo. Investigations conducted by personnel in specific programs in the department are among the highlights of this year's work.

An innovative wetland project using remote sensing technology to identify wetlands and a hydrologic calibration study that characterizes watersheds for total maximum daily loads (TMDLs) for impaired waters, is also discussed in this seventh Annual Report.

Efforts of several programs of the department are showcased in the 2002 Annual Report, including how the Land Reclamation Program's work remediates acid mine drainage into streams through the reclamation of abandoned mined lands, and how the Hazardous Waste Program's surface and groundwater monitoring activities help prevent water contamination.

In an effort to make this report more accessible to the public, this edition of the Annual Report is being published electronically on the web pages of the Department. Those with Internet access can print a report for desk use, or one may read the report directly from the computer monitor. Refer to **www.dnr.state.mo.us.**/geology/wrp/

WATER QUALITY AND QUANTITY

RSMo 640.400.2 - The department shall ensure that the quality and quantity of the water resources of the state are maintained at the highest level practicable to support present and future beneficial uses. The department shall inventory, monitor and protect the available water resources in order to maintain water quality, protect the public health, safety and general economic welfare.

PUBLIC DRINKING WATER SYSTEMS

The Department of Natural Resources (the department) regulates more than 2,700 public water systems in Missouri to ensure the safe quality and adequate quantity of drinking water provided throughout the state. More than 90% of Missouri's population is served by public water systems.

A public water system provides water through pipes or other constructed conveyances, for human consumption, to at least 15 service connections or serves an average of at least 25 people for at least 60 days each year. There are three types of public water systems: Community (such as towns, subdivisions, or mobile home parks), nontransient noncommunity (such as schools or factories), and transient noncommunity systems (such as rest stops or parks). The requirements for construction, operation, and water quality monitoring vary among systems, based on their type, size, and source of water. Regulation is carried out under the authority of sections 640.100 through 640.140, RSMo.

Systems must be routinely inspected and samples from each system must be frequently analyzed. The department, in cooperation with the Department of Health, routinely monitors drinking water quality. The results provide early detection of potential health problems. The "Monitoring Water Quality" section of this report contains additional information about the department's drinking water monitoring efforts.

In addition to monitoring, the department is involved in other initiatives to protect water quality. The State of Missouri and the U.S. Department of Agriculture signed an agreement on September 15, 2000 that forms a federal/state partnership to reduce contamination of public drinking water reservoirs. The Conservation Reserve Enhancement Program (CREP) compensates farmers for voluntarily removing cropland from production. This reduces pesticides, excess nutrients and sediment flowing into drinking water reservoirs. The department's Public Drinking Water Program (PDWP) and Soil and Water Conservation Program are jointly implementing the program with the U.S. Department of Agriculture. Eighty percent of the funding to compensate the farmers comes from federal funds and twenty per-

cent comes from state and local funds. A state incentive payment to farmers is provided from the Rural Water and Sewer Grant fund. Once in place, these agreements will protect drinking water sources and provide wildlife habitat for fifteen years. Eleven communities are currently participating in the CREP, with approximately 15,000 acres of land in critical drinking water system watersheds enrolled in the program.

The department also offers low-interest loans to eligible public water systems. Most of the funding for the loan program comes from the U.S. Environmental Protection Agency (EPA), with a 20 percent match from state funds required. The loan program provides a mechanism for the department to assist public systems in meeting water quality needs.

The department continues to be actively involved in assisting public water systems to provide an annual report to their customers on the quality of their drinking water. In 2001, community public water systems in Missouri produced their third annual Consumer Confidence Reports (CCRs). State and federal drinking water regulations require public water systems to provide an annual report to their customers on the quality of their drinking water. The PDWP annually provides over 1400 community water systems with nearly complete "skeleton" Consumer Confidence Reports (CCR) so they can meet this requirement with a minimum of effort. These reports included data from the department's environmental laboratory and the Department of Health laboratory concerning drinking water sample results, violation information from PDWP files and standard language required in each CCR. Many small systems are able to use these reports as their official CCR without any modifications. For those who wanted to customize the report, the PDWP made the report available as an electronic file for use in any word processor. CCRs were completed by water systems covering nearly 99 percent of the population served by community water systems in Missouri.

There is generally plenty of good quality water in Missouri. By far the largest source of water for Missourians is the Missouri and Mississippi River systems. The abundant supply of water in these rivers, and their proximity to the state's major population centers, makes them popular as a water source.

Groundwater is the next most used source for drinking water for Missouri's community supplies. This is especially true in southern Missouri where good quality groundwater is easy to obtain and requires very little treatment to be used as a drinking water source.

Raw water sources vary in quality and quantity from one area of the state to another. To produce finished water of satisfactory quality and quantity on a consistent basis, treatment plants must be designed specifically for the raw water sources. Department staff review engineering plans and reports for the construction or renovation of public drinking water systems to ensure that essential sanitary standards are met. Construction permits are issued as appropriate. Department staff members assure that all public water systems are properly operated and maintained and that they operate under a state permit to dispense water. The public water systems must be operated in compliance with the law and regulations.

MISSOURI GROUNDWATER

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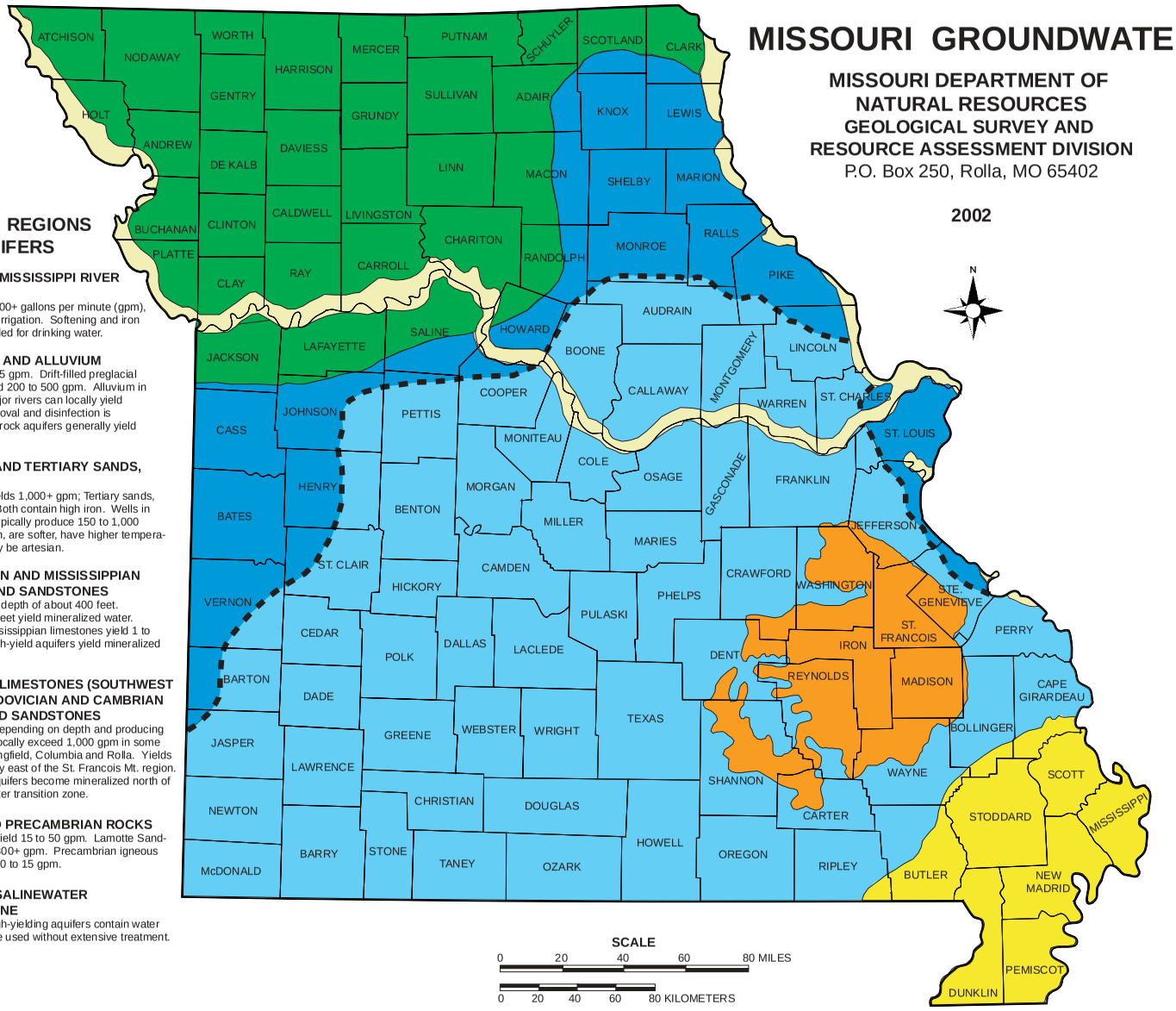
2002



PRODUCTION REGIONS AND AQUIFERS

MISSOURI AND MISSISSIPPI RIVER ALLUVIUM
Yield is normally 1,000+ gallons per minute (gpm), water is suitable for irrigation. Softening and iron removal recommended for drinking water.

GLACIAL DRIFT AND ALLUVIUM
Yield is normally 1-15 gpm. Drift-filled preglacial channels locally yield 200 to 500 gpm. Alluvium in lower reaches of major rivers can locally yield 400+ gpm. Iron removal and disinfection is recommended. Bedrock aquifers generally yield mineralized water.

CRETACEOUS AND TERTIARY SANDS, AND ALLUVIUM
Alluvium typically yields 1,000+ gpm; Tertiary sands, 500 to 1,000 gpm. Both contain high iron. Wells in Cretaceous sands typically produce 150 to 1,000 gpm, have lower iron, are softer, have higher temperature waters, and may be artesian.

PENNSYLVANIAN AND MISSISSIPPIAN LIMESTONES AND SANDSTONES
Yield 1 to 15 gpm to depth of about 400 feet. Aquifers below 400 feet yield mineralized water. Wells in shallow Mississippian limestones yield 1 to 10 gpm. Deeper high-yield aquifers yield mineralized water.

MISSISSIPPIAN LIMESTONES (SOUTHWEST MISSOURI), ORDOVICIAN AND CAMBRIAN DOLOMITES AND SANDSTONES
Yield 15-500 gpm, depending on depth and producing formations. Yields locally exceed 1,000 gpm in some areas including Springfield, Columbia and Rolla. Yields diminish substantially east of the St. Francois Mt. region. Highly-productive aquifers become mineralized north of freshwater-salinewater transition zone.

CAMBRIAN AND PRECAMBRIAN ROCKS
Dolomites typically yield 15 to 50 gpm. Lamotte Sandstone locally yields 300+ gpm. Precambrian igneous rocks normally yield 0 to 15 gpm.

FRESHWATER-SALINEWATER TRANSITION ZONE
North of this line, high-yielding aquifers contain water too mineralized to be used without extensive treatment.

DNR/GSRAD Fact Sheet No. 4

DELINEATING SOURCE WATER AREAS OF WATER WELLS

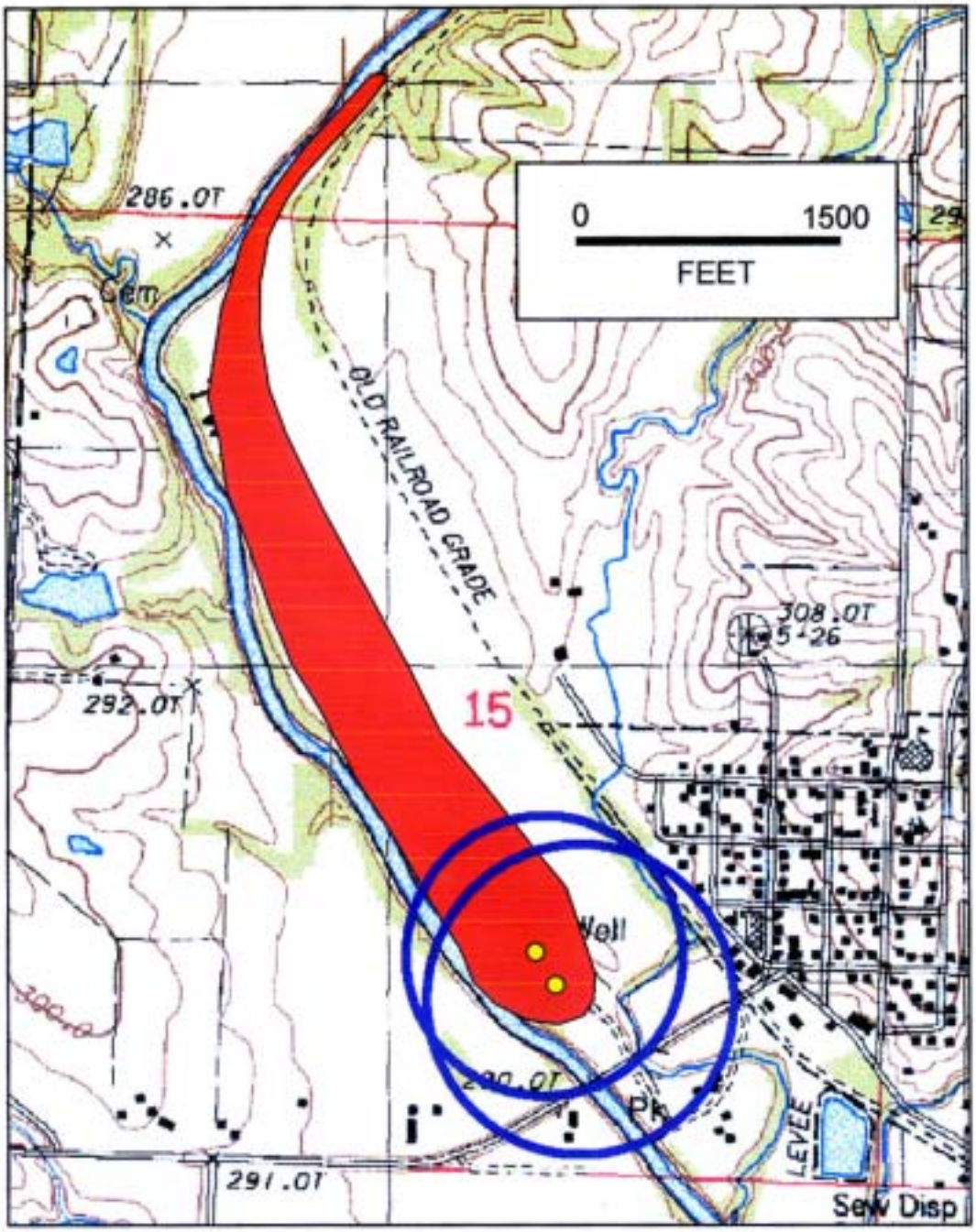
Groundwater is always on the move. Its direction of flow is from recharge areas to discharge areas. At recharge areas, groundwater is replenished by precipitation that percolates downward through surficial materials and bedrock on its vertical descent to the water table, which is the top of the groundwater system. Within the system, groundwater moves both laterally and vertically through interconnected pores and fractures in rock materials. The pathways and patterns of flow may be simple or complex. Eventually, old groundwater leaves the system at discharge areas, which include perennial streams, springs, and water wells. The amount of time required for groundwater to travel from recharge areas to discharge areas can vary from days to millennia, depending on distance traveled, steepness of hydraulic gradient, and the nature of geologic materials. To summarize, groundwater systems, in addition to being dynamic systems, are most definitely open systems. New water continually enters, existing water continually flows within, and old water continually exits.

Because of their openness, groundwater systems are to varying degrees susceptible to contamination by a variety of chemical and biological substances. Contaminants that are spilled or dumped onto the ground surface may migrate downward on their own accord or otherwise be carried down by infiltrating surface waters to the groundwater system. Having entered the system, contaminants may travel along with groundwater to discharge areas. When the point of discharge happens to be a water well, the consequences can be dire.

The Geological Survey and Resource Assessment Division (GSRAD), Water Resources Program (WRP), is engaged in delineating source water areas for public water supply wells. The work is being done as part of Missouri's Source Water Assessment Program (SWAP). Source water area is defined as the tract land around a well that supplies recharge to the well within a specified time interval. Accordingly, source water areas are being delineated for one-, five-, ten-, and twenty-year times-of-travel (TOT). These areas serve to predict when a well is most likely to receive water from a contaminated recharge event that occurs at some given distance from the well. For example, a recharge event involving contaminants that occurs at the outer edge of the 10 year TOT source water area would be expected to arrive at the well in 10 years. Source water areas can also serve as templates for planning land use around water wells.

Two methods are being used to delineate source water areas. The first is the cylindrical displacement method (CDM), in which (a) aquifer effective porosity, (b) saturated thickness of the aquifer above well bottom, (c) pumping rate, and (d) time-of-travel are used to calculate the radius of a cylindrical volume of aquifer that surrounds the well. The radius of the cylinder is the radius of the source water area. Consequently, CDM source water areas are perfect circles that are centered on the wells. CDM source water areas have been delineated for all the approximately 4000 active public water supply wells that reside in Missouri. A computational database automates the recurrent task of revising CDM source water areas to accurately reflect additions, deletions, and changes of information in well databases. Strengths of CDM include simplicity and speed. Its major weakness is that it does not take into account the hydraulic gradients that are always present in groundwater systems. In the real world, gradients profoundly affect the sizes, shapes, and orientations of source water areas.

Groundwater modeling is the second approach that is being taken to delineate source water areas. Modeling is being achieved with computer software marketed under the name *Groundwater Modeling System* (GMS 3.1). The software features windows-based preprocessing/postprocessing that facilitates construction and display of complex three-dimensional conceptual models that realistically portray actual hydrogeologic conditions. The venerable *MODFLOW* and *MODPATH* modeling routines are at the heart of the software. When done correctly, groundwater modeling delineates source water areas at a high level of accuracy. The areas are characteristically elongated shapes that pull out considerably in the up-gradient direction from wells.



Comparison of ten-year time-of-travel source water areas delineated by two different methods. The perfectly circular areas are drawn via the cylindrical displacement method. The greatly elongated (eel-like) source water area is drawn via computer groundwater modeling. The modeled area more accurately depicts the actual source water area. The two wells produce from shallow tributary alluvium in which groundwater flows primarily to the southeastward. This map was produced by the Groundwater Section, Water Resources Program, Geological Survey and Resource Assessment Division, Rolla.

WASTEWATER TREATMENT SYSTEMS

Many agencies and organizations are closely associated with water quality issues, however, the Department of Natural Resources is the agency responsible for maintaining and improving water quality in Missouri's streams, lakes and groundwater. It is also the agency responsible for enforcing the Missouri Clean Water Law.

Missouri water quality standards are rules made by the Missouri Clean Water Commission. The standards list the classified waters of the state, their beneficial uses, and the allowable concentrations of various pollutants.

The department requires all point source discharges of contaminants (other than from single-family residences and certain stormwater discharges) to obtain a water pollution control permit and comply with its terms.

Permits cover point-source discharges such as treated sewage from towns, subdivisions or businesses, industrial wastewater discharges, and runoff from large concentrated animal feeding operations (CAFOs), mines, quarries, large construction sites, and chemical storage areas. The permits limit the amount of pollutants that can be discharged so those water quality standards set for streams, lakes, and groundwater are not violated.

The State of Missouri issues permits that are recognized by the federal government as equivalent to federal permits (commonly referred to as National Pollutant Discharge Elimination System or NPDES permits under the federal Clean Water Act). This delegation of authority means that the state has the primary responsibility for permitting, inspection and enforcement activities on regulated facilities.

WATER QUALITY COORDINATING COMMITTEE

There is an ad hoc assembly of roughly 30 organizations meeting under the aegis of the Water Pollution Control Program, called the Water Quality Coordinating Committee. This group is an informal interagency and public committee dealing with water quality issues. It meets on the third Tuesday of each month at 10:00 A.M. in Jefferson City or Columbia. Nonprofit organizations, business representatives, agency employees and citizens attend to discuss water quality issues. This is a partnering effort that has been going on for several years, and is designed to keep attendees informed so that those with an interest can interact with each other efficiently.

NONPOINT SOURCE POLLUTION

Nonpoint source pollution (NPS) is defined as contamination caused by diffuse sources that are not regulated as point sources. This type of pollution is normally associated with agricultural, silvicultural and urban runoff. It results in human-made or

human-induced alteration of the chemical, physical, biological or radiological integrity of the water. In practical terms, nonpoint source pollution does not result from a discharge at a specific single location (such as a pipe), but generally results from land runoff, precipitation, atmospheric deposition or percolation. In simpler terms, it is pollution that enters waterways by overland flow or infiltration, as opposed to through conveyances such as pipes or channels.

The Missouri Nonpoint Source Management Plan was developed to address these nonpoint sources. The plan focuses state and federal activities and funds related to nonpoint source pollution. The stated mission and goals of the plan are as follows-

Mission:

- Preserve and protect the quality of the water resources of the state from nonpoint source impairments.

Goals:

- Continue and enhance statewide water quality assessment processes to evaluate water quality and prioritize watersheds affected by nonpoint source pollution;
- Improve water quality by implementing nonpoint source-related projects and other activities;
- Maintain a viable, relevant, and effective Nonpoint Source Management Program with the flexibility necessary to meet changing environmental conditions and regulations.

Specific, quantifiable objectives have been developed to help achieve these goals, accompanied by methods to be used in evaluating success in meeting the goals and objectives.

IMPAIRED WATERS

There has been heightened interest at both the state and national level in sections of the Clean Water Act pertaining to the identification and restoration of impaired waters. The 1972 federal Clean Water Act requires states to list all waters that do not meet established water quality standards. This listing of impaired waters is referred to as the 303(d) list, referencing the section of the law that contains the listing requirement. The 303(d) list must be periodically updated. The department is currently working from the EPA-approved list of impaired waters developed in 1998. The next revision must be submitted to EPA in 2002. There are 174 impaired lakes, streams or stream segments on Missouri's 1998 303(d) list.

The state is obligated to complete studies to determine actions needed to return the waters to compliance with water quality standards. These studies are used to determine what are referred to as Total Maximum Daily Loads (TMDLs). Based on existing data, calculations are performed to determine the maximum pollutant load a water body can receive without becoming impaired. This load is then divided up, or allocated, to all existing sources of the pollutant. Implementation plans are also part of the TMDL document and will identify the load reduction needed from all sources of the impairment. This includes point and nonpoint sources. The goal is to use existing regulations to address point source concerns and promote voluntary actions on the part of nonpoint sources through the provision of funding for the installation of best management practices. The recent emphasis on this part of the Clean Water Act has resulted in increases in federal funding to address both point and nonpoint sources of pollution.

There have been legal actions in 40 states related to TMDLs. The policies regarding TMDLs and the process for the development of restoration plans are constantly evolving. All agency actions related to this issue require public involvement and the

opportunity for public comment. For more information, visit the department's TMDL web site at http://www.dnr.state.mo.us/deq/wpcp/wpc-tmdl.htm or contact the Water Pollution Control Program at 573-751-1300.

Water Pollution Control Tools

There are many methods the state uses to protect its waters or repair damaged waters. These include monitoring water quality and the status of pollution control facilities, permitting, financial and technical assistance and enforcement.

Monitoring water quality is fully described in a separate chapter. Monitoring information is compiled into several reports, the most notable being the "305(b) report," which is required by the federal Clean Water Act, Section 305(b). This report documents how water**s** in each state meet that state's water quality standards. For example, it identifies the mileage of waters that provide for safe swimming, and those that are expected to be safe, but are not. These reports also provide the basis for establishing impaired waters lists and other management activities. The 305(b) reports are prepared every two years and the data are reported to Congress.

In addition to monitoring water quality throughout the state, the department compiles lists of water pollution control needs, which support the state's requests for federal grant and loan assistance. The Needs Survey, as it is known, documents the work that must be done to bring water quality related facilities into compliance with design standards or other conditions where they will not damage water quality. Federal grant and loan funds are apportioned to the states in relation to their needs.

The Department of Natural Resources administers a program that distributes grants or low-interest loans for the construction of wastewater treatment and drinking water treatment facilities. The funds for this program come from the state and the U.S. Environmental Protection Agency. In 1998, this loan program dispensed loans valued at $68 million.

The loan program has been in effect since 1990 and requires that most of the burden of funding falls on cities. From 1972 to 1992, a state-federal grant program funded up to 90 percent of the construction costs of wastewater treatment facilities, which helped meet the needs of both expanding populations and replacement of aging facilities. Today, there is concern about the ability of the present funding system to continue to meet construction needs.

In addition to permits described under Wastewater Treatment Systems, permits are required for concentrated animal feeding operations (CAFOs). The permits ensure that properly designed facilities are constructed for holding animal wastes. Letters of Approval (LOA) are offered for animal feeding operations smaller than 1,000 animal units. An animal unit is the equivalent of one beef steer. This voluntary program was developed two decades ago, and has been operated by the department as a free service to agricultural producers.

In 1995, the department entered into an agreement with the Department of Agriculture to operate an agricultural loan program. Under this program, the department will loan funds to the Agricultural and Small Business Development Authority (ASBDA). The ASBDA will use the funds to finance, at subsidized interest rates, animal waste facilities for producers. The loans are limited to animal feeding operations of less than 1,000 animal units. Producers' repayments are used by ASBDA to repay the loan. The department has committed $10,000,000 to these loans. Another

$10,000,000 is available if the program is successful.

Enforcement actions related to water pollution are sometimes necessary. During 1998, there were about 258 active cases involving violations of the Clean Water Law or regulations. Of these, 83 cases were resolved, and the facilities returned to compliance during the year. These settlements included collection by the department and the attorney general's office of more than $1,200,000 for environmental damages and penalties.

SOIL AND WATER CONSERVATION

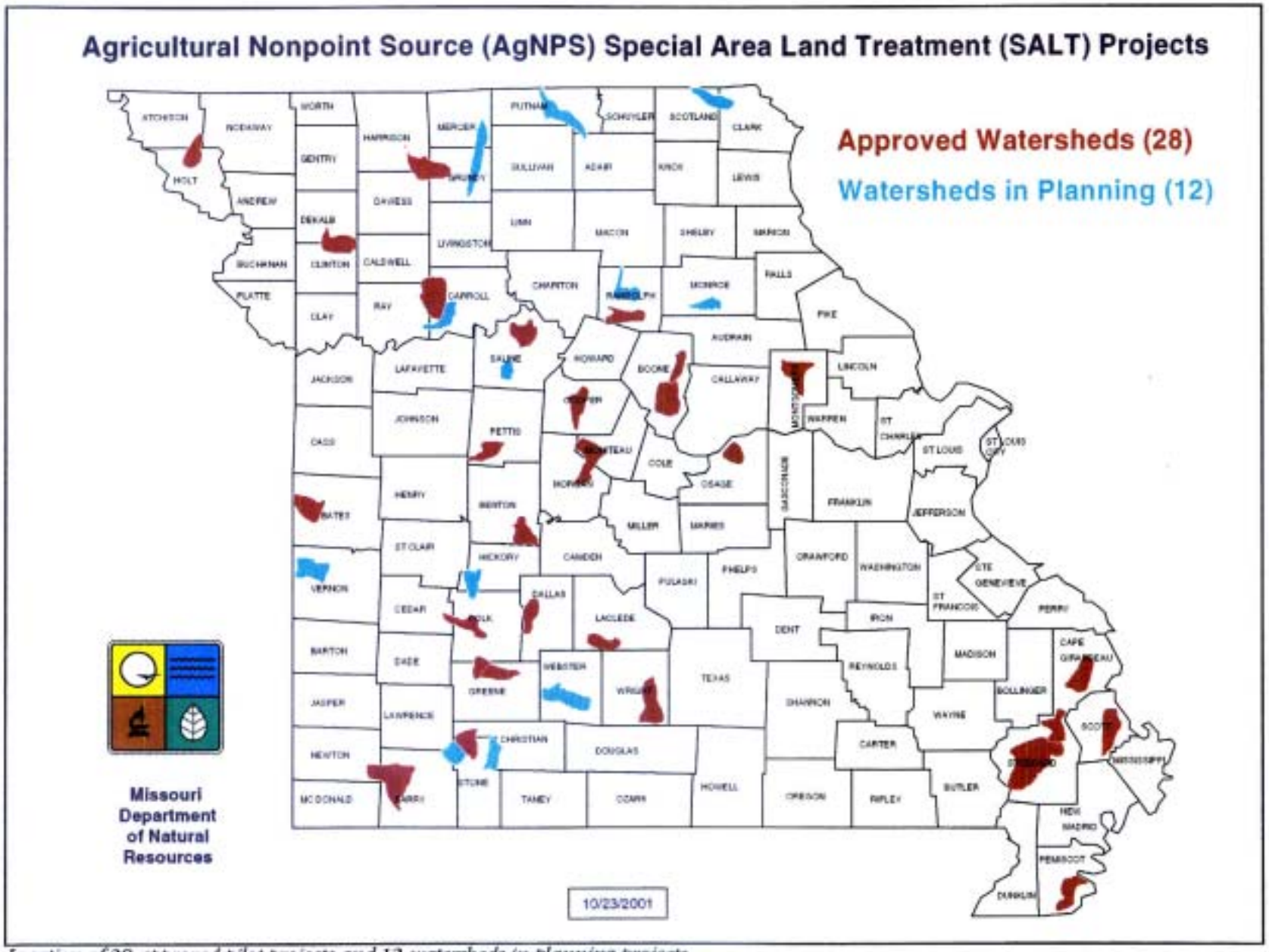
Currently, the Special Area Land Treatment (SALT) program is being expanded to address agricultural nonpoint source pollution (AgNPS) issues associated with runoff from production agriculture. The SALT program is a voluntary approach to natural resource management and conservation. A project grant is made available to local soil and water conservation districts to provide general support for the project, technical assistance, and information and education activities in the watershed. Financial assistance is available to landowners to encourage the adoption and implementation of best management practices (BMPs).

SALT projects are coordinated with the Natural Resources Conservation Service (NRCS) of the U.S. Department of Agriculture (USDA) for planning and technical support. AgNPS SALT projects can be included in other programs to achieve maximum results from the resources provided to treat associated water quality problems. The Environmental Quality Incentive Program (EQIP) is a federal watershed program administered by the NRCS that may fit with an AgNPS project to address water quality problems.

Other state and federal programs available that support AgNPS SALTs include the Water Pollution Control Program's Section 319 grants, the Missouri Department of Conservation's (MDC) wildlife incentive programs, and the Missouri Department of Agriculture's Animal Waste Treatment System loan program. Partnerships between programs are extremely important to accomplish environmental goals because they can bring together the resources needed to have a successful project. Missouri is fortunate to have these partnerships coming together to take on the water quality issues in the state.

The intent of the pilot AgNPS SALT projects is to provide a basic level of resources to make significant contributions to the control and reduction of nonpoint source water pollution from agricultural runoff. The concept is based on numerous partners contributing to the project and various tools utilized to accomplish project goals. Through joint efforts, limited resources and funding can be used in a cost-effective manner.

There are currently 28 approved pilot AgNPS SALT projects throughout the state. Currently, 12 more soil and water conservation districts are in the final planning phases of a watershed plan awaiting approval from the Missouri Soil and Water Districts Commission for an AgNPS SALT Project. The commission's intent is to offer a call for more AgNPS SALT projects at the beginning of every state fiscal year. Because boundaries of AgNPS SALT projects are based on hydrologic (or watershed) units, many of the projects span more than one county. The pilot projects are located in the following counties depicted in the map shown below:



Location of 28 approved pilot projects and 12 watersheds in planning projects.

Some of the water quality issues being addressed in the pilot projects include: Sedimentation, nutrification (by nitrogen and phosphorus), chemical contamination from pesticides and herbicides, loss of aquatic habitat, stream-bank erosion, fecal coliform bacteria from animal wastes, and karst groundwater contamination. Often, AgNPS SALT projects provide a springboard for landowners to address additional natural resource problems. Landowners working together in this way can address additional resource goals, such as improved water quality and improved pasture management, along with erosion treatment and control. The AgNPS SALT projects provide cost-share and low interest loan incentives to install and maintain conservation practices. To ensure the effectiveness of the practices used on the farm and to be eligible, practices have to be installed and certified complete according to NRCS or MDC technical specifications.

Two other programs administered by the Soil and Water Conservation Program are the Cost-Share and Loan Interest-Share Programs. These programs help landowners carry out conservation plans and the goals established in the Soil and Water Districts Commission's "Plan for the Future". The cost-share program funds up to 75 percent of the cost of installing conservation practices on agricultural land. Through this program, the state has installed some 128,023 conservation practices, saving over 160.3 million tons of topsoil on about 2 million acres of cropland and pastureland. The loan interest-share program refunds a portion of the interest on loans for purchasing conservation equipment. Conservation tillage is an excellent practice for conserving soil and keeping sediment out of streams and lakes.

The Soil and Water Districts Commission considers local soil and water conservation districts to be the delivery system for its conservation programs. As such, a major point of the Plan for the Future is to strengthen the role of the local districts. Districts receive grants to provide technical assistance for landowners and other operational costs.

Finally, the Commission assisted in completing the initial inventory of Missouri's soil resources (December 2001) and will continue to work with the NRCS on updating and improving information on Missouri's soil resources. The soil survey is used by a number of different occupations to provide valuable soils information to the citizens of Missouri. Soils information is highly regarded when working on soil conservation and related water quality issues.

Missouri is a leader in soil conservation as a result of soil and water conservation districts' work and the voluntary commitment of Missouri farmers. These soil successes will pay off for the state's water quality as well.

HAZARDOUS WASTES

The department regulates hazardous waste to protect human health and the environment and to ensure that any contamination is remediated as quickly as possible. The department oversees groundwater and surface water monitoring at hazardous waste sites within the state. As part of the department's oversight, hazardous waste facilities are required to determine the impact of past and present waste management practices on water quality. This includes determining the extent of contamination, the distribution of contamination, and the potential impact on other waters or water users. If contamination is found to pose a threat, the department will ensure that remedial actions are taken.

Groundwater and surface water monitoring activities, and any subsequent

remediation, can occur at five different types of sites:

1. Resource Conservation and Recovery Act (RCRA) treatment, storage and disposal facilities (TSDs);
2. Superfund cleanup sites, including Federal Facility sites;
3. Voluntary cleanup sites;
4. Enforcement directed cleanup sites; and
5. Leaking storage tank facilities

As of January 3, 2002, there were 2,801 of Missouri's hazardous waste generators considered "small quantity generators" and 477 considered "large quantity generators." There presently are 99 TSD's in Missouri.

The department may require RCRA TSD facilities whose practices might affect large bodies of surface water in Missouri to implement a surface water monitoring program. Currently, nine RCRA TSD facilities in Missouri are monitoring surface water for various contaminants. These facilities are required to report to the department at least once per year. The results of the monitoring are examined and tracked by the department. In accordance with state regulation, a TSD facility that is subject to federal groundwater monitoring requirements must conduct groundwater monitoring on a regular basis until released from such obligation by the department. Currently, 47 TSD sites are conducting groundwater monitoring in Missouri. Of these 47 sites, 21 are actively remediating groundwater contamination to improve the quality of water that may ultimately migrate to surface water bodies or drinking water sources.

Each TSD facility must submit an annual groundwater monitoring report to the department for an official evaluation. The evaluation includes determination of contamination data trends and the extent of contamination resulting from TSD facility operation. All groundwater monitoring data from RCRA TSDs in Missouri is entered into a database where it can be tracked and evaluated. The department periodically conducts groundwater monitoring field audits at TSD facilities to help ensure that their samples are collected and analyzed in accordance with accepted standard operating procedures and that the sampling data generated by TSDs is reliable.

The Federal Facilities Section is monitoring groundwater and surface water at 43 sites. There are currently 7 ground water remediation techniques being used at 3 sites. The remediation techniques include 3 pump and treat systems at 3 sites, 2 permeable reactive walls at 2 sites, 1 in situ chemical oxidation at 1 site, and 1 phytoremediation at 1 site. Two sites have proposed the use of enhanced natural attenuation and concurrence on this request is pending. The remaining 40 sites are undergoing surface and groundwater investigation for characterization of contamination and migration.

Additional hazardous waste sites fall under the "Superfund" law and its amendments. Superfund includes the authority to initiate and remediate actions when contamination is determined to present a threat to human health and the environment. The Department of Natural Resources performs site assessments on potential Superfund sites and from these assessments determines the degree of surface and groundwater investigations that will be required. Currently, 62 Superfund sites are undergoing some type of groundwater investigation. An additional 19 sites are undergoing regular groundwater and surface water monitoring. Of the 62 sites, 33 have initiated some form of groundwater remediation. The Superfund Section has four sites that are conducting groundwater investigations under Consent Agreements, and six additional sites that have completed investigations and are undergoing remediation. Remediation technologies in-

clude the use of in-situ chemical oxidation and permeable reactive barriers.

In 1994, a state law was passed allowing responsible parties to voluntarily initiate a cleanup of their site under the oversight of the department. These cleanups are supervised through the department's Voluntary Cleanup Program (VCP). In order to be eligible, VCP sites cannot be a RCRA TSD category, cannot be on the Superfund National Priority List (NPL), and cannot be eligible for the state *Registry of Confirmed Abandoned or Uncontrolled Hazardous Waste Disposal Sites in Missouri*

Before Voluntary Clean-up – Former Kansas City Terminal Railroad Coach Yard Roundhouse

After Voluntary Clean-up –Westside Business Park

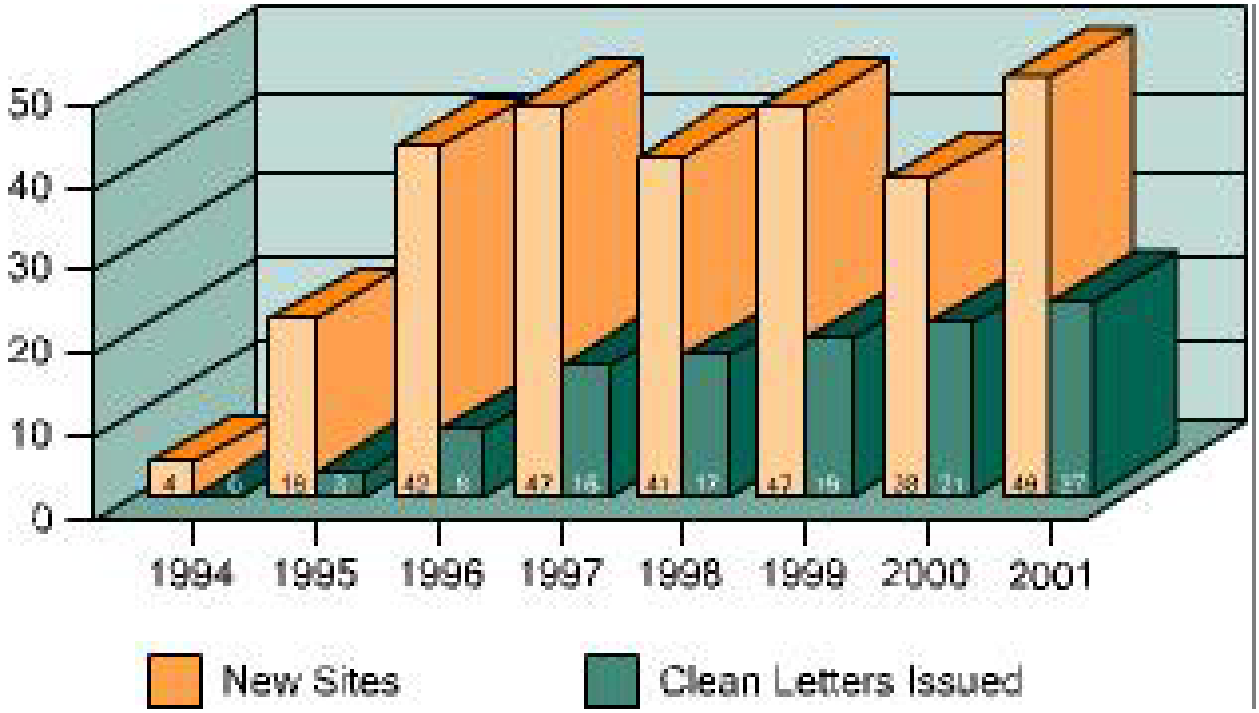
If a site is determined to be eligible, the responsible party must consent to remediate their site in accordance with an agreement with the department. Currently, 146 sites are undergoing voluntary cleanup, and 106 other sites have completed cleanup and received certificates of completion (clean letters). In 2001, four VCP sites began utilizing new in-situ technologies for groundwater remediation such as hydrogen release compounds (approved for use in Missouri). In September 2001, the Department published an updated Tier 1 table for its guidance document, *Cleanup Levels for Missouri (CALM).* The department worked closely with the Missouri Department of Health to update the Tier 1 standards. This is the first update of Tier 1 standards since the release of the CALM document in 1998.

The Hazardous Waste Enforcement Section also directs and provides oversight on sites with hazardous waste contamination and requires testing and remediation, where appropriate, to protect surface water and groundwater. The section also coordinates with the Water Pollution Control Program to assure that necessary permits are obtained at sites under Hazardous Waste Enforcement action.

STORAGE TANKS

The department regulates the operation and maintenance of underground storage tanks (USTs) containing petroleum products and hazardous substances. The vast majority of releases from USTs are petroleum fuels, which threaten water resources because of benzene, a known carcinogen, and other chemical constituents, such as methyl tertiary butyl ether (MTBE). EPA has tentatively classified MTBE as a possible human carcinogen. MTBE is an additive to fuel to help the gasoline burn more completely.

Federal and state requirements are designed to reduce and detect releases from



Site Clean-up Status

USTs. Effective December 22, 1998, UST systems must be equipped with spill and overfill prevention equipment. Steel tanks must have corrosion prevention systems. Leak detection is required for all USTs and related piping.

Tank owners and operators are required to report a release from a tank. The department oversees cleanup and remediation of releases from both underground and aboveground tanks. Over the past twelve years, over 5500 releases from underground storage tanks have been reported and more than 4200 (approximately 76 percent) of those have been remediated to department standards.

The department also investigates sites where petroleum releases have occurred but where the source of contamination is not known. Investigative techniques such as dye tracing, groundwater monitoring, soil drilling/probing, soil gas surveys and geophysical surveys are used to trace the contamination to its source and identify a responsible party. The department then works with the responsible party to remediate the contamination.

Tank Facts

Releases Reported (USTs and ASTs)	5,813
Releases Completed (USTs and ASTs)	4,357
Ongoing cleanups	1,456
Total USTs	36,848
Closed USTs	26,138
In-Use USTs	9,727
Temporarily Closed USTs	983
In-Use USTs Meeting Upgrade Requirements	96.8%
In-Use USTs Meeting Leak Detection Requirements	98.2%

(AST= Above ground storage tank)
(UST= Under ground storage tank)

SOLID WASTES

Historically, some landfills have been a source of surface and groundwater contamination. As of April, 1994, stricter federal subtitle D (of RCRA) design and operational requirements affected all operating landfills in Missouri. Some of the new requirements are related to establishing, developing and maintaining surface and groundwater monitoring. These include: Detailed hydro-geologic investigations; installation of groundwater monitoring wells capable of detecting any contaminants that could leave the site; and installation of a composite liner and leachate collection system on areas that were not covered by waste as of April, 1994.

Another change that should help protect water quality in Missouri relates to the final “cover cap” requirements. Areas already landfilled but not properly closed will require a final cover cap of at least two feet of compacted clay and one foot of soil. All areas with a geomembrane liner (an impermeable material that does not allow liquids to pass through it) require cap designs that include a geomembrane, even if the areas were previously permitted for another final cover cap design.

There are more than 150 closed or abandoned landfills scattered throughout Missouri. These older landfills were not constructed or operated like the modern subtitle D sanitary landfills we have today. The presence of these older landfills poses an unknown impact to the water resources of Missouri. No statewide assessment has been conducted; however, it is very possible that they are contributing leachate contamination to both surface and subsurface waters. Currently, such an assessment is in the planning stages. If implemented, information obtained over the several year study could confirm impacts or eliminate them on a site by site basis.

In 2000, the Solid Waste Management Program completed the design and installation of an artificial wetland to address a leachate discharge from an abandoned landfill in Warren County known to be impacting a nearby stream. The wetland will be used as a research tool to determine the effectiveness of such a treatment process in landfill leachate. If it is able to provide an acceptable level of treatment, it could be utilized at similar sites around the state and nation as an effective, low-cost solution.

WELLS FOR WATER, HEAT PUMPS, MONITORING AND MINERAL TESTING

If wells are not constructed or plugged properly, they may allow surface water, with its contaminant load, to bypass the earth's natural filtering system and enter directly into drinking water aquifers. The "Water Well Drillers' Act" (section 256.600 to 256.640 RSMo) was passed into law in 1985. By the fall of 1987, rules were in place governing the construction of domestic water wells, pump installations, and the plugging of abandoned wells. The drilling contractors and pump installation contractors were required to be permitted (licensed), and their drill rigs were required to be registered.

This law was passed to ensure that the quality of Missouri's groundwater is maintained at the highest level practical to support present and future use. The importance of this law and its enforcement plays a pivotal role in the protection of our groundwater.

An important amendment to this law was passed in 1991. The amendment brought the heat pump, monitoring well, and mineral test hole drilling industries under regulation. It also created the Well Installation Board. The department's Geological Survey and Resource Assessment Division (GSRAD), with the oversight of the Well Installation Board, is responsible for implementation of the Water Well Drillers' Act. The Geological Survey Program within GSRAD has been given the day to day tasks of implementation.

The chart shows the number of wells reported since the "Water Well Drillers' Act" was created. This chart shows the number of completed certified wells drilled in Missouri during any given year. The numbers for water wells reflect wells in the private category as well as the public well category. It is extremely hard to estimate how many wells are drilled each year that are never reported. Geological Survey Program (GSP) personnel have been very diligent with their limited staff in the enforcement of the rules but a certain number of wells still are not reported each year. The rules state that the permitted contractors do not have to report that a new well has been drilled until 60 days after they have completed the job.

It is important to note that after the 1991 amendment to the law was passed, rules had to be written and approved before reporting on monitoring wells and heat pump wells was required. These rules became effective December 13, 1993; therefore, the increase in numbers of heat pump wells and monitoring wells in 1994 reflects this regulatory change. Also, some contractors submitted records for heat pump and monitoring wells before they were required and these numbers are reflected in the chart. Typically, a mineral test hole is drilled, information obtained and the hole is plugged within 30 days; therefore, these types of wells are recorded only after they are plugged.

As a tool to aid in proper well construction and well plugging, the department purchased a waterproof, downhole camera in 1994 that can video the conditions within a

Date Completed	TYPE OF WELLS			
	Water	Monitoring	Heat Pump	Plugged Wells
1986	130	0	0	0
1987	4,390	0	12	4
1988	5,612	2	18	7
1989	5,451	14	9	13
1990	5,503	0	0	1
1991	5,246	0	2	4
1992	5,913	0	2	5
1993	5,732	1	4	4
1994	6,628	1,186	509	742
1995	6,653	1,125	488	1,174
1996	6,965	811	288	1,125
1997	6,788	1,058	250	1,298
1998	6,932	1,103	200	1,426
1999	8,080	1,565	143	1,555
2000	8,646	1,509	107	1,491
2001	7,028	1,513	159	1,347
TOTAL	95,573	9,937	2,192	10,196

Chart showing number of wells reported under the Water Well Drillers' Act.

wellbore to help identify problems. At the time the department purchased this camera, it was almost at the "cutting edge" of technology. The downhole camera is less than two inches in diameter and, when lowered into a well, can send back a video image that shows in detail underground features that few have seen. This single piece of equipment has revolutionized the division's ability to diagnose construction and con-

Downhole video camera. Camera head is less than 2 inches in diameter. Photo by Bruce Netzler.

tamination problems with water wells and provides the details needed to properly plug wells. Due to the large demand placed on the first downhole camera, a second one was purchased in the spring of 2000 to aid staff in their mission.

In an effort to improve the regulatory system associated with private well construction a new management tool endorsed by the Governor has been employed. The Managing for Results Initiative is a management tool for the Governor and his cabinet to help keep government focused on results and to drive meaningful improvements for citizens. The Managing for Results effort encourages fact based decision making and innovation and recognizes the need for agencies to work together to drive significant improvements. As part of the Governor's Managing for Results Initiative, the Geological Survey and Resource Assessment Division, Geological Survey Program, Wellhead Protection Section volunteered to participate in an effort to improve the efficiency of the well certification process for private wells. A task force was composed of industry, private citizens and division staff to examine the two most common problems associated with the well certification process, incorrect well locations and non-submittal of forms. Recommendations were made to Director Mahfood and are being considered.

ABANDONED WELL PLUGGING

It has been estimated that Missouri has from 150,000 to 300,000 unplugged abandoned wells. However, this may be a conservative estimate. More recent estimates place the number in excess of 500,000 unplugged wells and cisterns scattered across Missouri. Each one of these unplugged wells or cisterns is a danger either to the health, welfare or safety of Missourians or to the groundwater that we rely on so heavily for our water resources.

Whenever surface contamination (pesticides, septic tank effluent, animal waste, chemicals, oil and grease, solvents, etc.) finds an unplugged well, it can quickly bypass the natural filtering system of soil, unconsolidated material and rock and directly contaminate the underground aquifers. Once an underground aquifer is contaminated, it is very difficult and very expensive to clean up. Prevention is always cheaper and better than remediation.

Looking into an old hand-dug well with cover removed. The well is approximately 4 to 5 feet in diameter and 30 feet deep. It is lined with fieldstone. Photo by Bruce Netzler.

Abandoned and forgotten hand-dug well in farm lot. Notice rotted cover and old hand pump. Photo by Jim Vandike.

Many things have changed since Missouri's early settlement days more than 150 years ago, but one thing that has not changed is the need for a dependable supply of water. If early settlers did not live near a river, spring, lake or stream they had to dig a well or cistern. The first wells were hand-dug and many of them are still in existence today but are rarely used and often forgotten. A hand-dug well is typically 5 to 10 feet in diameter and up to 50 feet deep. These wells were lined with rock or brick and were covered with a concrete or wooden cap. (The biggest hand-dug well in the U.S. is located in southwestern Kansas in the town of Greensburg and is 32 feet in diameter and 109 feet deep.) These types of wells are considered a major danger to life and limb. People have died across Missouri by accidentally falling into one of these wells. These types of tragedies can be avoided with a little preventive action.

Unplugged abandoned drilled wells are also a danger to personal safety and a potential conduit for surface derived pollutants. The size of Missouri's drilled wells range from the normal 6-inch diameter of a private domestic well, upwards to 36 inches in diameter. Many people do not realize that a well as small as 8 inches in diameter can be a death trap to young children. Some people still remember the drama that played out on television years ago about a little girl named Jessica McClure who was trapped in a well in Texas. The well was just 8 inches in diameter. She was very lucky to have been rescued.

It may surprise many that the first and only law requiring abandoned wells to be plugged was enacted in 1991 and was an amendment to the Water Well Drillers Act (section 256.600 to 256.640 RSMo). This law states that wells abandoned after August 28, 1991 must be plugged according to approved standards. Therefore, wells abandoned before this date are not required to be plugged. That leaves a huge number of wells that have been abandoned before 1991 scattered across the countryside.

There are some exceptions to this general rule. When a person hooks up to a water district and is using a well for water supply, that well must be plugged, unless the landowner wishes to use it for other purposes. The law also states that if a landowner permits hazardous or potentially hazardous conditions to exist on owned property that may cause deterioration of the groundwater, the landowner can be held liable. This does give some enforcement ability but would require a Notice of Violation and enforcement follow-up. It is important to note that if the

landowner does not comply, the only recourse is referral to the Attorney General's Office and litigation. This is not the best way to achieve the goal of plugging abandoned wells and protecting groundwater.

Generally speaking, an educational effort has been in progress since 1991. It is felt that if people understand the dangers of leaving abandoned wells open, they will want to plug them in an approved manner. To accomplish this, several educational aids have been developed. These aids are described in the following paragraphs.

In the spring of 1992, a brochure entitled, "Eliminating An Unnecessary Risk: Abandoned Wells And Cisterns," was made available. The brochure focuses on the risk to human safety, livestock, and groundwater that exist when wells are left unplugged. The brochure begins with a history of Missouri's early settlement days and the types of wells that were dug, and finishes with the modern drilled wells of today. It is written in layman's terms and, with the use of diagrams, sets out easy to understand approved methods for plugging all types of wells. The brochure is geared to private landowners who have the right to plug wells located on their property. When the well plugging regulations were developed, the least expensive and easiest methods were developed as options for the private landowner. This brochure has been reprinted numerous times and is distributed free of charge to anyone requesting it. The brochure has been used extensively as part of well plugging demonstrations that have been carried out cooperatively between the University Extension System and the department's Geological Survey and Resource Assessment Division (GSRAD).

In an effort to reach more people and to embrace the computer age, GSRAD personnel are in the process of developing a computer-generated well plugging demonstration using Power Point software. These well plugging modules will have excellent computer graphics and sound effects. Presentations will be developed for each different type of well, hand-dug well or cistern, drilled well in bedrock and drilled well in unconsolidated material. The plan is to place this on the Geological Survey and Resource Assessment Division's web page (http://www.dnr.state.mo.us/geology.htm) so that it can be viewed and downloaded by anyone.

This will be an extremely important and pivotal accomplishment to further the message of how and why to plug abandoned wells. When this is placed on the Internet it will be instantly accessible to the entire world. Teachers will be able to incorporate this information into their teaching units on environmental issues.

WELLS FOR OIL, GAS AND UNDERGROUND INJECTION

The Oil and Gas Law was passed in 1965. This law requires wells used for oil and gas production, water disposal, enhanced oil recovery, gas storage and geologic information to be constructed in a manner that does not contaminate surface and groundwater resources. Approximately 9861 wells have been permitted since 1966. In 2001, 52 wells were permitted.

In addition to ensuring proper well construction, the oil and gas law requires a plugging bond to be placed on all permitted wells. This bond is required to be maintained until the wells are properly plugged. In the event an operator improperly abandons a well, the plugging bond is forfeited and the state, working through the Missouri Oil and Gas Council, has the authority to plug the well.

The Underground Injection Control Program is an EPA-delegated program for which Missouri has primacy. Injection wells have been divided into five classes by EPA, based upon the type of fluid injected and where it is injected in relation to underground sources of drinking water. Missouri has wells that fit into two of these classes - Class II and Class V.

Class II wells are oil- and gas-related injection wells. These wells may be used for the disposal of other fluids produced during oil extractions (mostly water) back into the producing horizon, or for enhanced recovery methods to increase production. These wells are subject to regulation under the Missouri Oil and Gas Law.

Class V wells (also called shallow injection wells) include a variety of well types that inject fluid into or above an underground source of drinking water. In Missouri, this well category includes mine backfill wells, septic systems (tank and lateral field), sinkholes improved for drainage purposes, heat pump systems, and injection wells used in groundwater cleanup projects. Septic systems are regulated by the Department of Health. Most other types of Class V injection wells are regulated through the Clean Water Law. The department administers the program and maintains an inventory of Class II and Class V wells.

RECLAMATION OF MINED LANDS

The mission of the Missouri Land Reclamation Commission and the department's Land Reclamation Program is to assure the beneficial restoration of mined lands and to protect public health, safety and the environment from the adverse effects of mining within Missouri. Active mining regulation includes permitting, inspection and enforcement activities. The minerals regulated include coal, industrial minerals (clay, barite, limestone, sandstone, sand and gravel, traprock and tar sands) and metallic minerals (lead, iron, zinc, copper, gold and silver). While the Land Reclamation Commission is responsible for overseeing coal and industrial mineral laws, the responsibility for carrying out the duties associated with metallic minerals regulations rests solely upon the Land Reclamation Program and the director of the Department of Natural Resources.

At active coal mines, surface water quality is protected through National Pollutant Discharge Elimination System (NPDES) permitting. NPDES monitoring ensures that acid-forming spoils are being properly managed and adequate soil erosion control measures are being taken to prevent sedimentation or acid mine drainage from entering downstream tributaries. As for the protection of groundwater, coal-mining companies are required, under land reclamation permits, to conduct hydrogeologic assessment prior to, during, and after mining. They evaluate any impacts to groundwater quantity or quality in the vicinity of mine sites. Mine operators are further required to mitigate adverse effects stemming from mining activities.

For industrial mineral sites, the hydrogeologic evaluations are not required. Measures to control erosion and sediment movement off-site are required. Under the Metallic Minerals Law, the two lead mining companies and the one iron ore mining company in Missouri are required to provide plans and financial assurance for the continued maintenance of the mine waste sites after mining ceases. The objective is to ensure that the sites are stable and not subject to wind or water erosion of the waste materials (tailings). This primarily involves a coordination role to ensure that dam safety, water pollution control, air pollution control, and hazardous waste management regulatory requirements are met.

An estimated 22,200 acres at approximately 900 industrial mineral mine sites in Missouri are permitted for mining. Nearly 17,000 acres at 14 coal mine sites are permitted and are either actively being mined or are in various stages of reclamation. In addition, there are 16 coal mine bond forfeiture sites with approximately 5,100 acres that the department now has or had the responsibility to reclaim. Seven of these projects have been completed and eight are in various stages of reclamation design or construction. The 10 lead mine sites and one iron ore mine site permitted under the Metallic Minerals Law comprises approximately 4,600 acres.

Significant health, safety, and environmental problems are often associated with coal mine lands that were abandoned or inadequately reclaimed prior to passage of state and federal coal mining statutes in 1972 and 1977, respectively. There are more than 67,000 acres of abandoned coal mine lands in Missouri. Although nature has adequately reclaimed much of this land over the years, more than 10,000 acres have been identified that require reclamation work to correct a wide range of public health, safety and environmental problems. The worst of these problems are being eliminated by the department's Land Reclamation Program through reclamation of abandoned mine lands. Federal funds for these projects are collected by fees charged for each ton of coal mined in the U.S. These funds are distributed to Missouri and other states by the federal Office of Surface Mining Reclamation and Enforcement.

Since 1982, 93 abandoned mine land projects have been completed, reclaiming 3,879 acres. Acid mine drainage from abandoned coal mine lands severely degraded several streams, most notably Cedar Creek in Boone and Callaway counties, Manacle Creek in Callaway County and Middle Fork of Tebo Creek in Henry County, resulting in massive fish kills in the past. Reclamation projects completed from 1988-1994 in these watersheds successfully alleviated most of the acid mine drainage problems of these streams. Negative impacts on aquatic resources have been greatly reduced.

During 2001 and 2002, additional reclamation work was conducted in the Cedar Creek watershed to further lessen the effects of mine drainage on the creek. Four wetlands were constructed to passively treat mine drainage, and streambank work was completed to stabilize erosion. The Land Reclamation Program received federal funds from the Office of Surface Mining's Clean Stream Initiative and from the EPA, under Section 319 of the Clean Water Act. These additional funds were used to complete this work.

ENVIRONMENTAL EMERGENCY RESPONSE

The department has Environmental Emergency Response (EER) personnel that are specially trained and equipped to provide technical assistance in the event of a hazardous chemical or petroleum spill. Based in Jefferson City within the Environmental Services Program, the EER staff operates a 24-hour emergency telephone line established for taking reports of hazardous substance spills and provides on-scene response to environmental emergencies. In addition to the central office, regional EER staff are located in Poplar Bluff, Macon, Springfield, St. Louis, and Kansas City to provide timely on-scene response throughout the state. Rapid and effective emergency response to hazardous substance spills is critical in protecting the public and preventing or minimizing adverse impacts to the environment. Water resources in particular are often threatened or impacted by spills

from petroleum pipelines, barges or other vessels, chemical and petroleum bulk storage tanks, train derailments, and highway accidents.

In FY 2001, EER staff documented 3,283 incident reports received on the 24-hour emergency telephone line. When a call is answered on the hotline relating to a chemi-

The department's environmental emergency response boat equipped for responding to petroleum and other chemical spills on major waterways. Photo from Environmental Service Program.

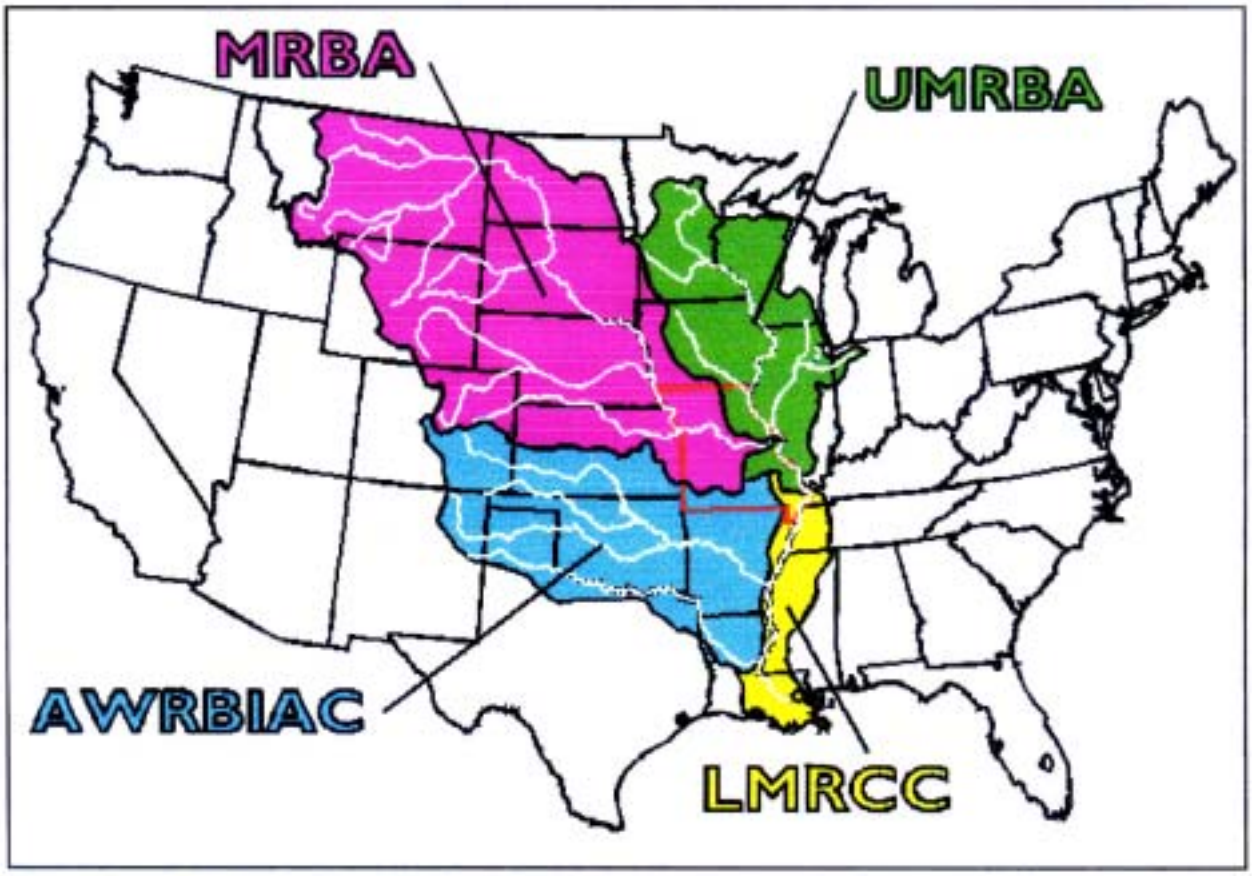
One of seven specially equipped EER (Environmental Emergency Response) trucks used by the department for on scene responses to environmental emergencies. Photo from Environmental Response Program.

cal or petroleum spill, a duty officer documents the incident in a written report and takes appropriate action. Such action may include providing technical advice on spill cleanup over the telephone and may involve subsequent notification to other agencies that would have an interest. When warranted, EER staff will respond on-scene to provide technical advice and oversight, work to ensure the protection and safety of the public and the environment, and assess and document any environmental damages. The EER staff maintains a fleet of specially-equipped response trucks and a 24-foot response boat that are used for on-scene response as needed. In FY 2001, EER staff responded on-scene to 759 incidents throughout the state. The 24-hour telephone number for reporting environmental emergencies to the department is (573) 634-2436.

INTERSTATE USE OF WATER

RSMo 640.405 - The department shall represent and protect the interests of the state of Missouri in all matters pertaining to interstate use of water, including the negotiation of interstate compacts and agreements, subject to the approval of the general assembly. Any department of state government affected by any compact or agreement shall be consulted prior to any final agreement.

Missouri shares the waters of its major rivers with 19 other states. Federal agencies also manage much of this water. To ensure that Missouri's interests are considered, the department represents the State of Missouri in the following interstate river associations:



Areas served by the following river basin associations

UPPER MISSISSIPPI RIVER BASIN ASSOCIATION

The Upper Mississippi River Basin Association (UMRBA) is made up of representatives of Missouri, Wisconsin, Minnesota, Iowa and Illinois. Steve Mahfood, director of the Department of Natural Resources, is Missouri's UMRBA representative.

The UMRBA developed a master plan to balance economic development with environmental improvement on the upper Mississippi River. The UMRBA works through Congress and the states to carry out provisions in the master plan, and pursues a legislative agenda as agreed upon by the state members.

The U.S. Army, Corps of Engineers, has recently restructured its Upper Mississippi River–Illinois Waterway System Navigation Study to include equal environmental and economic benefits. The UMRBA monitors the study's progress and have been an advocate for its timely completion. An interim report is being completed in the summer of 2002, and a feasibility report is due for completion in 2004. Mr. Mike Wells, deputy director GSRAD and Chief of Water Resources Program, is Missouri's representative to the navigation study. The UMRBA has been very successful in attracting private and federal funding to enhance the Mississippi River.

MISSOURI RIVER BASIN ASSOCIATION

Membership of the Missouri River Basin Association (MRBA) includes Missouri, Kansas, Iowa, Nebraska, North Dakota, South Dakota, Montana, and Wyoming, plus one member representing the basin's Indian tribes. Steve Mahfood, director of the Department, is Missouri's MRBA representative.

The MRBA is collaborating with the U.S. Army, Corps of Engineers, on revising the Master Water Control Manual for the Missouri River. The MRBA also pursues a legislative agenda as agreed upon by its Board of Directors, and provides a forum for the discussion of contemporary water resource issues in the basin, such as tribal water rights, flow management, diversions, agricultural issues, and endangered species.

For the past 14 years, the states of the Missouri River basin have been embroiled in controversy over how the river should be managed. The disagreement, brought on by severe and persistent drought that began about 1988 and ended with the Great Flood of '93, focuses on the requirements embodied in the Missouri River Master Water Control Manual. This document, familiarly called the "Master Manual," guides the Corps' Reservoir Control Center in Omaha. The Control Center operates the system of dams and reservoirs that enable management of the river's flow.

As long as rainfall in the basin was normal or above, there was little disagreement between the states of the upper basin and those of the lower river. However, the system was not severely tested by drought until reservoirs began to be drawn down in response to the six-year drought.

The crux of the disagreement is fundamental. Upper basin states contend that reservoir levels ought to be held at high levels - even in drought - to protect the recreational industry that has developed around the six large lakes on the upper river. Missouri views this position with considerable alarm, because it would deny our state the use of a significant share of the water stored in the reservoirs.

In effect, if the upstream states were successful in changing the management strategy to meet their demands, it would completely compromise the purposes for which the system was designed and built. The design objectives for the system were to store water in wet seasons, releasing it in dry sea-

sons to provide flood control, navigation, water supply, power generation, irrigation water, and fish and wildlife benefits throughout even the most severe droughts.

Since 1998, the MRBA has been working on a consensus management plan for the Missouri River to recommend to the Corps of Engineers. The plan MRBA eventually adopted was not supported by Missouri because it placed too much emphasis on retaining water in upstream reservoirs for recreational purposes, and placed Missourians at greater risk of flooding.

During the period of August, 2001, to February, 2002, the U.S. Army, Corps of Engineers (Corps), conducted public hearings and accepted comments on a Revised Draft Environmental Impact Statement (RDEIS) on proposed revisions to the Master Manual. The State of Missouri formally opposed all five of the proposed alternatives to the Current Water Control Plan (CWCP) presented in the RDEIS. The five new plans all include provisions that would dramatically increase reservoir storage while negatively impacting downstream uses, especially Mississippi and Missouri River commerce.

Four of the plans include features that would increase flows during the spring ("spring rise") while decreasing flows during the summer months. The spring rise would increase the risk of downstream flooding and the summer low flows would cripple or eliminate navigation on the Missouri River.

ARKANSAS-WHITE-RED BASINS INTER-AGENCY COMMITTEE

The Arkansas-White-Red Basins Inter-Agency Committee (AWRBIAC) includes representatives from the states of Missouri, Arkansas, Louisiana, Texas, Oklahoma, Kansas and New Mexico. Steve Mahfood, director of the Department, is Missouri's AWRBIAC representative. Federal agencies in AWRBIAC include the Department of the Interior, U.S. Geological Survey, Bureau of Reclamation, National Oceanic and Atmospheric Administration, Federal Emergency Management Agency, U.S. Army Corps of Engineers, Southwestern Power Administration and the Natural Resources Conservation Service, USDA.

The AWRBIAC exists primarily for coordination and communication purposes. Administration and hosting of meetings are rotated among both state and federal members. The primary activity of interest to Missouri is the development of operating plans for the White River, which includes Table Rock Dam, Clearwater Dam, and part of Lake Norfork in Missouri. Also of interest is the development of abatement measures and methodology to improve dissolved oxygen content of the tailwaters of White River dams. An annual operating plan for the White River, during the low dissolved oxygen season, has been developed that improves economic return while addressing issues related to low dissolved oxygen in the tailwaters that flow from hydropower dams.

In 2001, the Corps of Engineers began a White River comprehensive study. The Little Rock office of the Corps began this reallocation study of flood control and hydropower pools for downstream trout releases.

LOWER MISSISSIPPI RIVER CONSERVATION COMMITTEE

The Lower Mississippi River Conservation Committee (LMRCC) has membership that includes the states of Missouri, Tennessee, Kentucky, Arkansas, Mississippi, and Louisiana. Federal agencies represented (as non-voting associates) include the U.S. Army Corps of Engineers, Environmental Protection Agency, U. S. Geological Survey, Natu-

ral Resources Conservation Service and U.S. Fish & Wildlife Service.

The LMRCC differs from other basin associations by including fish and wildlife agencies as well as environmental regulatory agencies. The LMRCC has several standing subcommittees that deal with specific subsets of lower Mississippi interests, such as fish and wildlife and water quality.

The LMRCC is addressing several water quality issues, including Gulf hypoxia (low dissolved oxygen). Hypoxia is caused by excessive nitrogen in the Mississippi River water flowing into the Gulf of Mexico. High nitrogen levels ultimately result in oxygen depletion in the water and the development of a widespread "dead zone" in the Gulf that has been characterized as the marine equivalent of the "ozone hole" over Antarctica. This is an issue for Missouri because some of the nitrogen sources have been identified as coming from grain-producing states in the Midwest.

INTERSTATE COUNCIL ON WATER POLICY

The Interstate Council on Water Policy (ICWP) is a national organization, with members representing state water resource agencies, that strives to promote the interests of states in dealing with the federal government on issues related to water. Missouri is a member of ICWP. The ICWP has a Washington office and a board of directors elected from among state members. The organization sponsors annual forums addressing water resource issues of interest to states, and an annual conference in Washington to bring together federal agency officials and Congressional staff with state representatives to discuss water resource concerns of states. Missouri is an active participant in ICWP activities.

The ICWP has a standing committee to coordinate the activities of interstate river basin organizations toward a more effective national input.

MISSISSIPPI RIVER PARKWAY COMMISSION

The membership of the Mississippi River Parkway Commission (MRPC) includes all ten states bordering on the Mississippi River. The MRPC's major thrust is toward improving opportunities for tourism growth along the Mississippi River from New Orleans to St. Paul.

Missouri's Mississippi River Parkway Commission has five members appointed by the governor, plus two senators and two representatives appointed by the State Legislature. The department participates in a technical advisory capacity, with the Missouri departments of Transportation and Conservation, and the Division of Tourism.

Missouri's participation in the MRPC has focused on improving the environmental quality of the river corridor as a way to increase the region's attractiveness to tourism and economic development.

MISSISSIPPI RIVER BASIN ALLIANCE

The Mississippi River Basin Alliance (MRBA) includes both individual and agency/corporate memberships. The Alliance focuses on environmental issues throughout the Mississippi River basin. Various committees address issues of current importance, such as environmental justice, nonpoint source pollution, legislative agenda, and monitoring federal initiatives.

The MRBA meets annually for technical sessions and training activities.

MONITORING WATER QUALITY

RSMo 640.409 calls for the department to establish, develop and maintain an ongoing statewide surface and groundwater monitoring program, the purposes of which are the following: 1) determination of ambient surface and groundwater quality for use as background or baseline water quality data; 2) detection of trends in the character and concentration of contaminants in surface and groundwater resources; and 3) identification of areas highly vulnerable to contamination.

The Department of Natural Resources (the department) conducts an extensive monitoring program for chemicals and microbial contaminants in public drinking water systems. In FY 01, more than 2,700 public water supplies were tested, with over 147,000 samples analyzed. This effort covers both surface and groundwater sources.

Most of the tests are performed on tap water, the "finished" water that people drink or use for cooking; this is water after treatment. Some "raw" water monitoring also is done to provide operational data to water system operators, and to help them in their treatment processes. For example, well water is tested to help the water companies know what is entering their water works. This helps them know what treatment to provide and to prepare in advance.

The vast majority of water quality concerns are for failure to meet the requirements of the Total Coliform Rule. Total coliform bacteria serve as an indicator that harmful organisms may be present, and all public water systems in the state must test for this type of bacteria every month they dispense water to the public. The department's Public Drinking Water Program (PDWP) provides an annual compliance report that lists all of Missouri's public water systems with maximum contaminant level (MCL) exceedences.

The PDWP's fifth Annual Compliance Report became available to the public on July 1, 2001. The report covers all of Missouri's 2,762 public water systems for calendar year 2000. The report lists all public water systems with maximum contaminant level (MCL) exceedences and those systems with monitoring problems that have become chronic. New to the report this year was a listing of systems considered significant noncompliers (SNCs) by the Environmental Protection Agency. The most significant finding in the 2001 report was that the percentage of the population served by community water systems that met all of the health-based standards increased to 98.5 percent. This is already above the national target of 95 percent set by the EPA for 2005. The 2001 Annual Compliance Report is posted on the PDWP's home page at www.dnr.state.mo.us/deq/pdwp/homepdwp.htm, along with the prior year reports.

Public water systems with serious water quality exceedences potentially affecting public health or multiple monitoring violations are placed on a Significant Non-Compiler (SNC) list. The department works closely with violators to return them to compliance in a timely manner. During 2000, only 130 of the more than 2,700 public water systems were on the SNC list.

For all exceedences, public water systems are required to notify the customers they serve. The method of notification varies by the exceedence and system type. Some water quality violations, such as the confirmed detection of fecal coliform bacteria or *E. coli*, warrant more immediate action due to the threat to public health. Acute violations, the department requires systems to immediately notify their customers to boil their water before consumption. Boil water orders remain in effect until the problem has been corrected and the water is safe to consume.

In addition to compliance monitoring, the department also provides monitoring that assists public water systems to anticipate the impact of future regulations. For example, since 1994, the PDWP has been monitoring for disinfection by-products (DBPs) in public water systems not currently required by regulation to monitor for DBPs, including small surface water systems, groundwater systems with wells in unconsolidated formations, and secondary systems. Secondary systems do not have their own water source, but instead purchase their water from another water system.

Disinfection by-products are formed in drinking water when a disinfectant (usually chlorine) is added to the water to inactivate bacteria and other potentially harmful microbes. The disinfectant reacts with natural organic matter in the water to form disinfection by-products, some of which may have serious health effects.

The purpose of the special monitoring was to see if any of the systems would have problems with the lower maximum contaminant level (MCL) limits required by federal regulations in 2002 for large systems and 2004 for small systems. The monitoring revealed a number of systems that will need to work together with their water suppliers to try to reduce disinfection by-product levels before the rules apply. Because of the PDWP's special monitoring effort, these systems now have more time to prepare for the regulations that are coming.

VULNERABILITY

In 2001, the PDWP initiated special monitoring for Radium 228 (Ra228). RA228 is a naturally occurring radioactive element and potential drinking waster contaminant that had not been monitored routinely in the past. New routine monitoring will be required by federal regulations in 2004 for Missouri systems. The special monitoring begun by the PDWP will allow "grandfathering" of sample results and reduce the frequency of future monitoring.

Very few of the state's water systems are expected to have any Ra228, based on previous radionuclide monitoring, but they all would have to collect quarterly samples if the grandfathering of data cannot be done. The special monitoring should eliminate this time consuming quarterly monitoring for most systems and reduce analysis costs for the department. The early monitoring will also detect those few systems will Ra228 problems and allow them more time to prepare for the regulations that are coming.

The department first became aware of methyl tertiary butyl ether (MTBE) as a potential threat to Missouri's drinking water in 1994 and added it to the list of volatile or-

ganic chemicals (VOCs) routinely tested for. Public water systems served by surface water are routinely tested once a year, and groundwater systems, once every three years. The end of 2000 marked a milestone as the PDWP completed two rounds of MTBE testing for all public water systems. In addition to this routine testing, MTBE results are also provided when other volatile chemical tests are run. The larger public water systems (serving 10,000 or more people), all surface water systems and some groundwater systems are tested every three months. Missouri has been fortunate in that over the years only five public water systems (with a total of six wells) have been impacted by MTBE contamination. In all cases, the source of contamination was leaking underground petroleum storage tanks or associated piping.

The PDWP discovered gasoline contamination in New Madrid County Public Water District No. 2's only well during routine testing in October, 2000. This water district is located in Kewanee, Missouri, and serves about 500 people. Water district officials quickly evaluated their options and worked out an agreement with the City of New Madrid to hook onto their system. The PDWP continued to monitor the contaminated well throughout the project. The MTBE was slowly creeping up and benzene had started showing up in the summer of 2001.

The PDWP provided the water district with technical assistance and financial assistance in the form of a $150,000 grant in 2001. The Department of Economic Development also contributed to the project with a $150,000 grant and low interest loan of $100,000. The water district put in $50,000 of their own money. The project consisted of installing a booster pump station and laying six miles of water line to the City of New Madrid. The water district has been buying water since December 27, 2001.

A combination of technical and financial assistance from the PDWP, and quick action by the water district averted a potentially catastrophic loss of a public water supply, and assured that the drinking water for the people of the Kewanee area is once again safe.

A part of the PDWP's monitoring plan is a vulnerability assessment performed to support the waiver of monitoring requirements. This indicates various threats to specific public water supplies and allows that information to be considered in establishing monitoring requirements.

The Public Drinking Water Program uses a vulnerability assessment to determine which sources of drinking water need to be tested for certain chemicals. If certain chemicals are located in a geographic area and may potentially affect a drinking water source, that source is monitored for the presence of those chemicals in the water. This allows the cost of analysis to be focused on the vulnerable sources. Without these assessments, the department would have to test every drinking water source for every chemical listed by the U.S. Environmental Protection Agency (EPA) as a drinking water contaminant.

The department is implementing a source water assessment plan to identify areas highly vulnerable to contaminants. The source water assessment plan describes how Missouri will delineate geographic areas that may influence the quality of drinking water and identify potential contaminant sources within the areas. The goal is to protect public drinking water sources from contamination and provide safe drinking water. The PDWP is conducting these assessments with assistance from the department's Geological Survey and Resource Assessment Division and with the University of Missouri's Center for Agricultural, Resource, and Environmental Systems (CARES). The department's plan

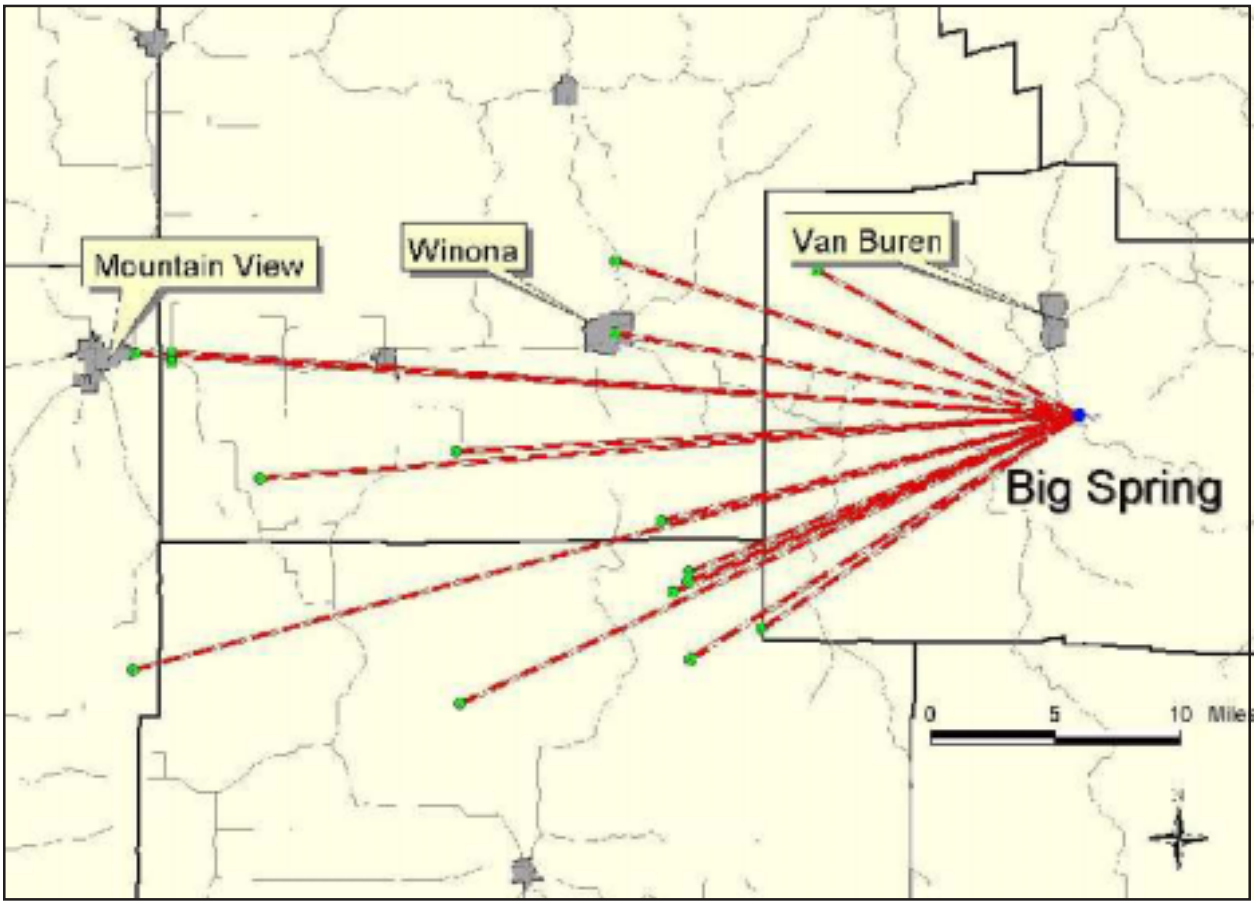
was approved by the U.S. EPA in June, 2000. The source water assessments will be completed in 2003.

The PDWP contracted with the University of Missouri to acquire accurate locations of potential drinking water contaminants in the vicinity of public drinking water sources. During 2001, the PDWP and the university located 5,621 potential drinking water contaminant sources, bringing the total number of inventoried sites to 15,391. All information is being collected, stored, and used in a geographic information system (GIS).

These assessments increase awareness of the threats to drinking water, but do not mean the public water systems have been contaminated. The assessments are being provided to water systems and the public to inform them of the potential threats to their drinking water source and to encourage local source water protection initiatives.

The PDWP and the University of Missouri's Center for Agricultural, Resource, and Environmental Systems (CARES) have made maps and other information on all public water system wells available to the public on the Internet at http://www.cares.missouri.edu.

Outreach activities have been conducted to educate the public about the importance of protecting their drinking water sources from contamination. The department strongly encourages voluntary source water protection efforts to protect water quality, and hopes that communities will take advantage of the source water assessment results as a starting point for local source water protection efforts.



Example of a water trace. The green dots represent points that dye was introduced into the ground through sinkholes or losing streams. The blue dot represents where the dye was recovered. This indicates direction of groundwater flow and helps define the recharge area of Big Spring.

GROUNDWATER MONITORING

The department studies the recharge areas of springs, and delineates losing streams and sinkholes to determine areas where groundwater is particularly prone to contamination. Harmless fluorescent dyes are used to trace the movement of groundwater from its recharge area to its discharge point.

Since 1989, the department has performed numerous water traces in karst areas where groundwater resources can easily become contaminated by surface activities. In karst areas, much surface water is channeled underground in losing streams and sinkholes. The water lost to the subsurface typically resurfaces, sometimes as far as 40 miles away, at a spring or springs. Water wells between the recharge point and the receiving spring can be affected by contaminants entering losing streams and sinkholes.

The results of individual dye traces are stored in the department's Dye Trace Data Base. Since 1989, several reports have been published that describe in-depth studies of several major spring systems *(Hydrogeology of the Bennett Spring Area, Laclede, Dallas, Webster, and Wright Counties, Missouri,* Water Resources Report No. 38; *Hydrogeology of the Maramec Spring Area,* Water Resources Report No. 55; and *The Springs of Greene County, Missouri*, Water Resources Report No. 68 which was published in 2001) are examples.

The Water Well Drillers law requires that all persons engaged in water tracing register with the department and renew the registration annually. All proposed injections must be reported to the department's Geological Survey and Resource Assessment Division prior to injection of dye, and written and graphical documentation of traces is provided to the department within 30 days after completion of each trace. The information will be provided to interested parties upon request, at cost of reproduction. For the trace to be included in the department's dye trace database, the data must be examined by the three-member Dye Trace Committee. If the data quality and documentation are satisfactory, then the results are entered into the department dye trace database.

The department performs a variety of water- and sediment-quality investigations each year in the form of complaint investigations, wasteload allocations, ecological risk assessments, and fish tissue contaminant monitoring. Department biologists are currently developing aquatic macroinvertebrate-based "biocriteria" for assessing stream quality in each eco-region of the state. These criteria will eventually be incorporated into the state water quality standards.

Due to the Flood of 1993, a federally funded sanitary landfill monitoring project for flood-damaged sanitary landfills was implemented. Effects of the flood included periods of surface ponding, soil saturation, and elevated groundwater table and increased velocity in the subsurface movement of water. The department received equipment and training from the federal program to monitor landfills that operated before and after the flood to determine if any surface or groundwater contamination occurred.

The results of the study indicated that landfills contributed no measurable contamination of surface water off-site. Also, no impact to groundwater could be determined to have taken place. However, many of the landfills studied did experience a significant increase in the migration of landfill gas (methane) through the soil away from their facilities.

Some of these migrations present a potential public safety problem due to the dangers associated with explosion or asphyxiation should the gas accumulate in nearby structures. For example, in the spring of 1998, a fire started in the basement of a pri-

vate home situated next to a closed landfill. A field investigation conducted by the department confirmed that the fire was caused by methane gas migrating from the landfill into cracks in the floor, and igniting from the water heater. No one was injured; however, within weeks of the investigation, the landfill owner purchased the home and property from the citizen, and bought another home that was threatened. Both homes were vacated due to the ongoing threat of explosion. Through an extension of the original project, further study is underway to gain a better understanding of what can be done to evaluate and address these methane gas migrations that may occur at landfills throughout the state.

SURFACE WATER QUALITY MONITORING

The major purposes of the water quality monitoring program are to:

1) characterize "background" or "reference" water quality conditions;
2) better understand flow events, and diurnal and seasonal water quality variation and its underlying processes;
3) characterize aquatic biological communities and habitats, and distinguish between the impacts of water and habitat quality;
4) assess time trends in water quality;
5) characterize specific and regional impacts of point and nonpoint source discharges on water quality and;
6) check for compliance with water quality standards or wastewater permit limits.

All of these objectives are statewide in scope. Reference conditions of water chemistry and of aquatic macroinvertebrates have been or are being used to develop water quality standards. Due to the cost of environmental monitoring, the department routinely coordinates its monitoring activities with other state and federal agencies.

The strategy for monitoring varies by the waters being sampled. Many water quality monitoring strategies exist including monitoring effluent discharges, monitoring the impacts of discharges upon localized surface waters, monitoring extended impacts from effluent sources, and conducting surveys of "background" conditions. The monitoring activities through which these strategies are implemented take several forms:

1) Fixed station chemical monitoring networks. The department maintains 63 fixed stations through cooperative agreements with the U.S. Geological Survey and 56 sites maintained by the department's lab, and routinely track data from about 60 other sites monitored by other agencies.
2) Intensive surveys
3) Special topic monitoring (fish kill investigations, bacterial monitoring, contaminant transport studies, etc.)
4) Toxics monitoring
5) Biological monitoring (of aquatic macroinvertebrates). The department presently is monitoring 60 streams annually.
6) Fish tissue, sediment, and shellfish monitoring. The Missouri Department of Conservation monitors about 30 sites and the department/USEPA monitors about 20 sites annually for toxicants, primarily pesticides and metals, in fish tissue.
7) Monitoring by volunteers - A cooperative program sponsored by the Department of Natural Resources, the Department of Conservation, and the Conservation Federation of Missouri, known as Stream Teams, has trained and equipped volunteers around the state to conduct both chemical and biological monitoring of streams. At present, there are approxi-

mately 1,200 active volunteers monitoring 1,015 different sites. Most of the data collected by these volunteers are reported back to the department's Water Pollution Control Program.

MONITORING PROGRAM EVALUATION

The water quality monitoring program within the department evolved as a program to characterize and cope with point source wastewater discharges. This program, which has stressed chemical monitoring, appears to have been successful.

In 1998, the department shifted emphasis of monitoring programs in the following ways:

1) maintain the size of the fixed station flow and chemistry network, and include chemical analysis of sediments in some streams;
2) increase the amount of intensive chemical and biological water quality studies; and
3) increase the amount of aquatic invertebrate sampling statewide toward the development of biological criteria within the water quality standards.

The major reasons for these changes are the perception that:

1) more large municipal or industrial wastewater discharges need substantial water quality study to fully understand their impacts on receiving waters than the department is presently able to conduct;
2) biological criteria may be better than conventional chemical monitoring for characterizing many nonpoint pollution sources;
3) many problems in streams are not due to water chemistry problems, but to physical problems in the stream channel, in the riparian zone, or farther up in the watershed.

The biggest challenge will be to find a way to assess the water quality impact of thousands of confined animal feeding operations across the state. To date, the Department of Natural Resources and the Department of Conservation have been able to investigate and document at least a portion of all discharges that have caused fish kills, but no monitoring program has ever tried to assess the day-to-day sub-acute impacts of these pollution sources, which may be significant.

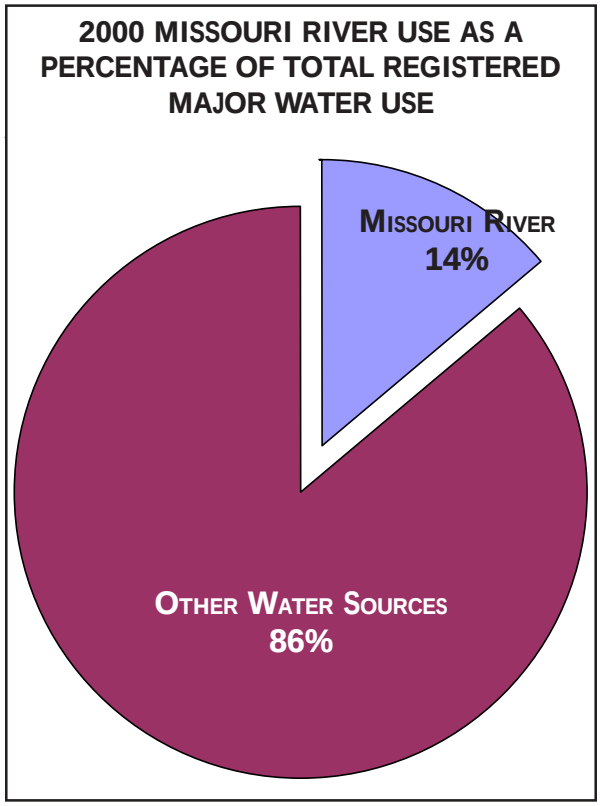
INVENTORY OF WATER USE AND AVAILABILITY

RSMo 640.412 - The department shall maintain an inventory of ground and surface water uses, quantity and users. - The department shall inventory the following: 1) existing surface and groundwater uses; 2) quantity of surface and groundwater available for uses in the future; and 3) water extraction and use patterns.

WATER USE

As part of the Major Water Users Law (RSMo 256.400), the department compiles water use information. Major water users are defined as those users that are capable of pumping greater than 100,000 gallons per day from either groundwater or surface water. There were 1,971 users registered in 2000. There is no financial penalty for failing to report but users that do not report can be requested to cease diversion by the attorney generals office through an injunction (RSMo 256.415). The Major Water Users Database includes information about location, amount of water used and type of use (domestic, municipal, irrigation, recreation, industrial, electrical generation, fish and wildlife, and drainage.)

The department is updating the water user registration forms for Internet compatibility. Currently, the water user registration forms are mailed via the U.S. Postal Service to the major water users in the state. Users type in or print in the information and then mail the completed form back to the depart-



According to reported Major Water Users data, 791.5 billion gallons of Missouri River water was used in 2000. This accounts for 14% of all water use reported for the state in 2000. The majority of Missouri River water is used for production of electrical power (83%, 660 billions gallons), followed by municipal water supply (16%, 128 billion gallons), with 3 billion gallons used for fish and wildlife, and 55 million gallons used for irrigation. These figures include withdrawal reported from the river and its alluvium.

ment. The first stage of the programming is finished and allows Internet access to the registration forms. Adobe Public Document Format (PDF) computer files of the registration forms are now available. These PDF files are linked to the Water Resources Program-Major Water Users Unit Internet web page (http://www. dnr.state.mo.us/dgls/wrp/waterusestatutes.html).

In the future, the second stage will allow users to complete their annual reporting obligation by filling out the forms on their home computers, and then submitting them via e-mail (mowaters@mail.dnr.state.mo.us) to the department, or (nrbarnj@mail.dnr.state.mo.us).

The final stage, some time away, will allow interactive communication between the users' computers and the department's computers, so that the public can view their own water usage and anyone can view and study water use trends by area and source. The department's Internet firewall and other safeguards must be in place before public sharing of the Major Water Users database will be allowed. The data may be copied or "downloaded" to individual computers so that people can study them. The original, master database will be write-protected and in read-only mode so that the data are not altered. During the last several years, the data have been geographically referenced so data users can develop data layers on geographic-based data platforms. Water withdrawal information is now in both the latitude-longitude format and the township-range format.

The Census of Missouri Public Water Systems, published by the department, provides many details about water use by public water systems. It includes the water source, the production capacity and average daily consumption, the location of surface water intakes, and the number of customers served. Currently, there are 2,762 public water systems serving cities, water districts, subdivisions, trailer parks, and institutions. Almost five million citizens of Missouri use public water systems as their source of water. The total production capacity of Missouri's community water systems is 1,840 million gallons daily (MGD), with an average daily consumption of 807 MGD. (Cities and water districts are examples of community water systems.)

GROUNDWATER AVAILABILITY

The importance of groundwater to Missouri cannot be overstressed. Based on statistics in the 2000 Census of Missouri Public Water Supplies, of the 1,444 community public water supplies in Missouri, 1,205, or about 83.4 percent, use groundwater as their water source. If only primary supplies are considered, 92.6 percent of the 1,191 primary water supplies use groundwater. Only 88 primary water supply systems use surface water. Secondary water supply systems are public water systems that purchase water from a primary system. Nearly all of the 1,296 noncommunity public water supplies use groundwater. There are about 3,800 active public water supply wells in use in Missouri, and another 600 public water supply wells that are inactive.

In terms of population served by public water supplies, surface water systems supply a greater percentage of Missouri residents than groundwater systems. Approximately 84.5 percent of Missouri's 5,595,200 residents, or about 4,730,000 people, are served by community public water supplies. About 34 percent of these, 1,610,000 people, use groundwater. Surface water supplies about 3,125,000 people or 66 percent of the state's population.

An estimated 864,000 Missouri residents, or about 15 percent of the state's popula-

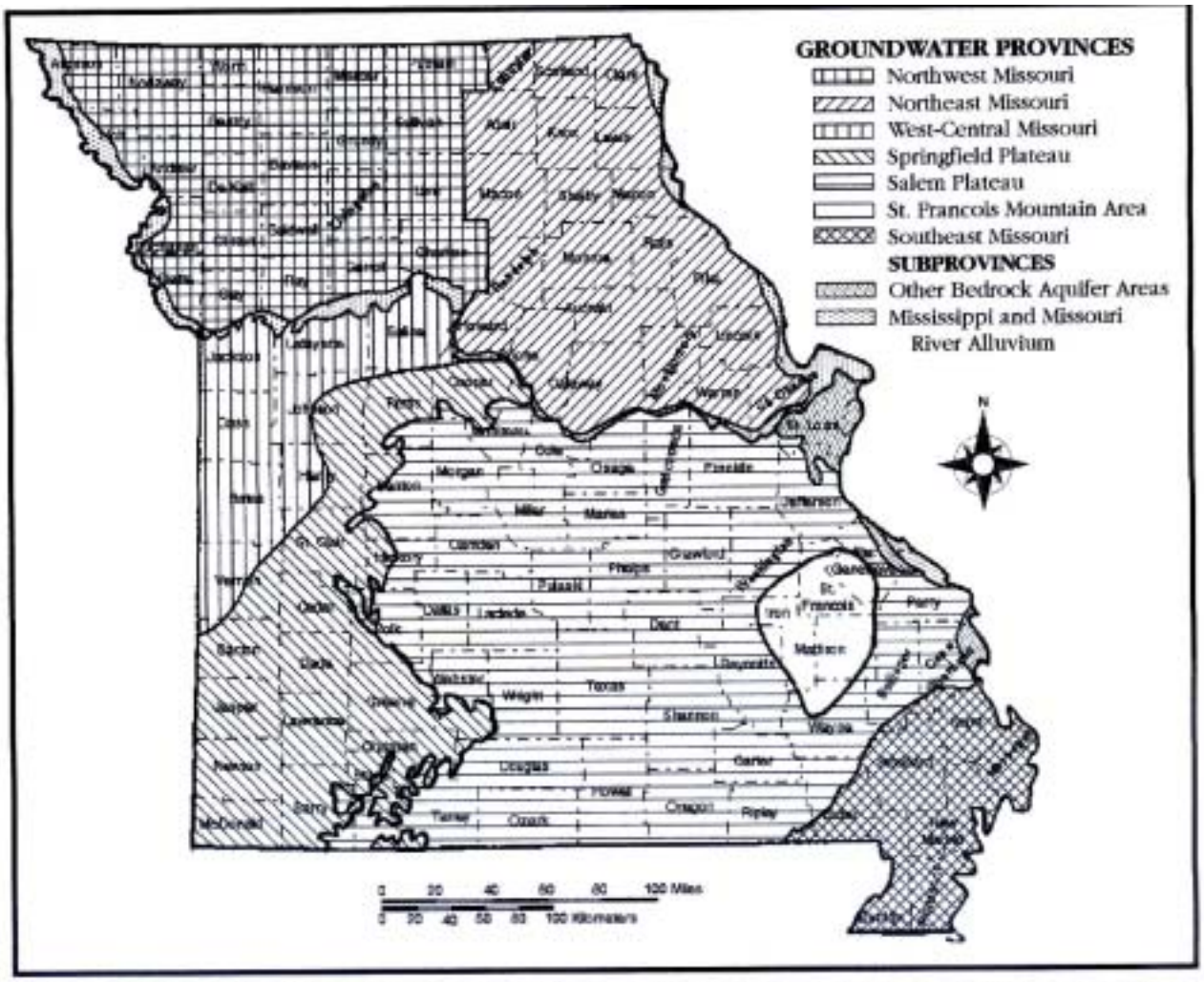
tion, use private water supplies. Since small-scale private surface-water supplies suitable for providing safe drinking water to single families or farms are both complicated and expensive to construct and maintain, it is safe to say that most of these residents use groundwater but cisterns are still used in some rural areas. Approximately 7,000 private water supply wells are drilled yearly in Missouri, mostly in the southern part of the state.

Missouri's groundwater resources are not evenly distributed across the state. Potable groundwater, water that is essentially usable as it is produced and requires no elaborate treatment to remove undesirable constituents, is much more common in southern Missouri than in the northern part of the state. This is mostly due to the geologic variations across Missouri. Estimates made as parts of the Missouri State Water Plan Series indicate that potable groundwater in storage in Missouri may be as great as 500 trillion gallons. Only about 13.3 percent of this is in northern Missouri north of the Missouri River. The remainder is south of the Missouri River, principally in the Ozark region and in the Southeastern Lowlands.

The state can be divided into seven groundwater provinces, each having distinct groundwater and aquifer characteristics. The St. Francois Mountains groundwater province of southeastern Missouri contains the oldest rocks in the state that are exposed at land surface. Precambrian igneous rocks are found at or near the surface throughout much of this region. Upper Cambrian-age sedimentary rocks consisting of thin shales and siltstones and much thicker dolomite and sandstone units overlie them. The igneous rocks are nearly impermeable except where fractured. Thus, yields of wells drilled into the Precambrian igneous rock are generally only a few gallons per minute or less. The younger sedimentary rocks overlying the igneous rocks comprise the St. Francois aquifer. Where it is very thin, the St. Francois aquifer may only supply a few gallons of water per minute. Where it is the thickest and contains the greatest amount of sandstone it can produce more than 300 gallons of water per minute. The St. Francois Mountains area is one of the most difficult areas in Missouri in which to obtain a reliable groundwater supply for private domestic use. In most places, it is not possible to develop a groundwater supply capable of meeting even modest municipal or irrigation demands. Groundwater storage estimates indicate this region contains only about 0.92 trillion gallons of potable groundwater, which represents only about 0.2 percent of Missouri's groundwater resources.

The Salem Plateau groundwater province surrounds the St. Francois Mountains. The Salem Plateau is most extensive to the north, west, and south of the St. Francois Mountains, and relatively small on the east side. Thick Ordovician- and Cambrian-age dolomite and sandstone units comprising the Ozark aquifer overlie the St. Francis aquifer in this region. Groundwater resources in the Salem Plateau groundwater province are the most extensive in the state. About 46.6 percent of Missouri's potable groundwater is in this region, a volume of about 233 trillion gallons. All but a very few communities and essentially all of the rural residents in this province rely on groundwater. Depending on well depth and location, private domestic wells a few hundred feet deep can easily produce water ample for domestic purposes, while larger-diameter wells 1,200 to 1,500 feet deep typically can produce from 300 to more than 1,000 gallons of water per minute.

Although this region contains abundant groundwater resources, the geology here makes groundwater particularly prone to contamination. Permeable residual soils and karst features such as sinkholes and losing



Groundwater provinces and subprovinces of Missouri. Source: WR#46 – Groundwater Resources of Missouri

streams allow rapid groundwater recharge to occur. In some areas, most of the normal flows of streams are channeled underground in losing streams. Proper land use and waste disposal practices are paramount to protecting the wells and springs of this region.

The Springfield Plateau groundwater province occupies the southwestern part of the state and a small region of central Missouri south of the Missouri River. Thick Mississippian-age limestones and cherty limestones form the bedrock surface in the region and overlie the same Ordovician and Cambrian strata found in the Salem Plateau. The Mississippian strata comprise the Springfield Plateau aquifer that is widely used as a private water supply source in this province. Yields of wells producing from the Springfield Plateau aquifer are typically less than about 20 gallons per minute. Wells fully penetrating the deeper Ozark and St. Francois aquifers can yield more than 1,000 gallons per minute. Groundwater in storage in this province is estimated to be about 122.5 trillion gallons, or about 24.5 percent of the usable groundwater in Missouri.

Like in the Salem Plateau, weathering of the limestone bedrock in the Springfield Plateau has created pathways for rapid groundwater recharge such as losing streams

and sinkholes. These features are particularly well developed in parts of Greene and Christian counties, so much so that wells constructed in Greene and northern Christian counties since 1987 must be constructed to exclude production from the Springfield Plateau aquifer. A low-permeability shale unit between the shallow Springfield Plateau aquifer and the deeper Ozark aquifer greatly limits the vertical interchange of water between the two units and helps to protect the Ozark aquifer from contamination.

The West-Central Missouri groundwater province lies northwest of the Salem Plateau. The boundary between the two is the fresh water-saline water transition zone. South and west of the transition zone, groundwater in the Springfield Plateau, Ozark, and St. Francois aquifers is of good chemical quality. North and west of the transition zone these same aquifers yield water that is too mineralized for domestic use. The transition zone coincides with where the aquifers yield water containing 1,000 mg/L total dissolved solids. Water with less than 1,000 mg/L total dissolved solids is generally considered fresh water while that containing between 1,000 and 10,000 mg/L total dissolved solids is termed brackish. Water quality in deep aquifers further deteriorates to the north and west.

Potable groundwater in the West-Central Missouri groundwater province is typically difficult to obtain. Relatively shallow Pennsylvanian-age limestones and sandstones can produce marginal quality water but yields are generally low. In some areas it is impractical to develop a suitable groundwater source that will even supply a private residence. This province contains an estimated 1.2 trillion gallons of potable groundwater, or about 0.24 percent of the state's resource.

Many of the bedrock formations found throughout southern Missouri are also found north of the Missouri River. The southern part of the Northeast Missouri groundwater province lies to the south of the fresh water-saline water transition zone. Mississippian-, Ordovician-, and Cambrian-age strata in this area can supply from 10 to more than 1,000 gallons per minute of potable water, depending on depth. North of the transition zone water from deeper bedrock aquifers is generally too highly mineralized for most uses. Modest quantities of marginally potable groundwater are locally available in some of the shallow Mississippian strata where it is not overlain by Pennsylvanian strata. The Pennsylvanian strata have an overall low permeability and generally yield small quantities of marginal to poor quality water.

Glacial drift overlies the bedrock throughout much of this region. It is generally thickest in the northwestern counties of the province and thins toward the Missouri and Mississippi rivers. Thousands of shallow, large-diameter, hand-dug glacial drift wells once supplied many of the rural residents, but the development of rural public water supply districts has rendered most of these wells obsolete. The shallow glacial drift wells generally yielded less than 3 gallons per minute and relied on their large diameters for storage. Their shallow depths and poor construction made them very vulnerable to contamination from bacteria, animal wastes, and agricultural chemicals.

In most places, the glacial drift in this part of the state is not capable of supplying a volume of water suitable for public water supply. Alluvial deposits consisting of sand and gravel underlying the floodplains of major rivers in this area can yield large quantities of good-quality water. Yields as high as 2,000 gallons per minute are possible from properly constructed wells in favorable areas of the major alluvial aquifers.

The Northwest Missouri groundwater province has geologic characteristics similar

to those in the northeastern part of the state. However, in northwest Missouri there are no high-yield, potable bedrock aquifers available, and the glacial drift is typically more water productive than to the east. A test drilling program conducted in northwestern Missouri in the 1950s delineated the axes of numerous drift-filled preglacial channels, most of which are covered with younger glacial drift. The channels were the preglacial stream valleys, and were filled with waterborne coarse sediments during glacial periods. Properly constructed wells producing from favorable locations in the drift-filled channels can produce several hundred gallons of water per minute, and are locally used for irrigation as well as public water supply.

Like in northeastern Missouri, thick alluvial deposits underlying the floodplains of the major rivers are a significant source of water for agriculture as well as public water supply. Yields of 2,000 gallons of water per minute or more are possible from properly constructed wells in favorable areas of the Missouri River alluvium. Alluvial deposits along lesser streams generally yield substantially less water.

Groundwater, like all natural resources, is finite. Groundwater use in parts of the state has caused significant water-level declines in some aquifers. This is particularly true where groundwater is or was heavily depended upon to supply larger towns and cities. Water-level decline in the Ozark aquifer in the Springfield area, for example, has been well documented, and is partly responsible for the city seeking alternative supplies from surface-water sources.

Water-use conflicts occur on almost a yearly basis in numerous areas of the state. Often the conflicts stem from competing uses of the water. For example, an aquifer that has historically been used to supply private domestic wells for households and farms is suddenly tapped to supply water for irrigation, a rural water district, or a large industry. The result of the increase in groundwater demand commonly is a decline in groundwater level in the area in and adjacent to the major withdrawal. Many of these declines occur in aquifers that are more than 1,200 feet thick. A decline of, say, 100 to 200 feet, may seem reasonably minor compared to the total saturated thickness of such an aquifer, but it may completely de-water, shallower private wells, or at least substantially decrease their yields. Such conflicts are further amplified during drought periods when groundwater use is above normal and lack of rainfall precludes any groundwater recharge, even to relatively shallow unconfined aquifers.

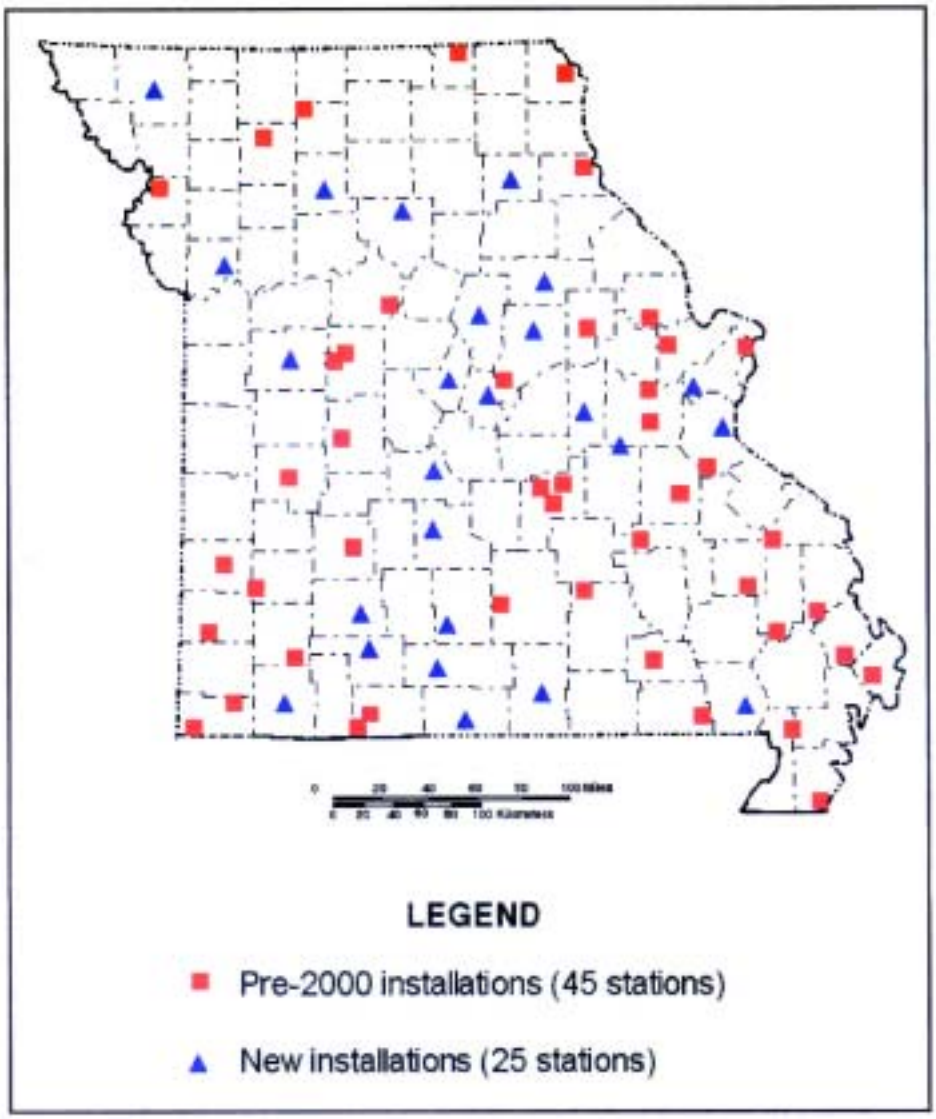
Unlike surface water, groundwater typically requires little or no treatment to make it suitable for most purposes. Assuming the resource is available, the cost of developing a groundwater supply is a small fraction of that of developing a similar volume surface-water supply. Thus, where groundwater is available, it is most commonly used. Historically, most industries using large quantities of water typically developed near urban areas where there were established water supplies. However, in recent years there seems to be an increasing trend of developing water-intensive industries, especially those related to agri-business, in rural areas, and supplying them with groundwater. New developments such as these, coupled with existing demands placed on groundwater from irrigation, municipal and domestic water supply, and other uses will likely continue to fuel water controversies for the foreseeable future.

GROUNDWATER-LEVEL OBSERVATION WELL NETWORK

The Department of Natural Resources, Water Resources Program, operates and maintains a network of groundwater-level observation wells throughout Missouri. This work began during the 1950s when extended drought conditions were causing serious water-supply deficiencies. Drought affects surface-water resources almost immediately, but because groundwater is ultimately replenished by precipitation, it, too, is adversely affected by prolonged dry weather. Shallow aquifers are typically replenished faster than deeper aquifers, and likewise are more readily affected by drought conditions. Deeper aquifers are typically recharged by downward movement of water from shallower aquifers, or from water moving laterally down-gradient from areas where the deeper aquifers are near land surface.

Most of Missouri's aquifers are dynamic groundwater flow systems. Water that is stored in the aquifers is actually in motion, slowly moving from areas of higher hydraulic head or water level to areas of lower hydraulic head or water level. Water in some karst aquifers that supply the major Ozark springs can move a mile per day or more, but most groundwater movement is measured in feet per year. Groundwater levels in unconfined aquifers directly relate to the volume of water in storage. In confined or artesian aquifers, the levels depict the head pressure in the aquifer. In both cases, an observation well is analogous to a dipstick in an automobile engine's crankcase. It allows the fluid level to be monitored accurately.

Water-level changes in aquifers can be due to many factors, both natural



Location of Groundwater-level Observation Wells across Missouri.

and man-induced. Tidal effects caused by the position of the Sun and Moon relative to the Earth can cause small fluctuations in groundwater levels in some aquifers. Barometric pressure changes can likewise cause significant temporary changes in water levels of confined aquifers when high and low pressure systems pass through Missouri. Earthquakes in different parts of the world can cause rapid fluctuations of groundwater levels in some wells up to several feet in magnitude. Water levels in some aquifers can be affected briefly by the passing of nearby trains or heavy trucks. However, most major changes in water levels stem from the removal of large quantities of groundwater through wells.

Prior to man's construction of water wells, groundwater flow systems were, for the most part, under steady-state conditions. The volume of water exiting the aquifers through seeps, springs, diffuse groundwater movement into streams, and other natural means was essentially equal to the volume of recharge the aquifer received. During dry years, when recharge was low, spring flows and inflow of groundwater into streams would likewise decrease. During wet years, the reverse took place; there was additional recharge and a greater volume of groundwater exiting the system. Water-level changes that occurred in the aquifers were relatively minor. This began to change with the development of water wells.

There were very few water wells in Missouri prior to 1900, other than shallow, hand-dug wells in the glacial drift area of northern Missouri. Streams and springs were mostly relied upon in the southern part of the state where shallow bedrock greatly hampers the construction of hand-dug wells. Early wells were mostly drilled for towns and cities. As drilling machines improved and drilling companies became more common, there was an increase in the development of private wells. Today, there are probably several hundred thousand wells in use in the state. Each year, some 7,000 new wells are drilled in Missouri, which are probably more than were drilled in a decade or more in the early part of the 1900s.

The total volume of groundwater removed each year from Missouri aquifers is not precisely known. Major water users, those entities capable of producing 100,000 gallons of water per day or more, reported using a total of about 271 billion gallons of groundwater during 2000, the latest year for which statistics have been compiled. This does not include the groundwater that is used by smaller suppliers, so it is safe to assume that actual groundwater use is substantially greater than 271 billion gallons. In 1995, the U.S. Geological Survey estimated that groundwater use in Missouri was about 890 million gallons per day, or about 325 billion gallons per year. If it were assumed that current groundwater use in Missouri is 350 billion gallons of water per year, this would be equal to an average yearly use of 62,554 gallons per resident, or a daily per capita use of 171 gallons, which is not an unreasonable value. If groundwater use per unit area is considered, then Missouri uses an estimated 5,020,872 gallons of groundwater per square mile each year. This is equal to 9.55 gallons of water per minute, per square mile, throughout the state.

A groundwater usage of less than 10 gallons of water per minute for each square mile of the state hardly seems excessive, and certainly would not be if the usage were evenly distributed. However, it is not. Large-scale groundwater use is generally localized. A town of 12,000 residents in the Ozarks will likely use more groundwater within an area of a few square miles than is used throughout the remainder of the county. A single industry in a rural area can use as much groundwater as a town of 15,000. Agricul-

tural irrigation is widely practiced in only a few areas of the state, including the southeast lowlands, west-central Missouri in Jasper, Barton, Vernon, and Dade counties, northeast Missouri in Audrain, Montgomery, and Callaway counties, and along the Missouri and Mississippi Rivers. In these areas, irrigation can have a pronounced impact on groundwater conditions.

Groundwater-level observation wells measure the effects of groundwater usage on aquifers. Observation well installations in relatively isolated rural settings have measured very modest groundwater-level changes during the last 45 years. Most of the fluctuations in groundwater levels have been due to natural phenomena. However, in other areas of the state, observation wells have documented groundwater-level declines in excess of 400 feet since the 1950s.

Prior to 2000, the observation well network consisted of about 45 to 50 observation wells that were mostly in the area south of the Missouri River. All were equipped with instruments to measure and record water-level changes. Data were collected from the wells every few weeks or months, depending on their location. The data collected by newer digital recorders were stored on paper punch tape that could

Wave of the future – new observation well recorders. These new data collection platforms consist of electronic data recorders and digital encoders. Water level information from each observation well is transmitted via satellite every four hours, allowing almost instantaneous access to important data. Photo by Susan Dunn.

be read by a tape reader and directly fed into a computer for processing. Older mechanical recorders recorded data using a pen and chart paper. The charts had to be processed by hand to obtain the data, a time-consuming task. In both cases there was typically a several week to several month delay between when data were collected and when they were available for use.

All of this changed in 1999, when the Missouri Legislature approved of an expansion to increase the number of observation wells and replace the recording instruments with state-of-the-art equipment. During 2000, equipment was purchased to equip 70 groundwater-level observation wells with data collection platforms that not only measure and record groundwater levels, but also transmit the data from the field to the office using the Geostationary Operational Environmental Satellite (GOES) weather satellite system. Data are collected at each installation at 30-minute intervals. Every 4 hours, the GOES satellite listens for data from only one station, and that station has a 1 minute time window in which to send the data. Within a few moments, the data are routed from the well, to the GOES satellite 22,000 miles in space, and back to a receiving station in Little Rock, Arkansas, operated by the U.S. Geological Survey. From there, it is transmitted by phone line to the U. S. Geological Survey office in Rolla, and posted on an Internet web site that is being developed as part of this project.

As part of this work, the department contracted for the construction of eight new observation wells in areas where information is needed and no existing unused wells could be located. Another 16 unused wells were donated or loaned to the department for use as observation wells by cities or other interested parties. New observation wells are now on line at or near Columbia, Drake, McDaniel Lake (near Springfield), Mexico, Shelbina, West Plains, Ozark, Springfield, Eureka, Camdenton, Qulin, Farmington, Lebanon, Richland, Cassville, Lewis and Clark State Park, Fountain Grove Wildlife Area, Theodosia, Urich, Dresden, Coffey, Warrensburg, Festus, southern Jefferson County, and Troy. Additional wells have been obtained at Mountain Grove, the Callaway Nuclear Power Plant, and Monett.

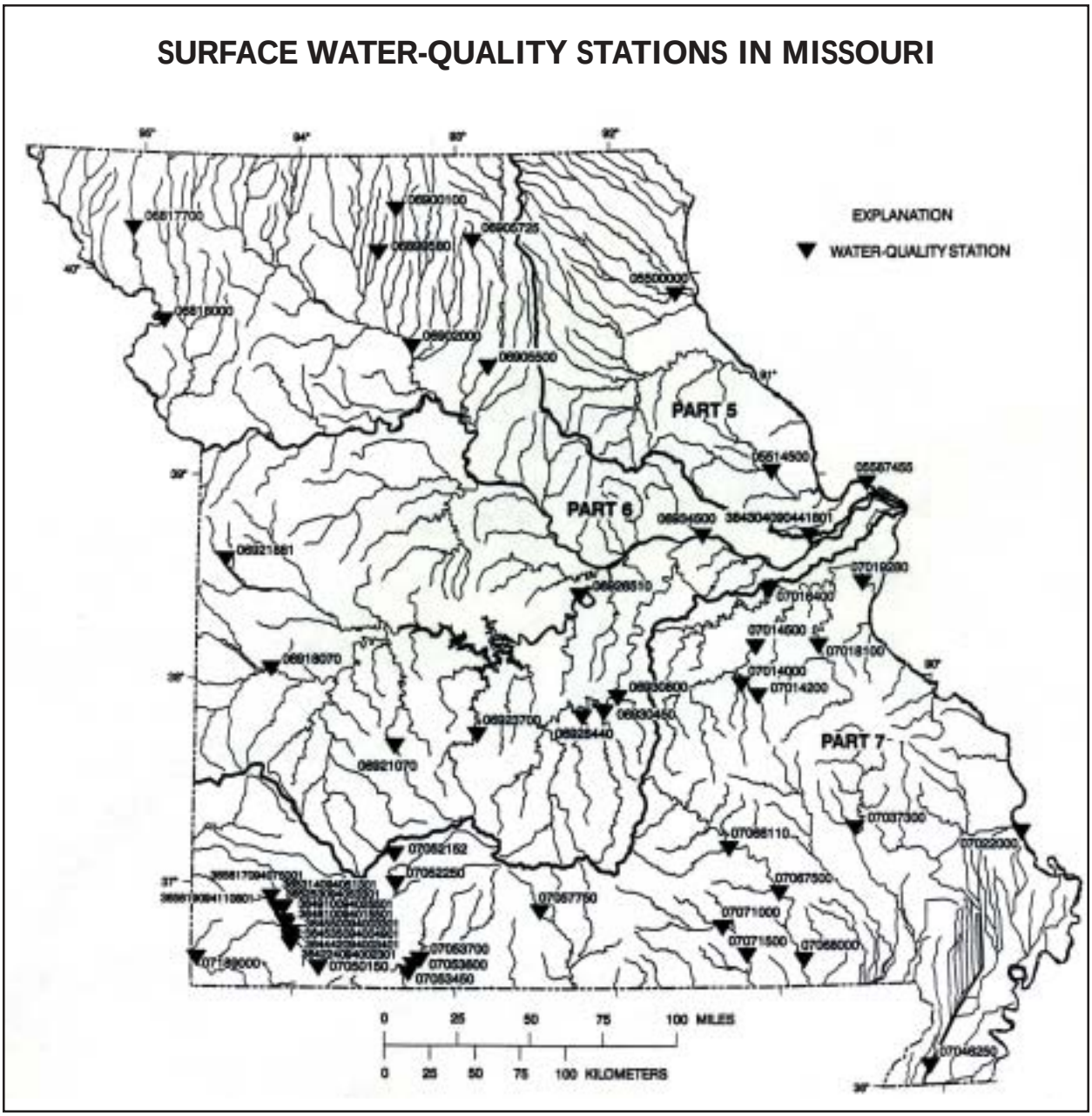
Currently, 70 groundwater-level observation wells equipped with satellite-linked data recorders are on line. The additional three wells will be placed on line during 2002.

This expansion is allowing groundwater data to be used in ways that were previously not possible. Towns with observation wells can directly view the effects that their producing wells are having on groundwater levels. This information has been especially welcome during the past year because of widespread drought conditions. A good example is the recently constructed monitoring well near the Pettis County R-12 school in Dresden. This well and other existing wells have helped delineate the groundwater level changes in the Dresden area. Residents with private wells in areas of high groundwater use can monitor changes in water levels. The network will likely grow one to four wells per year in response to water-use conflicts, or where information is needed for other purposes. Real-time groundwater data can be obtained from the department's web site, www.dnr.state.mo.us/water.htm.

SURFACE WATER AVAILABILITY

The department is a cooperator in the U.S. Geological Survey program that collects and publishes water data for Missouri's surface and groundwater resources. Substantial amounts of surface and groundwater information have been collected through this effort, and published annually in a report series titled Water Resources Data-Missouri. Records have been collected in this manner for nearly 75 years. The scope of data collection efforts has widened to include surface and groundwater quality information. Presently, the stream-gaging network monitors flow and stage at 138 stations, the stage at 12 lakes and reservoirs, and surface water quality at 53 sites statewide (including 2 lakes

Surface Water Gaging Stations in Missouri. Source: USGS, "Water Resourcese Data – Missouri, Water Year 2001"



Surface Water Quality Stations in Missouri. Source: USGS, "Water Resources Data – Missouri, Water Year 2001"

and reservoirs). Water quality stations include physical, chemical, and biological parameters such as water temperatures, specific conductance, dissolved oxygen, pH, carbonate, bicarbonate, alkalinity, inorganic constituents, nutrients, trace elements, indicator bacteria, sediment, and pesticides.

DAM SAFETY

The mission of the Dam and Reservoir Safety Program is to ensure that dams in the state are constructed, maintained and operated in a safe manner. This is accomplished by regulation of all non-agricultural, non-

federal dams more than 35 feet in height and by providing technical assistance and informational resources to all dam owners. The department maintains two databases on dams in the state. The STATUS database contains only those dams that are regulated in accordance with Chapter 236 of the Revised Statutes of Missouri. This includes dams that are 35 feet or more in height as measured from the crest to the downstream toe of the dam. The number of dams currently included in this database is 629. The database includes spatial and physical data, downstream hazard classifications, ownership information, water use, and the current regulatory status of each dam.

The NATDAM database is maintained through a continuing contract with the Federal Emergency Management Agency (FEMA) and the Association of State Dam Safety Officials. This database includes dams that meet the height and storage criteria established by FEMA and are identical to the criteria established by the U.S. Army Corps of Engineers for the original national inventory compiled in the 1970s. Dams which are 25 feet or more in height with a storage volume of at least 15 acre-feet, or which are 6 feet or more in height with a storage volume of at least 50 acre-feet, are included in this inventory. The number of dams currently inventoried in this database is 4,088. The database includes spatial and physical data, downstream hazard rating, water use, ownership information and purpose of the dam.

The Dam and Reservoir Safety Program of the Missouri Department of Natural Resources, Geological Survey and Resource Assessment Division, has recently acquired a tractor-mounted pipe inspection camera. This camera can be used to inspect spillway pipes through dams that are too small for a person to enter and inspect.

The camera is operated remotely from a control unit that is connected to the camera by 500 feet of cable, and is powered by a generator. The camera head has full tilt and pan capabilities, allowing for a full 360 degree observation of pipe joints. A video cassette recorder (VCR) attaches to the control unit to allow recording of the pipe inspection on a standard VHS tape.

A John Deere Gator ™ all-terrain vehicle was purchased to transport the camera, control unit, cable reel and generator to either the pipe inlet or outlet. A goose-neck trailer was also acquired to transport the equipment from the office to the site.

Missouri is one of only a few state dam safety programs that have this capability. The program has performed several pipe inspections with the camera, many of which have indicated defects in the pipe. This information has been used in determining the best method of remediation for the defective pipes.

The funding for the pipe inspection camera came through a grant from the National Dam Safety Program Act, sponsored by Missouri Senator Christopher Bond through the Senate Appropriations Committee. Funding for the grant program was established through the Federal Emergency Management Agency and was administered by the Association of State Dam Safety Officials.

A Case History

The following case history, illustrating the benefits of using the remotely controlled pipe inspection camera, occurred during the construction of a 118-feet-tall earthen dam that, when full, will create a 300+ acre recreational lake near St. Louis, Missouri. To divert water during the construction of the dam, a 16-inch diameter polyvinyl chloride

Tractor mounted pipe inspection camera system. Source: Dam and Reservoir Safety Program.

(PVC) pipe was installed and passed through the foundation of the dam.

Upon completion of the dam, the construction plans called for this pipe to be filled with grout so that the lake could begin filling. However, when it came time to fill the pipe with grout, the owner suddenly decided he would prefer to put a valve on the downstream end of the pipe and use it to control the lake level. For reasons explained below, The program engineers were opposed to this, but it eventually came down to having to either approve the valve, or show a reason why we were denying the request.

On April 5, 2000, a site visit was made to the dam for the purpose of inspecting the pipe. The engineer, the contractor building the dam, and representatives of the owner met us at the site. The owner's request to place a valve on the downstream end of the lake drainpipe was a concern for two reasons.

First, the construction permit was originally approved with the understanding that this pipe would remain open until the dam was completed and the spillways were in place and functional. Once the dam was completed, the pipe would be grouted full of concrete. Putting a valve on the end of the pipe would have created a situation where the pipe, which passes through the foundation of the dam, would be full of water under pressure conditions. The final depth of the reservoir is approximately 100 feet.

Secondly, concerns had been raised about the structural integrity of the pipe by Strata Services. In their March 12, 2000, report on the recently completed grouting of the foundation of the dam, Strata Services stated that the grouting of hole 4+35 was stopped due to a pressure drop in the hole and possible grout infiltration into the lake drainpipe. At the time of this incident, the

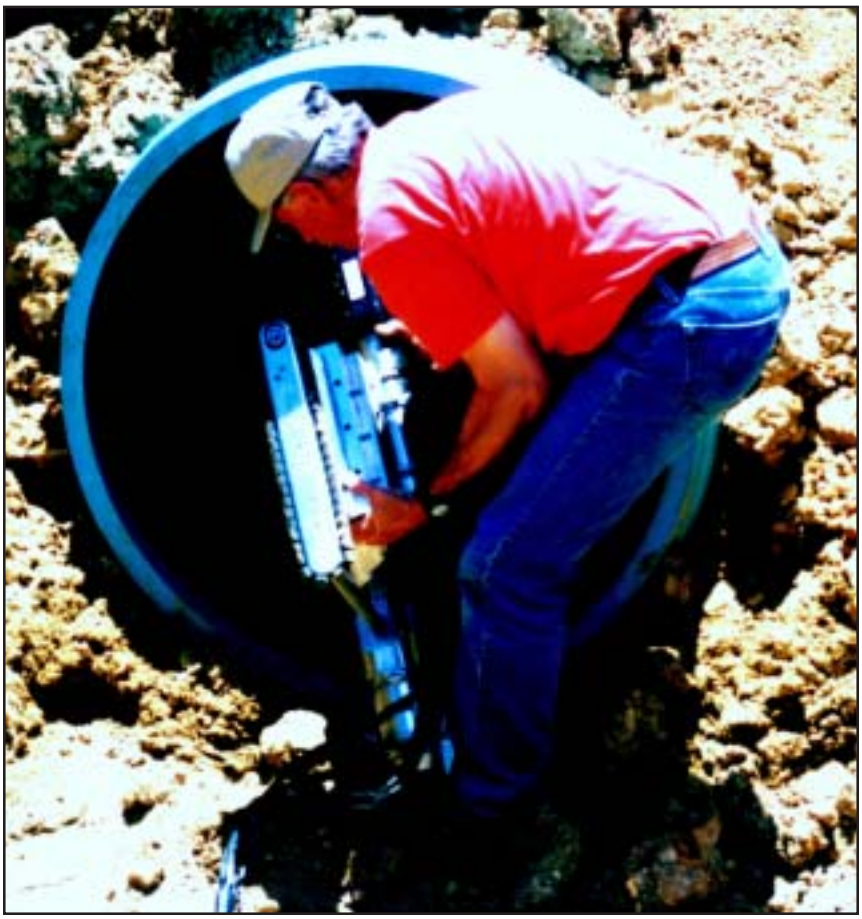
pipe was under full flow conditions. Grout was visually detected in the water discharging from the pipe at the time the pressure drop was detected.

Based primarily on our concern that the pipe had been physically damaged, the owner had been advised that the valve could not be installed until a pipe inspection was conducted.

To inspect the pipe, two obstacles had to be overcome. First, the lake drainpipe passed through the foundation of the dam in a trench. This put the inlet of the pipe at the bottom of the reservoir in a narrow, steep sided cut section. A few weeks prior to the inspection, heavy rainfalls in the area created enough runoff to bury the inlet of the pipe with sediment and several feet of water. Although the pipe inlet was unclogged and the water drained from the reservoir, piles of rock (some baseball sized) remained in the pipe. The tractor for the camera had to climb over these rocks to inspect the pipe.

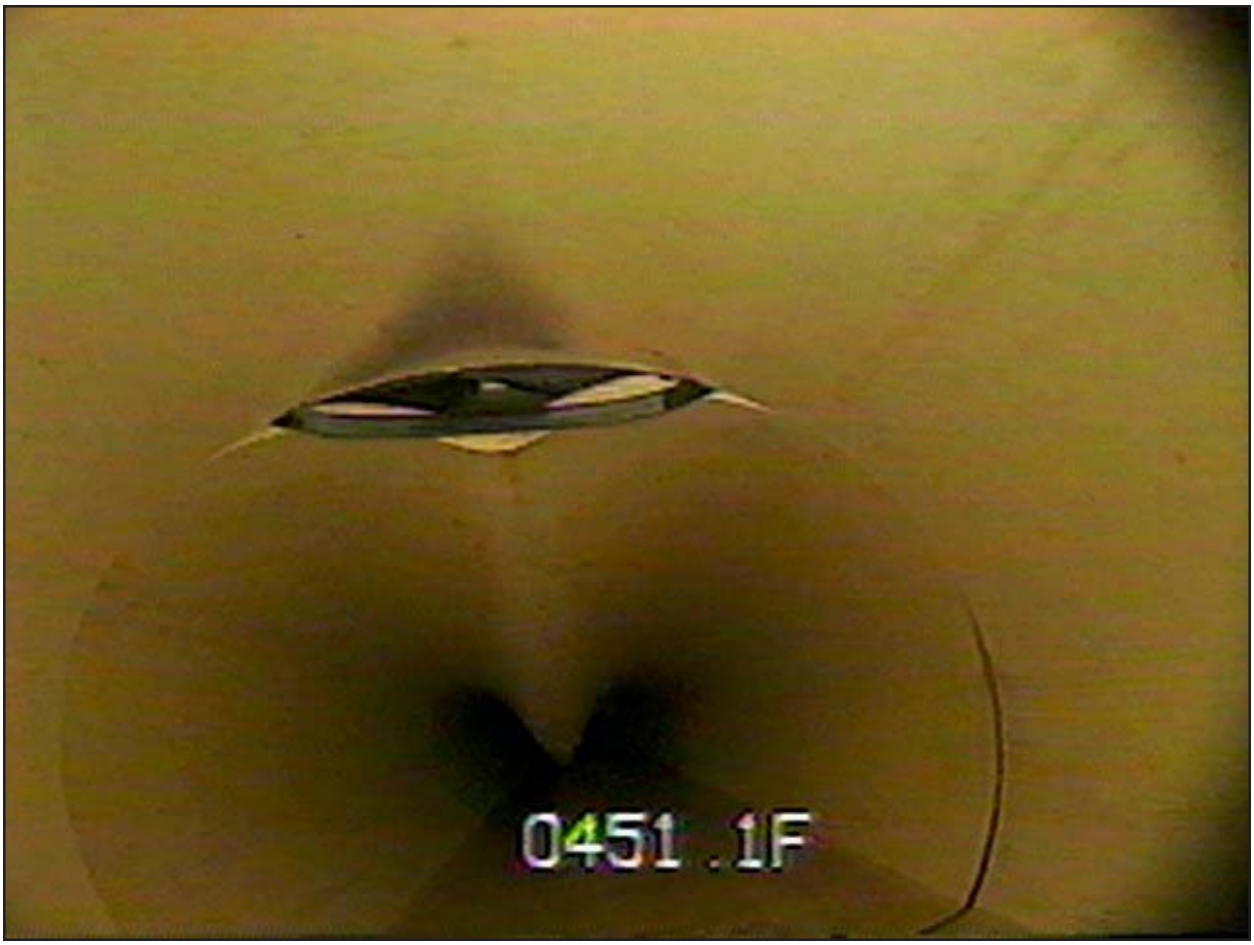
Secondly, the pipe was roughly 800 feet long and we only had 500 feet of cable for the camera. To do an inspection of the full length of the pipe we would have to run the camera up the pipe from the downstream end and then move to the pipe inlet and run downstream.

We started at the downstream end of the pipe. Our first attempt to inspect the pipe was unsuccessful due to the tractor being unable to get past the rocks in the bottom of the pipe. The tractor was reconfigured and the second attempt was successful.



Pipe inspection camera being placed into spillway pipe. Source: Dam and Reservoir Safety Program.

At approximately 450 feet upstream of the pipe outlet, a joint was discovered with roughly 2 – 3 inches of vertical deflection at the pipe crown. The deflection caused the joint to separate. Approximately 4 feet farther upstream from the pipe joint separation, a major bow in the pipe was discovered. The top of the pipe had been pushed in, reducing the pipe diameter to about half its original size. While the bow in the pipe was most pronounced at this location, the bow extended to a lesser degree downstream to the joint that had separated at the pipe crown. As the tractor for the camera was unable to get under the bow in the pipe, the inspection of the pipe was terminated at this point.



Pipe damage as seen by the inspection camera. Source: Dam and Reservoir Safety Program.

What caused the damage to the pipe is unclear at this point. The pipe may have been damaged during the installation process and the grouting operation just helped to point out the problem. The possibility also exists that the grouting being done in the vicinity of the pipe caused the pipe to fail. Regardless of the cause, it was obvious that the pipe had to be taken out of service and filled with grout immediately.

The detection of this problem would not have been possible without the pipe camera. If the owner had been allowed to put the valve on the downstream end of the pipe and the lake had filled, major problems would have developed and the dam may well have failed as a result.

The owner later admitted that he was prepared to force the issue of the valve if necessary until he was shown the problem with the pipe. The pipe has been grouted shut and the dam is now within 15 feet of the design normal pool.

APPLIED STUDY PROJECTS UNDERWAY

During 2001, eight investigative projects were being undertaken by the Water Resources Program (WRP) of the Geological Survey and Resource Assessment Division (GSRAD) in order to accumulate data for future water resources decision-making.

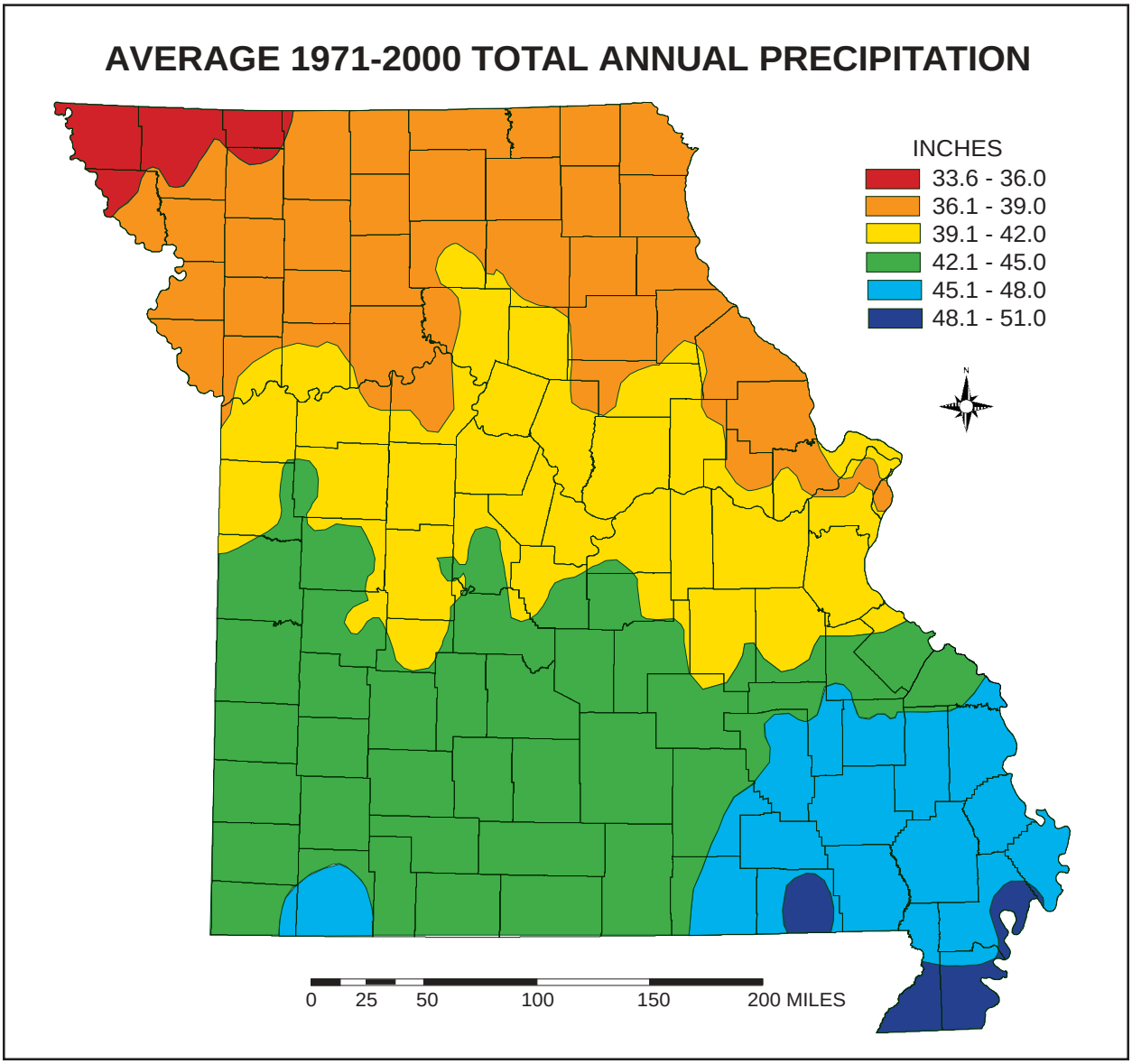
Both water quality and water quantity issues are involved in these investigations.

Climatic Atlas Project

Together with the Water Pollution Control Program (WPCP), Water Protection and Soil Conservation Division (WPSCD), the WRP jointly funded the first year investigation of the Climatic Atlas Project. The purpose of the project is to gain the data needed to help with other projects, such as drought modeling and stormwater runoff modeling.

Using the most recent data (1971-2000), precipitation norms, evaporation norms, and temperature norms for the State of Missouri, were prepared in order to produce a database and maps. This information will help engineers to recommend proper size reservoirs or wastewater stabilization lagoons, to name a few examples.

The data also will be useful for determining land application rates for liquid manure, and models for determining Total Maximum Daily Loads (TMDLs) to reduce water pollution. The second year of the project



Missouri Average Annual Precipitation, over the last 30 years. Source: Missouri State Climatologist

will prepare runoff data, based on the data collected during the first year of the project.

Base data were obtained from the National Weather Service (NWS), National Oceanic and Atmospheric Administration (NOAA). An example of one of the maps produced from the data appears below.

Sac River, Spring River, and Lamine River Basin Total Maximum Daily Loads Project

Impaired waters may have total maximum daily loads (TMDLs) established in an attempt to lessen their water quality impairment. When a water body is listed as impaired by the state it becomes part of the Section 303(d) list of the Clean Water Act. Since non-point source contributions involve entire watersheds, complex simulation models are used to lessen data collection requirements.

The purpose of this project is to support the state's effort, to develop and establish TMDLs for the public drinking water reservoirs in the Sac River, Spring Fork River, and Lamine River basins.

The project focuses on performing hydrological and water quality simulations for Fellows Lake and McDaniel Lake in order to develop TMDLs that address nutrient loading to those water bodies.

The Water Resource Program has contracted to use a hydrologic simulation program to simulate the levels of nutrients, total nitrogen and total phosphorus, relative to lake algae growth to determine load reductions required to mitigate taste and odor problems. The Water Pollution Control Program establishes the limits and implements a plan to control nutrient contributions.

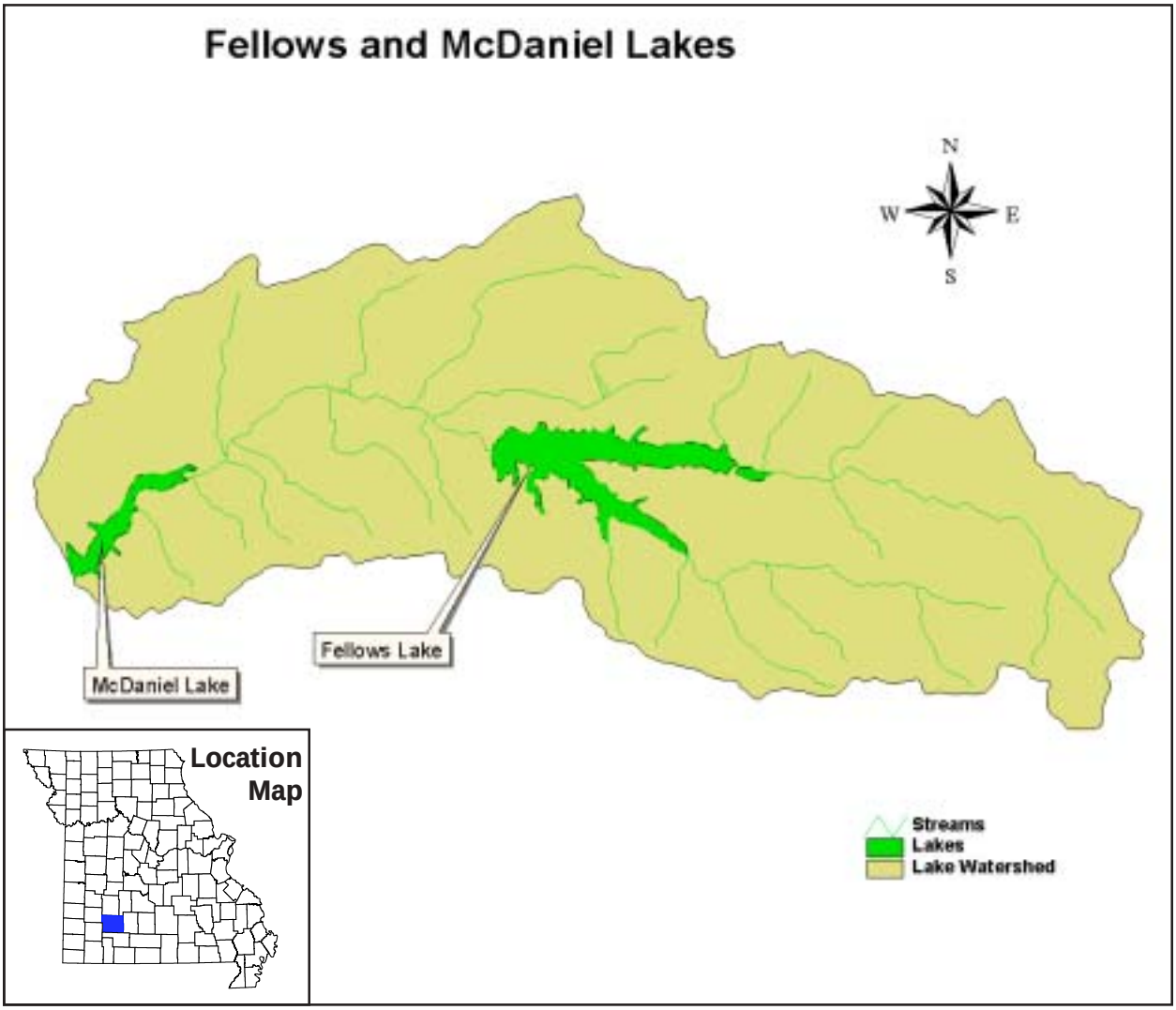
The lake bathymetry, volume, depth and surface areas are required to simulate the watershed and lake water budgets. By knowing the size and shape of the lakes we can determine how much water a lake will hold which is necessary to determine the TMDL. Maximum loads are calculated based upon concentration and flow. The size and shape of the reservoir determines how much water is lost to evaporation, seepage and spillage, and is a required component to an accurate modeling effort.

This study will help local suppliers meet water supply needs and water quality standards. Work on Lamar Lake and Spring Fork Lake are planned to begin in 2002.

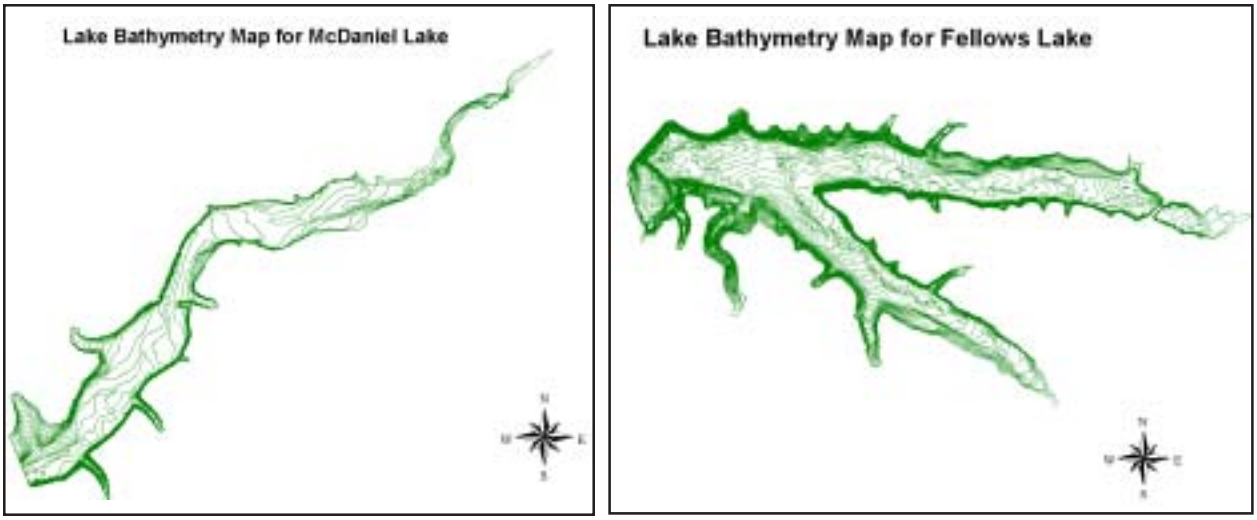
Monitoring Pesticides in Groundwater Project, with Quality Assurance Project Plan (QAPP)

The Groundwater Pesticide Monitoring Project is an effort of the Water Resources Program. This project has been supported by a continuing grant from the U.S. Environmental Protection Agency (EPA) through the Missouri Department of Agriculture to the Department of Natural Resources. It is based on an approved Quality Assurance Project Plan. Work on the project is expected to continue through the year 2002 and beyond.

To allow the state to continue to use certain restricted use pesticides such as atrizine and metalachlor, the Missouri Department of Agriculture must evaluate their impacts upon groundwater. The state pesticide monitoring plan written by the Department of Natural Resources', Geological Survey and Resource Assessment Division, identified high use areas and high vulnerability areas. Sampling in 2002 focused on high use and high vulnerable regions. The sampling and analysis of 45 shallow wells showed only a few samples that detected pesticides. These detects were below the EPA limits for the pesticides. The report should be finalized in August, 2002.



Map showing watershed of McDaniel Lake and Fellows Lake. Source: Sherry Chen



Maps showing bathymetry of McDaniel Lake and Fellows Lake. Source: USGS

Upper Mississippi River System Flow Frequency Study

This is a Corps of Engineers study of the hydrology and hydraulics of the Upper Mississippi River "system," which includes the Lower Missouri River, Illinois River, and Upper Mississippi River. The study is needed because the flow/frequency relationships for the Missouri River were last derived in 1962, and those of the Upper and Middle Mississippi River were last derived in 1979. Additional data, combined with changes in river flow and hydraulics of the three rivers, have made the new study necessary.

The Water Resources Program is cooperating in this study with participation in the Study Task Force, contributing information and reviewing the data that the study project is producing.

Surface Water Supply Study

This is a study to determine reservoir yield at various demand levels, and to show the demand level that must not be exceeded in order to have water in a reservoir through the end of a historic drought. In the chart, below, the demand is plotted against the historic drought of the 1950s.

The Reservoir Operation Study Computer Program (RESOP) is used to determine how much water can be taken from a given reservoir over a given period of time, and not exceed the amount of water in the reservoir on any date within that time period, based on expected inflow, outflow, precipitation, use, and evaporation.

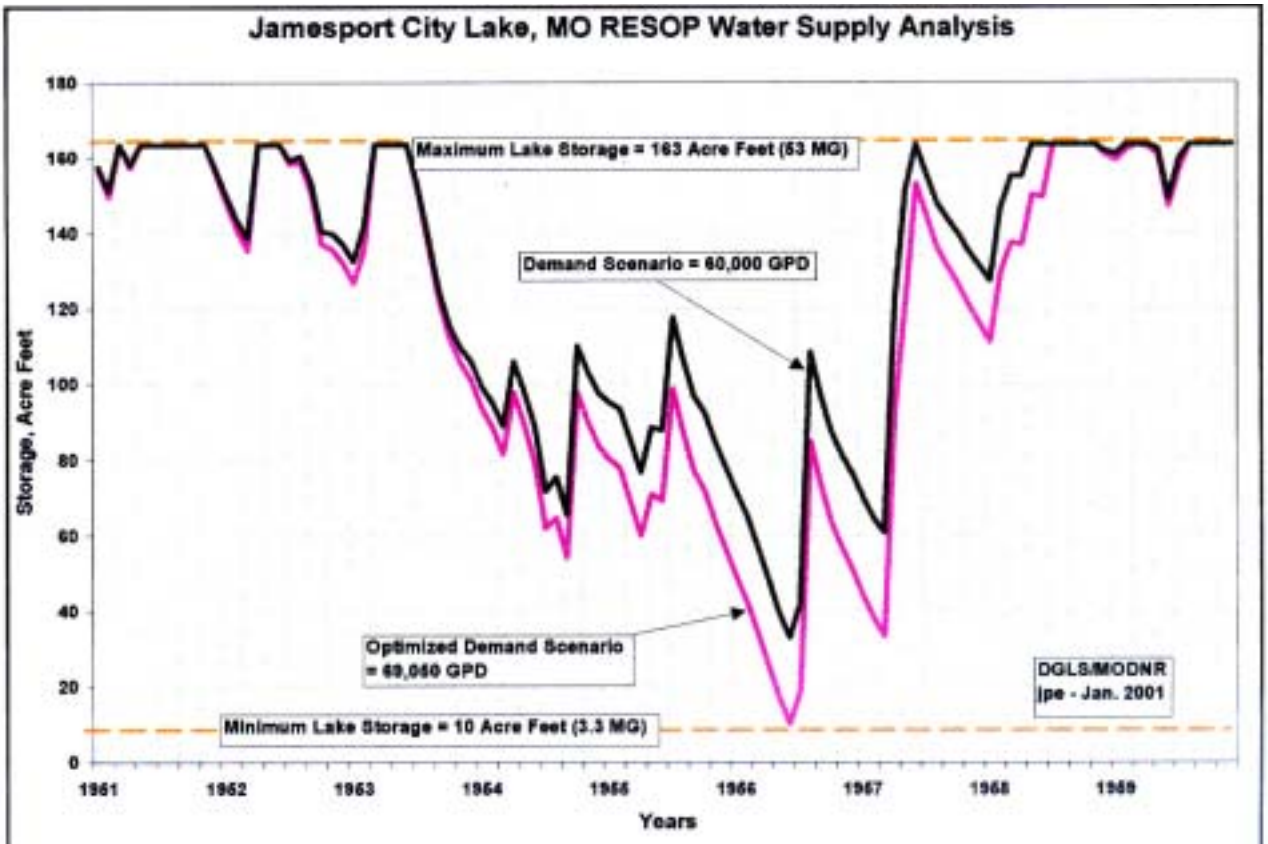
The most vulnerable surface water lakes are located in areas where fresh groundwater is not available. Water supply systems completed include: Milan, Green City, Shelbina, Brookfield, Jamesport, King City, Hamilton, Dearborn, Memphis, and Butler. Work is underway for Monroe City, Vandalia, Lamar, Sedalia, Concordia, Higginsville and Ridgeway. Six more vulnerable lakes will be completed in state fiscal year 2003.

To determine if a lake is capable of sustaining itself beyond a major dry spell, the Water Resources Program hydrologists model that the reservoir is full then place the actual drought climate record of the 1950's against the lake utilizing volume, evaporation, use, seepage, runoff, rainfall, and spillage to determine if it can survive. The following charts show the lakes full draw down – optimized to highest sustainable yield and then re-filled.

Wetland Image Analysis Project (WIAP)

This project applied remote sensing technologies to wetland identification in a six-county area of central Missouri. Several different satellite images were processed using selected parameters and band combinations to identify and evaluate wetlands in the project area. Relative comparison of the

Fountain Grove Conservation Area / Pershing State Park Area as shown in IKONOS Multi-spectral Imagery, August, 2000.



This RESOP graph illustrates the water supply and water demand relationships for the Jamesport community reservoir – Green City and Jamesport. It shows the volume of water in the reservoir for a specific historical time frame compared against variable water consumption demands. In other words, based on the actual precipitation and inflows received at the Jamesport City Lake for 1951 through 1959, we can calculate the remaining reservoir storage, if water withdrawals from the reservoir were at today's current level of 60,000 gallons per day or at an optimized demand of 69,050 gallons per day. The net effect of this modeling allows the use of current or projected water use demands to be measured against the backdrop of actual documented historical low precipitation / low inflow / drought events. This gives us the ability to anticipate the reservoir's future ability to supply a given amount of water over a given set of water inflow conditions, and thereby manage the available water supply most effectively.

The vertical left side of the graph "Storage-Acre Feet" shows the volume range of water storage for the reservoir. The horizontal bottom side of the graph "Years" indicates the historical data set being analyzed. "Maximum Lake Storage" is how much water the lake can hold when full, and "Minimum Lake Storage" is the lower volume limit of water that is accessible for consumptive use. The upper jagged line transecting the graph from left to right, "Demand Scenario" applies a chosen rate of water usage and applies that usage rate to the lake during the historical "Years" profile. The lower jagged line, "Optimized Demand Scenario," shows the maximum water consumption rate allowable but without going below the "Minimum Lake Storage" limit.

results determined which image platform is most effective for different types of wetland analysis. Products include an evaluation matrix and methodology that will aid wetland scientists who wish to use remote sensing as an analysis tool.

The Wetland Image Analysis Project was undertaken with the support of a grant from the EPA, and in conjunction with the Missouri Resource Assessment Partnership (MoRAP), Columbia, Mo.

Seven different satellite-based image data products were evaluated for this project. These were panchromatic, multi-spectral, and merged Landsat 7 Enhanced Thematic Mapper (ETM+) imagery, multi-spectral SPOT imagery, panchromatic Indian Remote Sensing Satellite (IRS) imagery, and panchromatic and multi-spectral IKONOS imagery.

Panchromatic imagery, similar to black-and-white photography, is generally suited for visual interpretation, but not digital interpretation. Multi-spectral imagery is suited for both visual and digital interpretation. Also, as the spatial resolution of the product increases, the relative cost of the product and of computer storage also increase.

The spatial resolution of the Landsat 7 and the SPOT data products (15 meters to 30 meters) are not detailed enough to discriminate between wetland plant assemblages, but are able to distinguish between larger wetland complexes. The IKONOS and IRS products are better suited for local scale analyses.

Currently, Landsat 7 ETM+ multi-spectral is the most cost-effective platform that can identify wetland types. This project should aid wetland scientists in choosing satellite imagery that is most beneficial to their projects. This project has been completed and sent to the EPA for review.

Assessing Urban Wetland Loss Project, with Quality Assurance Project Plan (QAPP).

This project is attempting to quantify and qualify the wetland resources that have been impacted in urbanizing watersheds within the State of Missouri. The results will include determination of net wetland loss within urbanizing watersheds, assessment of wetland function and value, and collection of water quality data on remaining wetlands.

Aerial photographs are being used to determine the extent of land use changes within the watersheds being studied. Photography available for the study areas in this project date back to the 1950s. Fieldwork is being conducted in both Jackson County and Jefferson County, using water sampling and water quality meters. Aerial flights have been made by to establish Spring, 2002, wetland extent. This project began in 2000 with the completion date expected to be in 2004.

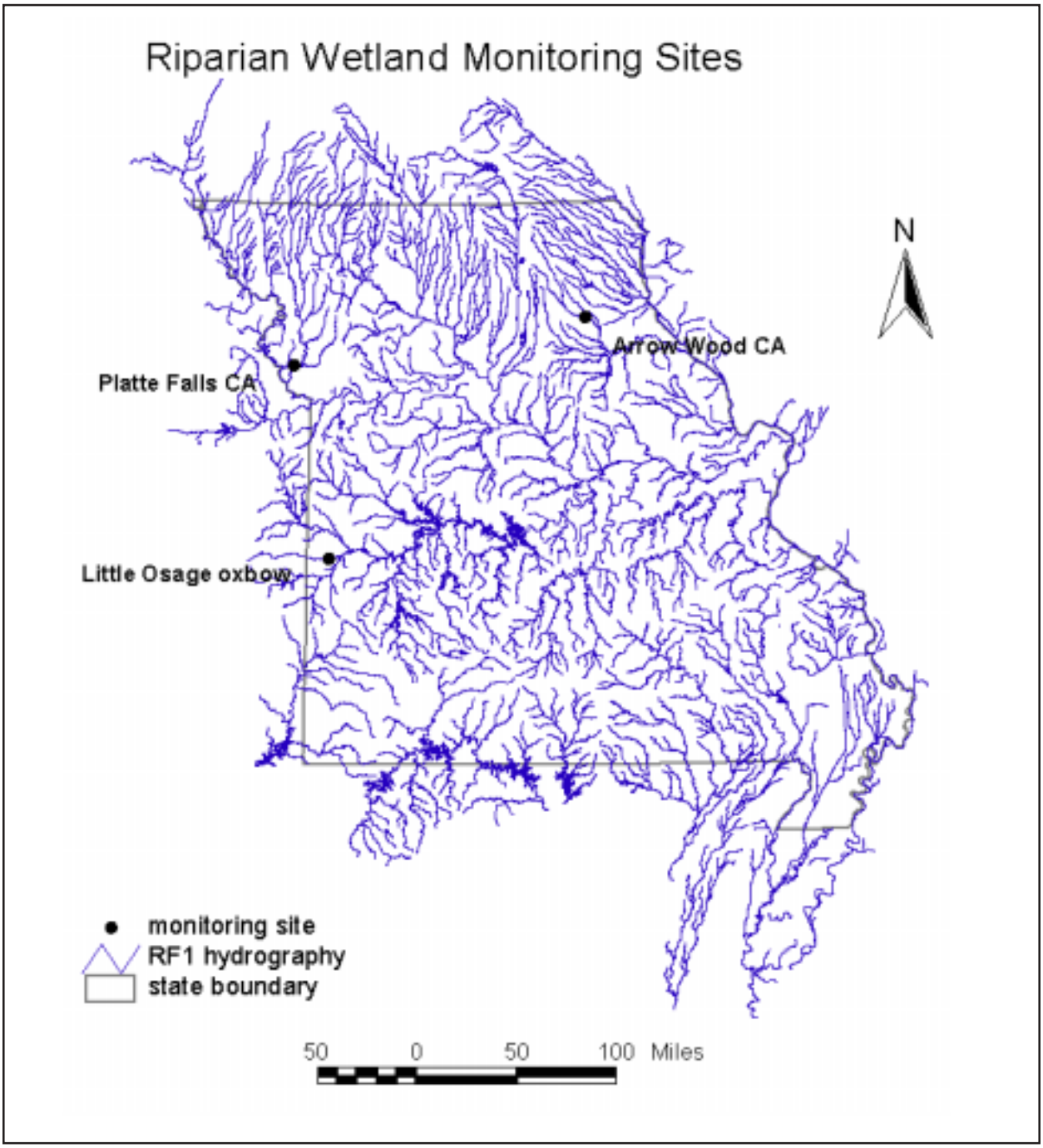
Riparian Wetland Hydrology Project

Three riparian (area adjacent to a stream or river) wetland sites in relative proximity to river flow gages were monitored for their surface water levels. Riparian wetland surface water levels were compared temporally to river gage surface water levels on the river contributing water to each monitored wetland. Statistical flow frequencies for each of the rivers were applied to the respective riparian wetlands for the purpose of characterizing and predicting inundation of riparian areas by surface water from their adjacent rivers. Regression equations were developed, using daily streamflow data from

long term stream gages throughout the state and correlation of streamflow duration frequency statistics with watershed size.

The results of this study will assist anyone interested in determining hydrology of riparian wetlands, as well as restoring or creating riparian wetlands along Missouri's rivers. It provides insight to probable sources of water to a riparian wetland. Results also demonstrate applicability for technique in determining wetland hydrology as recommended by the U.S. Department of Agriculture.

Major funding for this project was provided by the U.S. Environmental Protection Agency and the Missouri Department of Natural Resources. The U.S. Geological Survey contributed funding to installation and maintenance of water level recorders at the three monitored sites.



Location of three Monitored Riparian Wetland Sites.

STATE WATER PLAN

640.415 —1. The department shall develop, maintain and periodically update a state water plan for a long-range, comprehensive statewide program for the use of surface water and groundwater resources of the state, including existing and future need for drinking water supplies, agriculture, industry, recreation, environmental protection and related needs. This plan shall be known as the "State Water Resources Plan."

2. The department shall establish procedures to ensure public participation in the development and revision of the state water plan.

3. The department shall submit a report to the general assembly at least one year prior to the submission of the state water resources plan, and may recommend any statutory revision, which may be necessary to implement the requirements of this section. The plan shall be submitted to the general assembly for approval or disapproval by concurrent resolution.

BACKGROUND

Since 1989, when the Water Resources Law was passed by the Legislature, the Department of Natural Resources (the department) has undertaken activities to address and fulfill the requirements set forth in RSMo 640.415. Specifically, these activities include public participation, issue identification, needs assessment, resource inventory, and multi-level planning and coordination.

The department has sought public input through the use of various forums that have included statewide public meetings and conferences, regional meetings and stakeholder meetings. This effort has included the Missouri Rural Opportunities Council (which is composed of various private groups as well as state and federal agencies), Regional Planning commissions, the Water Quality Coordinating Committee, the Missouri Irrigators Association, Missouri Association of Counties, the Clean Water Commission, Distributive Educational Clubs of America, the department sponsored "Open Houses," the Small Watershed Program Conference, Ozark Scenic Riverways Association, and the Missouri Municipal League. These public input forums serve to support, enrich, and further define the water resource issues first defined in 1990, identify new issues, and inform and educate the public on the broader, and often interrelated, water resource planning issues.

A three-phase approach is well underway to create a thorough, well thought-out water plan. Phase 1 is the completion of a series of technical documents referred to as the State Water Plan Volumes described in the next section. Phase 2 of the plan is the identification and description of water use problems and opportunities by region. See

Phase 2-Regional Reports' section for description of regions. Six regional reports will be completed in this Phase. Phase 3 of the plan will focus on solutions to solving Missouri's main water use challenges.

PHASE 1 - STATE WATER PLAN VOLUMES

The department has completed a series of seven technical documents to provide basic information about Missouri's surface water, groundwater, water use, water quality, interstate issues, hydrologic extremes and water law. These volumes will assist in focusing the development of the Missouri State Water Plan. They will serve to support and complement public participation, issue identification, needs assessment, and multi-level planning coordination. The Interagency Task Force (created by section 640.430 RSMo) will also have input into the State Water Plan before it is finalized and submitted to the governor and General Assembly.

The seven basic information volumes have been published serially. Completed volumes include *Volume I - Surface Water Resources of Missouri, Water Resources Report No. 45,* by James E. Vandike; *Volume II - Groundwater Resources of Missouri, Water Resources Report No. 46,* by Don E. Miller and James E. Vandike; *Volume III - Missouri Water Quality Assessment, Water Resources Report No 47*, by Cynthia N. Brookshire; *Volume IV - Water Use of Missouri, Water Resources Report No. 48*, by Charles B. DuCharme and Todd M. Miller; *Volume V - Hydrologic Extremes in Missouri: Flood and Drought, Water Resources Report No. 49*, by John D. Drew and Sherry Chen; *Volume VI - Water Resource Sharing: The Realities of Interstate Rivers, Water Resources Report No. 50,* by Jerry D. Vineyard, and the last in the series, *Volume VII- A Summary of Missouri Water Laws,* Water Resources Report No. 51, by Richard M. Gaffney and Charles R. Hays, with help from William J. Bryan, IV, and Amy E. Randles, of the Missouri Attorney General's Office, was *[recently]* published late in 2000. This volume now is available from the Publications Desk in Rolla. A review of that important volume follows**.**

VOLUME VII - A SUMMARY OF MISSOURI WATER LAWS

The seventh volume in the first phase of the State Water Plan publications addresses statutory law, case law, and common law dealing with many aspects of water use, supply, and resources. Like the other volumes in Phase 1, this document is an inventory and technical assessment book. It is written to be as useful as possible to the widest audience. It can be used as a base source of information, as a reference work, or in conjunction with other State Water Plan volumes to provide comprehensive, factual information on the status of water law and water issues in the late 1990s.

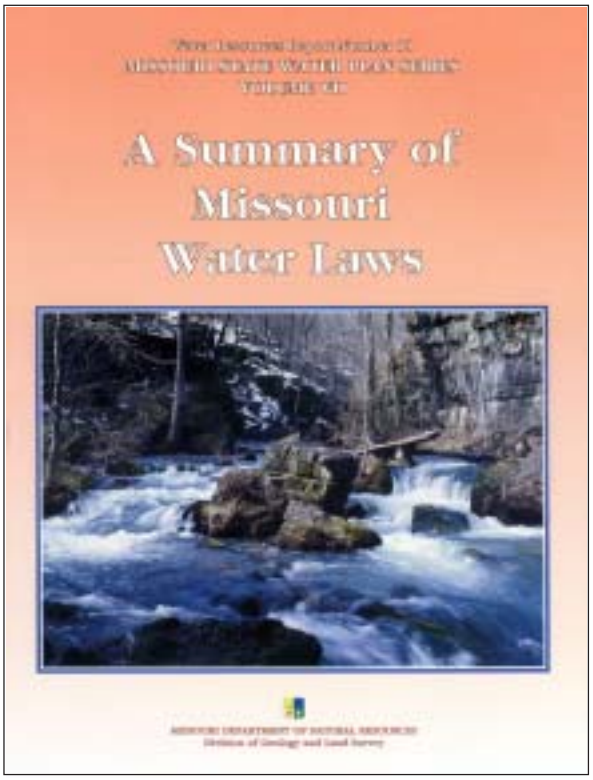
The major emphasis of this volume is on contemporary water law (water use, water supply, and water quality) from both judicial (case law) and legislative (statutory law) perspectives. The document is a review of Missouri water law from an historical inventory approach. For the most part, statutory water law addresses forward looking, generalized, broad scope issues that have gained widespread attention of the public, or represent high priorities of our elected officials.

The focal points of statutory laws tend to be on the needs and well being of society as a whole. This differs from case law in that much of its emphasis centers on dispute resolution between individuals, and is of a

highly detailed and limited nature. Generally, case law's focal points are on ownership and property, natural water, protection from water, water quality, water supply, and water use.

Water law is aimed at defining our use of water resources in a fair and equitable manner so as to serve the best interests of all citizens and their rights. With the passage of time, rights and priorities change, new questions arise, and historical facts are re-evaluated. These factors drive the evolution of water law. Legal restrictions and requirements on how we use and protect our water resources serve to balance individual rights with the rights of society. Public health, public safety, and the economic well being of the state and its citizens depend on the adequate availability of usable water. The value of our water resources continues to increase in proportion to demand and the recognition of its significance to our quality of life.

For these reasons, *A Summary of Missouri Water Laws* will be of immeasurable value to its readers, and to the continuing State Water Planning process. The largest of the seven volumes of Phase 1, this book will be of importance to students, various government agency personnel, property owners, concerned citizens, and anyone who uses water in daily life.



PHASE 2 - REGIONAL REPORTS

The seven technical volumes have been prepared in Phase 1 of the State Water Planning effort. Publication of the final volume concluded the first phase. Meanwhile, Phase 2 of the effort has commenced, and the first of several regional reports, *Topics in Water Use - Northeastern Missouri,* Water Resources Report No. 59, is available from the Publications Desk of the Geological Survey and Resource Assessment Division, Rolla.

Beginning with Northeast Missouri, the department is preparing a series of six regional reports, identifying water use problems and opportunities. The six regions are congruent with the six regional office territories of the department. See Appendix 2 for a map showing regional outlines. The staff of the Water Resources Program is preparing the reports, with the help of regional office personnel and other agency staffs. A summary of the contents of this report and information on the rest of the Phase 2 reports follows.

TOPICS IN WATER USE - NORTHEASTERN MISSOURI, WATER RESOURCES REPORT NO. 59

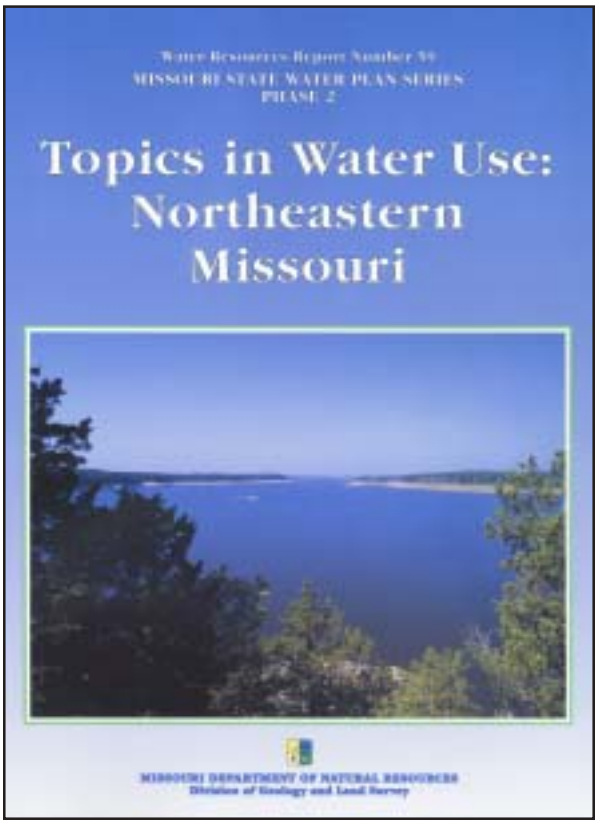
According to the Missouri Water Resources Law, the state water resources plan is to address water needs for the following uses: drinking, agriculture, industry, recreation and environmental protection. Ad-

dressing water "needs" requires us to establish why these needs exist in the first place. In some cases, an existing water need is tied to one or more unresolved water problems. For example, communities "need" clean water. To meet this need, communities may have to address problems with water supply infrastructure and source water quality. This report explores the current issues facing the water resources of the northeastern Missouri region. Also included is a section addressing recent successes various water-related programs have enjoyed, and how they have affected the water resources of the region.

Although considered individually in this report, water use problems are not truly independent of each other. When reading through the water use problems identified in northeastern Missouri, it will quickly become apparent that many of them are, in fact, very closely related. For example, the aging infrastructure of some public water supply systems is considered in this report and closely related is the cost of replacing, maintaining and expanding existing systems.

Water resource professionals commonly subdivide the state into physiographic units, such as watersheds or aquifers. While this approach is important for resource-based discussions, it may not adequately address water use problems or solutions. This series of reports addresses the subject using the broad geographic similarities of the departments six field service areas (Appendix 2). Each of these regions has distinctive physiographic features and socio-economic characteristics, and therefore was chosen for the ease of referencing water use problems. This approach allows us to recognize Missouri's diversity, and lends itself well to the second phase of the State Water Plan.

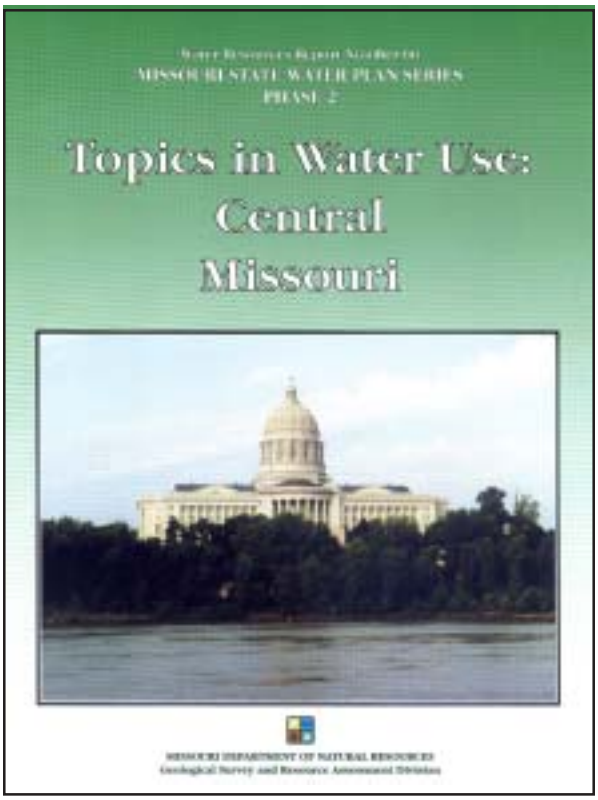
The area served by the department's Northeast Regional Office is the focus of this report. To this point, staff from this office and other state agencies dealing with water resources have served as the primary sources of input. This has enabled us to draw upon the insight and experience of field staff who, by virtue of their work, deal with many water use issues facing northeastern Missouri on a daily basis. Input was also requested from the general public via the internet.



TOPICS IN WATER USE -
CENTRAL MISSOURI

This, the second volume, has just been completed (June, 2002). This regional report discusses water use problems in the region that includes the Lake of the Ozarks and the rapidly growing nearby counties, as well as part of the Missouri River Valley in the Capitol district of the state. The central region area includes Benton, Boone, Callaway, Camden, Cole, Cooper, Crawford,

Gasconade, Maries, Miller, Moniteau, Montgomery, Morgan, Osage, Pettis, Phelps, and Pulaski counties. In this 15-county region, the Gasconade River, the Maries River, the Osage River, the Moreau River, Cedar Creek, and the Lamine River all flow into the Missouri River. The Inter-Agency Task Force reviewed and discussed this report at a meeting held in June, 2001.



TOPICS IN WATER USE - *NORTHWESTERN MISSOURI*

The third of the regional reports, this volume has been written and has undergone initial reviews. The Inter-Agency Task Force will meet to review this report in September, 2002, and publication is expected by the end of the year. The northwest region includes Atchison, Nodaway, Worth, Harrison, Daviess, Gentry, Andrew, Holt, Buchanan, DeKalb, Clinton, Caldwell, Clay, Ray, Platte, Jackson, Lafayette, Cass, Johnson, Henry, and Bates counties. This report will describe the water use problems in the 21-county area of the Kansas City Regional Office, which includes Smithville Reservoir and a long reach of the Missouri River.

TOPICS IN WATER USE – *SOUTHWESTERN MISSOURI*

The reconnaissance meeting with the regional office staff in Springfield was held in December, 2001, and topic preparation has begun on this volume. The southwest region includes McDonald, Newton, Jasper, Barton, Vernon, St. Clair, Hickory, Dallas, Laclede, Wright, Douglas, Ozark, Taney, Stone, Barry, Lawrence, Dade, Cedar, Polk, Greene, Webster, and Christian counties. This 22 county region includes the Joplin – Neosho area, and the rapidly growing district south of Springfield where Branson and Table Rock Lake are situated. The region also includes Stockton and Pomme de Terre Lakes in the western Ozark Plateau.

OTHER REGIONAL REPORTS

The reconnaissance meeting with the Southeast Regional Office staff in Poplar Bluff also was conducted in December, 2001, with a list of topics derived for future development. The east central Missouri region will be addressed last among the six regional reports planned.

SPECIAL WATER QUALITY PROTECTION AREAS

640.418-Special water protection area, procedure to establish.

1. The department may establish special water quality protection areas where it finds a contaminant in a public water system in concentration which exceeds a maximum contaminant level established by the environmental protection agency pursuant to the Safe Drinking Water Act, as amended, or a maximum contaminant level established by the department pursuant to this chapter or sections 640.400 to 640.435 or a contaminant in surface or groundwater which exceeds water quality standards established pursuant to chapter 644, RSMo, which presents a threat to public health or the environment. In making such a determination, the department shall consider the probable effect of the contaminant or contaminants on human health and the environment, the probable duration of the elevated levels of the contaminant, the quality, quantity and probable uses of surface or groundwater within the area, and whether protective measures are likely to prevent, mitigate or minimize the level of the contaminant in the surface of groundwater.

2. If the department determines that a special water quality protection area should be established, it shall consult with the interagency task force and with the public water system or systems affected and determine the boundaries of such area. When the boundaries of any such areas have been determined, the department shall, after a public hearing, issue an order designating the area as a special water quality protection area. Such an order shall include a geographic, hydrologic and stratigraphic definition of the area.

3. The department shall hold a public hearing or a public meeting within the area under consideration for designation as a special water quality protection area. The department shall notify every city and county within the proposed area and shall notify the public by press release and by publication of a notice in a newspaper of general circulation in the region.

640.420-Special water protection area, information program to be established, purpose, duties. -When a special water quality protection area has been established, the department shall implement an area informational program to help prevent, eliminate, mitigate or minimize the continued introduction of the contaminant or contaminants into the surface or groundwater.

640.423-Designation as protection area removed, when. -The department shall determine when the level of a contaminant or contaminants in a special water quality protection area does not exceed, and are not likely to exceed, the water quality standards

established pursuant to sections 640.400 to 640.435 and this chapter, and chapter 644, RSMo. Upon such determination, the designation of an area as a special water quality protection area pursuant to section 192.300, RSMo, sections 640.100, 640.120, and 640.400 to 640.435 shall be removed.

No special water quality protection areas have been formed under this statute.

INTERAGENCY TASK FORCE

640.430-Interagency task force established, members, meetings.1. The department shall establish an interagency task force consisting of the departments of health, conservation, agriculture, the University of Missouri College of Agriculture, and other such departments and agencies as may be necessary to effectuate the purposes and provisions of sections 640.400 to 640.435.

2. The interagency task force shall meet at least semi-annually. The department shall be the lead agency in matters related to surface and groundwater protection.

The Inter-Agency Task Force (IATF) met in June, 2001, and thoroughly discussed the developed topic papers for the Central Missouri Regional Report. The result of the meeting has been that several topics needed re-working, and additional review and discussion. State Water Planning staff has completed that effort, and the Central Missouri Regional Report was published in June, 2002.

NORTHWESTERN MISSOURI

The department and the Interagency Task Force (IATF) are currently developing the regional water resource problems and opportunities of northwestern Missouri. The geographic area being considered is the territory served by the departments Northwestern Regional Office in Kansas City (KCRO). Initial work has been completed on KCRO problems and opportunities, in preparation for an IATF meeting in September, 2002.

Water Resources Program staff members are now developing topics contributed by field staff and others in the department for the Southwestern Missouri Regional Office territory. The IATF members will also be developing problem and opportunity statements for program staff to develop.

RECOMMENDATIONS

640.426-The department shall prepare and submit to the general assembly and the governor an annual report which details the progress it has made in meeting the objectives of sections 640.400 to 640.435 and which contains recommendations in furtherance of the purpose and provisions of sections 640.000 to 640.435.

This *2002 Annual Report* explains how the staff of the Missouri Department of Natural Resources carries out the legislative mandates of the Missouri Water Resources Law. It demonstrates the breadth of activities that the department conducts and the progress that has been made in meeting the objectives of the Water Resources law. This report is not a comprehensive listing of the department's water related activities.

As the State Water Plan volumes and reports continue to be created, the state's water quantity and quality needs will become more apparent. The goal of the State Water Plan is to produce a set of recommendations for local, regional, and statewide implementation, both short-range and long-range.

Phase 2 of the State Water Plan has shown a number of critical areas that need to be addressed across the state. Of special importance is a lack of sustainable surface water supplies in north and west Missouri during drought conditions and reductions in groundwater tables in southwest Missouri due to use activity.

Phase 3 will build upon Phase 2 questions and concerns and begin by exploring the critical drinking water – water usage problems and look towards infrastructure and supply development solutions.