S.S. PAPADOPULOS & ASSOCIATES, INC.

Leaders in Environmental and Water-Resource Consulting

Statement of Qualifications

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THE COMPANY

S.S. PAPADOPULOS AND ASSOCIATES, INC. (SSP&A) provide professional water-resource and environmental consulting services to clients in industry and government.

Since its beginnings in 1979, SSP&A has been at the forefront of the water resource and groundwater industry, successfully completing hundreds of water-resource projects in diverse geologic environs throughout the United States and internationally. We are proud of our reputation for innovative approaches to our client's needs, the specialized technical expertise of our staff, and the recognition that we have earned. Our staff's expertise is in:

Earth Sciences:	Hydrogeology, Hydrology, Geology, Geochemistry, Geophysics, and Environmental Science
Engineering:	Civil (Water Resource, Hydrology, Hydraulics), Chemical, Environmental, and Geological
Technical Specialties:	Modeling (groundwater, surface water, conjunctive use, contaminant flow and transport), Geographic Information Systems (GIS)
Field Studies:	Aquifer tests, surface-water/groundwater interactions, seepage analyses, irrigation efficiency tracer tests, soil and water-quality monitoring, isotope analyses.

SSP&A has applied this expertise to provide solutions in many venues, including:

- Contamination studies;
- Remediation feasibility studies and design;
- Interstate or trans-boundary aquifer evaluations;
- Water supply, planning and management;
- Environmental impact statements, habitat restoration and endangered species issues; and
- Irrigation system evaluations.

Modeling for problem solving constitutes SSP&A's core strength. SSP&A takes pride in the rapid and cost-effective development of models to address key questions, considering dynamic flow and water quality processes within the surface, subsurface and biological domains.

SSP&A is a relatively small company of about 55 employees. Our small size allows us to address technical issues with innovative approaches that come from multiple project experience plus the interaction and ease of familiar communication among the various geoscience and engineering disciplines that make up SSP&A. All of our offices are closely affiliated, and staff members routinely work together to provide the technical expertise and experience needed to complete a particular project. SSP&A's corporate office is located in **Bethesda, Maryland.**

Regional offices are located in Boulder, Colorado; San Francisco, California; Portland, Oregon; Olympia, Washington; and Waterloo, Ontario-Canada.

KEY PERSONNEL

What distinguishes SSP&A in the environmental consulting industry is its staff's

- *Leadership in environmental and groundwater consulting,*
- *History of practical experience,*
- *Technical expertise,*
- *Innovative, site-specific solutions, and*
- *National and international recognition.*

The individual experience of key SSP&A personnel ranges from 10 to over 40 years working on groundwater, environmental, and remediation investigations and participating in research that has contributed to the development of groundwater hydrology as an applied science.

For any project, the required expertise is drafted from any SSP&A office and often includes one or more principals. The principals and project managers ensure that the skills of the specialists are effectively integrated while providing a bridge from the technical to the legal and regulatory demands associated with each project.

Brief descriptions of key SSP&A personnel are provided below.

PRINCIPALS

The principals of the firm are Dr. Stavros S. Papadopulos, Dr. Charles B. Andrews, Mr. Steven P. Larson, Ms. Deborah Hathaway, and Dr. Remy J.-C. Hennet.

STAVROS S. PAPADOPULOS, PhD, Founder and Senior Principal, is an internationally recognized expert on the analysis of groundwater systems, the evaluation of aquifer test data, and the use of analytical and numerical models for evaluating groundwater flow, contamination, and supply issues. He has served on advisory panels offering technical opinion on a variety of complex groundwater issues and has provided expert testimony in court proceedings. Prior to initiating SSP&A in 1979, he served at the U.S. Geological Survey where he planned and directed research on groundwater systems and development of new methods for analyzing aquifer tests. He is the author or co-author of numerous publications in well hydraulics, aquifer test methodology, groundwater and geothermal energy resource evaluation and subsurface waste disposal.

COMPANY PRINCIPALS — *continued*

CHARLES B. ANDREWS, PhD, President of SSP&A, is an experienced project designer and manager who has the special ability to identify practical solutions for complex hydrogeologic issues. His technical expertise is the development of new, and the modification of off-the-shelf, models to solve groundwater flow, contaminant migration, and heat-transport problems, as well as the design of remedial plans for mitigating groundwater and soil contamination. Dr. Andrews is a frequently requested member of groundwater advisory panels for the evaluation of state-of-the-art hydrology and for pioneering research and evaluation of contaminant transport in the subsurface. He is a member of the National Ground Water Association (NGWA) Group 2020, a strategic visioning institute of internationally respected ground water professionals. Dr. Andrews has served on the National Academy of Sciences and National Research Council Board Committees on groundwater models and cleanup alternatives. He is the author and co-author of numerous publications on modeling of groundwater flow / transport of chemical constituents, and on the use of analytical models in identifying appropriate remediation alternatives for a site.

STEVEN P. LARSON, Executive Vice-President of SSP&A, is an internationally recognized authority on the development of numerical simulation models and their application in the analysis of a variety of groundwater problems. Mr. Larson has developed numerical simulation models for analyzing groundwater flow, mass, and heat transport in groundwater systems; contaminant migration; saltwater intrusion in coastal aquifers; thermal energy storage in aquifers; efficient recovery of petroleum products from groundwater; and the design of remediation plans for mitigating soil and groundwater contamination. Mr. Larson is the author or co-author of many scientific and technical papers on these subjects, including publications documenting aquifer simulation models that are widely used by practicing hydrologists. His contributions to the science of groundwater extend into the courtroom where Mr. Larson is an effective expert witness at all levels, including the U.S. Supreme Court.

DEBORAH L. HATHAWAY, PE, Principal of SSP&A, has over 20 years of experience performing hydrologic and hydrogeologic investigations related to water supply development, environmental restoration and contaminant migration in groundwater. Ms. Hathaway has managed numerous projects involving water rights and water supply development in the Southwest U.S. She has directed model development and/or hydrologic studies to address riparian groundwater conditions and in-stream flow conditions related to endangered species habitat. Ms. Hathaway has conducted groundwater modeling or contaminant transport evaluations involving abandoned disposal sites, landfills, petroleum terminals, mines and manufacturing facilities; and has evaluated and designed groundwater remedial alternatives at RCRA, CERCLA and state-led sites. She has conducted hydrogeologic investigations throughout the U.S. Ms. Hathaway has testified as an expert witness in groundwater hydrology in U.S. Supreme Court hearings, state courts, and water rights hearings. She is a Registered Professional Engineer in Colorado, New Mexico, Maryland, and Florida.

REMY J.-C. HENNET, PhD, **PG,** Principal of SSP&A. A geochemist with 20 years of research and professional experience, Dr. Hennet specializes in the evaluation of the origin, fate, and transport of organic and inorganic chemicals in the environment. Dr. Hennet is often retained as an expert witness for litigation providing services to industry, law firms, and the U.S. Department of Justice. His areas of expertise include the analysis of geochemical fingerprints, the evaluation of the timing of chemical releases, cost allocation, geochemical modeling, and the evaluation and application of novel on-site technologies to solve environmental problems. He is a member of the American Academy of Forensic Sciences, the American Chemical Society, and the Association of Groundwater Scientists and Engineers. He was awarded the Woods Hole Oceanographic Institution's Postdoctoral Scholarship in 1987 and has numerous publications in the fields of inorganic and organic geochemistry.

Vice-Presidents and Senior Associates

MICHAEL J. RILEY, PhD, Vice President and Senior Hydrologist, has over 15 years of experience in groundwater and surface-water. His special interests are risk assessments and analysis of exposure pathways, identification of effective innovative technologies for groundwater remediation, hydrology of coastal environments, groundwater/surface-water interactions, and remediation of contaminated sediments. He has performed environmental impact, remediation, and reservoir investigations, and NPDES studies at numerous sites in the western United States. Dr. Riley is Office Manager of the Olympia, Washington office.

MICHAEL T. RAFFERTY, PE, Vice President and Principal Engineer, has extensive experience in the design, construction, and operation of groundwater treatment, soil treatment, and oil and chemical process facilities. He has been responsible for design of process systems (including equipment, piping and instrumentation), construction, startup, and operation of treatment plants; project material control; and various construction-related activities. Mr. Rafferty has been directly responsible for development of design drawings and specifications; material procurement and expediting; bid document preparation and evaluation; construction management; field inspection for quality and payment purposes; supervision of craft labor; field re-design to match conditions encountered; and negotiation of change orders and claims with contractors and subcontractors. Mr. Rafferty is Office Manager of the San Francisco, California office.

CHRISTOPHER J. NEVILLE, PEng, Vice President, performs regional groundwater flow modeling, and numerical and analytical solutions for solute transport. His project experience has involved interpretation of hydrogeologic data, evaluation of groundwater resources, investigation of groundwater and soil contamination, and design, evaluation, and optimization of remedial measures. Mr. Neville has developed and taught several professional short courses through SSP&A and the International Groundwater Modeling Center in Colorado. His education is in civil engineering from McGill University in Montreal and in hydrogeology at the University of Waterloo. Mr. Neville is Office Manager of SSP&A's Waterloo, Ontario, Canada office.

GORDON D. BENNETT, Senior Associate, is an internationally known hydrogeologist who has over 42 years of experience in groundwater hydrology. Much of his career has been with the U.S. Geological Survey where he served as Chief of the Ground Water Branch and Assistant Chief of the Water Resources Division. Since joining SSP&A in 1987, his diversity and depth of background and experience have contributed significantly to the success of SSP&A projects. Mr. Bennett specializes in groundwater and solute-transport modeling and their application to complex groundwater systems, remediation of hazardous waste sites, and groundwater development. His publications are on borehole geophysics, well hydraulics, freshwater-saltwater relationships, and regional groundwater hydrology. Mr. Bennett also has written a programmed text on groundwater hydraulics and is co-author of a textbook on contaminant transport modeling.

EXPERIENCE

*While **GROUNDWATER INVESTIGATIONS** are the cornerstone of SSP&A's expertise, the firm has extensive experience in related areas including*

Surface-Water Hydrology,
Environmental Remediation,
and
Geochemistry.

SSP&A's experience is best illustrated through representative projects. Brief summaries and/or more detailed descriptions of several projects are provided in this section.

WATER RESOURCE STUDIES

SSP&A has extensive experience in water resource studies, including surface-water hydrology and groundwater/surface-water interactions.

MIDDLE RIO GRANDE WATER SUPPLY STUDY
NEW MEXICO

This study integrated vast quantities of existing data, models and investigations conducted over the past 100 years over a 150-mile reach of the Rio Grande to obtain a probabilistic description of the conjunctive-use groundwater and surface-water supply. Using historic data, a water budget was developed for the linked groundwater/surface-water system. To characterize the water budget elements and their variability, descriptive statistics and probability density functions were developed for each water budget inflow and outflow term using data recorded over a 50-year period. Groundwater inflow/outflow to the river system was characterized through MODFLOW simulation. Monte Carlo simulation of the river system water budget was conducted to characterize the probabilistic nature of the overall water supply and likelihood of meeting Rio Grande Compact obligations under several potential future development conditions.

The probabilistic water supply, based on surface-water and groundwater supplies, was quantified as probability density functions under various scenarios. The source data, methodologies and results were presented in a final report, through oral presentation at several public meetings, and in an interactive website. The results are being used by regional planning groups as they develop regional water plans.

MADISON LIMESTONE AQUIFER STUDY
WYOMING

SSP&A developed mathematical models of the Madison Limestone and the underlying Bighorn dolomite in Wyoming to evaluate the potential for long-term groundwater development**.** A multi-layer, finite-difference model was used to simulate three-dimensional groundwater flow. The model allowed SSP&A to represent many of the specific features of the aquifers, including the boundary conditions, the unconfined conditions near rock outcrop areas, the hydraulic connection between aquifers, and the aquifer/stream interaction. Through the results of this modeling effort, SSP&A was able to determine the water-supply potential of the formations and to outline an efficient strategy for the development of a well field that would provide the projected water supply.

BERKELEY PIT
BUTTE, MONTANA

This study involved hydrogeologic and water budget characterization of abandoned and active mine areas. Evaluations included hydrologic data compilation; database construction; trend analysis of spring, pit-level and chemical data; and GIS mapping of pre-development conditions and present conditions. SSP&A collected spring and seep water-quality and flow data, and developed a geochemical model to predict temporal changes in water chemistry in the abandoned open-pit mine. The purpose of the model was to evaluate options for treatment of contaminated surface water and to evaluate the impacts of various sources of water inflow into the pit on the long-term chemistry of the pit. In addition, the volume and chemistry of the pit-water was allocated to the different sources of inflow to the pit over time. SSP&A provided support in litigation regarding future and past groundwater/surface-water conditions under alternate mine operation plans.

WATER RESOURCE STUDIES — *continued*

MESILLA BOLSON STUDY
NEW MEXICO

In order to secure a long-term water supply, the City of El Paso filed application with the New Mexico State Engineer's office to appropriate 246,000 acre-feet per year from the Mesilla valley wellfield in the Lower Rio Grande Basin. The State of New Mexico required evaluation of the impacts of the proposed pumping on existing groundwater and surface-water rights in the region. SSP&A was retained to conduct hydrogeologic evaluations of the proposed development, including assessment of impacts on groundwater levels, surface-water flow, and water-quality conditions. SSP&A compiled an extensive database of water levels, water quality, and pumpage and developed numerical models to calculate water-quality impacts and water availability.

CONTAMINATION STUDIES

SSP&A has a successful history of conducting contamination studies at chemically and geologically complex sites where NAPL and dissolved contaminants are present in geologic media, including sites where both primary and secondary porosities occur.

STRINGFELLOW SUPERFUND SITE FEASIBILITY STUDY AND REMEDIATION GLEN AVON, CALIFORNIA

The Stringfellow Hazardous Waste Site is located within the Glen Avon Basin, a segment of the Chino groundwater basin, in Riverside County, California, approximately 50 miles east of Los Angeles. The original disposal area is located at the head of Pyrite Canyon in the southern portion of the Jurupa Mountains where five hydrostratigraphic units have been identified onsite. The disposal area was operated as a Class I industrial waste disposal facility from 1956 through 1972 on land owned by the Stringfellow Quarry Company. Approximately 34 million gallons of industrial process wastes containing spent acids and caustics, solvents, pesticide by-products, metals and other inorganic and organic contaminants were discharged into evaporation ponds onsite during this period. Because the site is geographically separated into four contaminant zones, site characterization, groundwater modeling, and development and implementation of remediation plans required careful attention due to the hydrologic, geographic, and contaminant complexities at this site. The primary contaminants of concern included TCE, chloroform, nitrates, and sulfates.

SSP&A has acted as principal technical advisor on groundwater issues, overseen field investigations, and evaluated remedial activities. SSP&A was initially retained as groundwater advisor by the PRP group to respond to the California Department of Health Services' contractor's Remedial Investigation/Feasibility Study (RI/FS). Based on a review of the RI/FS and supportive data, SSP&A was able to demonstrate that the FS groundwater remediation plans were not feasible. SSP&A's role was expanded to include:

- Conducting a feasibility study for identifying potential remediation alternatives,
- Conducting hydrogeologic investigations,
- Performing flow and transport modeling,
- Providing expert testimony regarding the nature and extent of site contamination and investigative programs,
- Participating in technical presentations to the PRP group and government agencies, and
- Providing oversight and evaluation of continuing work performed by state agencies.

SSP&A developed alternative groundwater remediation scenarios for both on-site and off-site contamination. Remedial measures included groundwater extraction (onsite wells and drains), onsite pre-treatment of metals and organics followed by treatment in Orange County POTW and discharge into the Pacific Ocean.

CONTAMINATION STUDIES — *continued*

HARDAGE SUPERFUND SITE
CRINER, OKLAHOMA

SSP&A has conducted several investigations at this former hazardous waste disposal facility now in litigation under CERCLA. As part of the site Feasibility Study, SSP&A conducted groundwater flow and transport modeling. A three-dimensional flow model of the site was constructed, calibrated, and used to assess proposed remedial alternatives and to optimize well locations and pumping rates for the preferred alternative. SSP&A's work at the site involved:

- Evaluation and re-analysis of existing data.
- Design of field tests and analysis of results to determine hydraulic conductivities and piezometric heads in formations of low permeability.
- Analyses to relate fracture spacings and apertures to regional hydraulic parameters.
- Regional flow simulation to estimate hydraulic parameters and to identify potential long-term contaminant migration pathways.
- Evaluation of the potential for dense non-aqueous phase liquid (DNAPL) migration from the waste mounds.
- Analysis of water-quality data to determine contaminant pathways.
- Simulations of flow and solute transport to analyze the effectiveness of various proposed source-control remedies and groundwater clean-up schemes.
- Negotiations with the U.S. Environmental Protection Agency on source-control issues.

SSP&A interacted with a technical committee representing numerous potentially responsible parties (PRPs) and with other consulting firms. Additionally, SSP&A coordinated the activities of an expert panel retained by the PRPs and provided technical support for legal counsel in charge of the defense. Expert testimony was presented on behalf of the client.

MARTIN-MARIETTA SUPERFUND SITE
COLORADO

At the site of this 5200-acre aerospace equipment manufacturing facility, liquid and solid waste had been disposed in ponds until facility closure in 1980. Two narrow 3000- and 8000-foot-long VOC-contaminated groundwater plumes were identified in the alluvium and metal contamination was found in the soil and groundwater. As part of the Remedial Investigation for this site**,** SSP&A was asked to evaluate the fate and transport of the VOCs, metals and other contaminants from on-site to the down-gradient river alluvium and the South Platte River. SSP&A developed a linked groundwater and surface-water flow model of the shallow alluvial aquifer, the Pierre Shale, and other dipping bedrock units and used this model to evaluate the risk of the contamination to Denver municipal wells located in the river alluvium, and the effectiveness of existing groundwater interception measures. SSP&A also used the model to assess alternate groundwater remedial measures and to determine optimal well locations in alluvial channels for expediting clean-up. SSP&A's services complemented engineering services provided by another consultant performing the RI/FS. SSP&A also provided expert technical support for Martin-Marietta in insurance litigation.

TOMS RIVER PLANT SUPERFUND SITE ADVISORY
NEW JERSEY

The Toms River Plant is operated by Ciba-Geigy, Inc. in Toms River, New Jersey. The area is underlain by the Cohansey/Kirkwood Formation, an aquifer that has become contaminated as a result of plant activities. Dr. Stavros Papadopulos, founder of SSP&A, has acted in an expert capacity on the Scientific Advisory Committee, comprised of four internationally-renowned hydrogeologists, reviewing and analyzing existing site data. The primary issues of concern included: (1) the hydrogeologic character of the Kirkwood Formation, (2) the effects of the Toms River on the regional flow system, (3) the potential for migration of dense non-aqueous phase liquids (DNAPLs), and (4) the potential for contaminant migration within the Kirkwood No. 1 sand.

Dr. Papadopulos and the other members of the committee placed particular emphasis on gaining an understanding of the nature and continuity of the various units of the Cohansey/Kirkwood Formation, for the purposes of identifying likely mechanisms for contaminant transport. Based on their evaluations, the committee concluded that flow and associated dissolved contaminants from these aquifers would discharge to the river.

Detailed studies were also conducted concerning possible mechanisms for and paths of migration of DNAPL in the subsurface. The committee noted in particular the lithologic contacts associated with aquitards that could act as a preferential flow mechanisms for and paths of migration of DNAPL in the subsurface. An additional study relating to contaminant transport led the committee to conclusions regarding the relative mobility of organics and inorganics within the Kirkwood aquifers, which helped to explain current patterns of contamination and to predict future patterns.

REMEDIATION: FEASIBILITY STUDIES & DESIGN

SSP&A's experience in remediation investigations, feasibility studies, and remedial system design and implementation has been performed at many Superfund sites contaminated with chlorinated and other recalcitrant compounds. Many of these projects have involved SSP&A's effective negotiations with regulatory agencies.

BAY ROAD SUPERFUND SITE
EAST PALO ALTO, CALIFORNIA

Since 1984, S.S. Papadopulos & Associates has directed the investigation and remediation of the 1990 Bay Road Superfund site. Arsenic contamination has affected soil and shallow groundwater in the 20-acre site area adjacent to San Francisco Bay, including wetland areas having both tidal and non-tidal marshes. The site is being administered by the California Water Quality Control Board, San Francisco Region and the U.S. Environmental Protection Agency. Other agencies involved include the U.S. Fish and Wildlife Service, the California Department of Fish and Game, and the National Oceanic and Atmospheric Administration.

SSP&A has conducted extensive hydrologic investigations and modeling at the site in both the shallow and deep groundwater zones to (1) assess the impacts of historic disposal practices, and (2) estimate the extent of further migration over time at the site. Horizontal and vertical flow characteristics were evaluated using MODFLOW, and chemical transport was evaluated using MT3D. Groundwater modeling for the site incorporated the additional complexities of the surface-water in the study zone — tidal inundation from San Francisco Bay and seasonally ponded water in the non-tidal marshes. SSP&A has also conducted sampling and geochemical modeling of arsenic transport from the oxidizing, upland groundwater conditions to the reducing conditions beneath the tidal marsh to evaluate natural attenuation of the arsenic in the groundwater.

LONE PINE LANDFILL SUPERFUND SITE
NEW JERSEY

SSP&A performed an RI/FS for the off-site area surrounding the Lone Pine landfill. For the RI, SSP&A conducted field investigations and analyzed the data to describe the hydrogeologic and chemical systems. The extent and magnitude of existing off-site contamination and the potential for migration of this contamination in the groundwater and surface-water systems outside the landfill were assessed.

For the FS, potential remedial alternatives for the off-site area were evaluated in detail. A three-dimensional groundwater flow model was used to predict the effects of the various potential remedial actions on the hydrogeologic system. Remedial alternatives that were considered and modeled included a slurry wall with french drain and impermeable cap, combined with various arrays of injection and extraction wells and interceptor trenches. A particle-tracking method was used in conjunction with the flow model to describe the direction and rates of groundwater flow associated with each simulation. A mixed linear-reservoir model was used to estimate the time required to achieve remedial goals for site cleanup. SSP&A prepared all required RI/FS documents and participated in negotiations with the regulatory agencies for selection of the final remedy.

REMEDIATION — *continued*

CHEM-DYNE SUPERFUND SITE
HAMILTON, OHIO

At this hazardous waste treatment plant, spills and dumping of chemicals had created a plume of VOC-contaminated groundwater that extended over 40 acres. SSP&A's participation in this project included:

- Delineation of the plume (post Remedial Investigation study).
- Development of the remediation plan that involved pumping and treatment of the contaminated water and injection of a portion of the treated water to increase flushing in the aquifer.
- Design and supervision of the construction of 25 monitoring wells, 36 piezometers, 18 shallow extraction wells, 7 intermediate extraction wells, and 8 injection wells.
- Assistance to the PRPs in negotiations leading to a Consent Decree and other settlement negotiations with regulatory agencies.
- Annual assessment of operation and effectiveness of on-going remediation system.

At the end of the first five years of operation, an average of nearly one million gallons per day were pumped and treated, with over one-third of the treated water re-injected into the aquifer. SSP&A conducted a chemical assessment, the results of which showed that the plume had been sufficiently diluted where water from the treatment plant could be discharged directly to surface water, without the need for injection. The injection system was shut down, and the contaminant load from the treated water, which meets applicable NPDES limits, is discharged into the Ford Hydraulic Canal.

STRINGFELLOW SUPERFUND SITE FEASIBILITY STUDY AND REMEDIATION
GLEN AVON, CALIFORNIA

Over 34 million gallons of liquid waste were disposed in an unlined pond at this site. Groundwater and soil contamination extended from the disposal area down a canyon to the aquifer beneath the community of Glen Avon. The primary contaminants of concern included TCE, chloroform, nitrates, and sulfates. SSP&A was retained by the PRP group to serve as groundwater advisor and to respond to the California Department of Health Services' contractor's Remedial Investigation/Feasibility Study (RI/FS). Based on a review of the RI/FS and supportive data, SSP&A was able to demonstrate that the Feasibility Study groundwater remediation plans were not feasible. SSP&A's role was expanded to include:

- Conducting a feasibility study for identifying potential remediation alternatives.
- Conducting hydrogeologic investigations.
- Performing flow and transport modeling.
- Providing expert testimony regarding the nature and extent of site contamination.
- Participating in technical presentations to the PRP group and government agencies.
- Providing oversight and evaluation of continuing work performed by state agencies.

SSP&A developed alternative groundwater remediation scenarios to address both on-site and off-site contamination. Remedial measures included groundwater extraction (onsite wells and drains), onsite pre-treatment of metals and organics followed by treatment in Orange County POTW and discharge into the Pacific Ocean.

GEOCHEMICAL STUDIES

SSP&A has performed geochemical studies of groundwater, the unsaturated zone, and surface water at sites where the contaminants of concern were organic compounds in dissolved and NAPL phases.

RESOLVE SUPERFUND SITE
NORTH DARTMOUTH, MASSACHUSETTS

Contamination at this former chemical reclamation facility included DNAPL and dissolved-phase VOC contamination of soil, a 10-acre plume of dissolved VOCs in bedrock groundwater and a 7-acre plume in overburden groundwater emitting from former on-site disposal facilities (unlined lagoons, cooling ponds, and oil-spreading area). Work included

- An assessment of geochemical and hydrogeologic data to identify the potential extent of DNAPL and dissolved phase contaminants.
- Analyses of aquifer tests.
- Development and calibration of a three-dimensional numerical groundwater flow and particle-tracking model.
- Modeling analyses of alternate extraction well scenarios.
- Design of an extraction well system considering performance objectives, wetland issues, and risk of DNAPL remobilization.

SSP&A prepared the preliminary design for an extraction well system at the site to contain and restore, where practical, the contaminated groundwater. As part of this project, SSP&A served on an Expert Committee assembled to provide state-of-the-art advice on DNAPL issues.

MINING SITE IMPACT EVALUATION
BUTTE/ANACONDA AREA, MONTANA

For a confidential client involved in natural resource damage litigation, SSP&A reviewed and evaluated the impacts of mining-related activities on groundwater resources in the Butte/Anaconda area and along the Silver Bow Creek and Clark Fork River to the Milltown reservoir. Contamination in these areas resulted from historic mining and smelting operations around the Butte copper sulfide ore body. Mining operations had included underground and open pit mining, the operation of large acid leach pads and tailings ponds, and the milling, concentrating, and smelting of ore materials. The contaminants-of-concern included both toxic and non-toxic metals (cadmium, copper, lead, iron, manganese and zinc), non-metals (arsenic, sulfate, nitrate and fluoride), and other chemicals or products associated with ore processing and wood treatment.

To assess the impact of past mining activities on groundwater quality, SSP&A conducted a comprehensive geologic and geochemical site characterization to demonstrate natural attenuation of contaminants and to characterize background conditions beyond the effect of the mining operations. SSP&A performed detailed mineralogical studies of bedrock along groundwater flowpaths and interpreted stable isotope signatures to assess attenuation processes down-gradient of the tailings impoundments.

GEOCHEMICAL STUDIES — *continued*

TEXAS EASTERN / DUKE ENERGY GAS PIPELINE REMEDIATION
TEXAS

Beginning in 1998, SSP&A was retained to evaluate groundwater and soil contamination at compressor stations along this underground gas pipeline system extending from the Texas Gulf coast to New Jersey and to develop remedial alternatives for those sites. Multiple authorizations followed since that original contract and ongoing projects focused on remedial investigations of new sites and application of innovative technologies.

In the late 1980s, groundwater in the vicinity of over 50 compressor stations along the pipeline was found to contain polychlorinated biphenyls (PCBs) at concentrations in excess of the drinking-water standards. The contamination was from PCB-containing lubricating oils used during normal pipeline operation. At the time that SSP&A was retained, the estimated costs for groundwater remediation at all of the sites was projected to exceed $1billion.

SSP&A's approach focused on the mechanism of groundwater contamination and the potential for further migration of PCBs. SSP&A determined that PCBs were widely distributed in groundwater because they had migrated with large volumes of gasoline-like liquids in the subsurface — liquids that had almost completely biodegraded in the 20 years since initial disposal. Through geochemical analyses, SSP&A was able to conclusively demonstrate that the PCBs had migrated in the subsurface only where they were co-dissolved in an organic liquid. Consequently, the only appropriate remedial action for these sites was long-term monitoring. (Note: At the time these studies were undertaken, this implication was contrary to the conventional wisdom that groundwater restoration was the goal of remediation.) SSP&A's activities for this effort included

- A one-year analysis of data on the distribution of PCBs in groundwater.
- A study of the mobility and fate of PCBs in the environment.
- An evaluation of the effect of physical, chemical and biological processes on the long-term fate of PCBs in a fractured-rock environment.
- Detailed study of representative sites to evaluate hypotheses on contaminant migration.
- Research, testing, and application of innovative technologies for the removal of PCBs.
- Preparation of long-term monitoring plans for the compressor station sites.

SSP&A worked with all concerned parties to demonstrate the appropriateness of long-term monitoring as the appropriate remedial alternative. Long-term monitoring has been implemented at most of the sites.

MOJAVE DESERT CONTAMINATION
CALIFORNIA

SSP&A was retained by the U.S. Department of Justice to provide expert opinions regarding an allegation of environmental property damage at a site located to the north of the Town of Barstow in the Mojave Desert. The geochemistry of a large amount of solid waste was evaluated to determine the origin of the substance and the fate and impact of the disposal on soil, surface water and groundwater in the Mojave desert. SSP&A also critiqued the defendant's remediation costs and estimated the costs for covering or removing the remaining powder for offsite disposal.

GEOCHEMICAL STUDIES — *continued*

RCRA INVESTIGATION OF FORMER REFINERY SITE
WYOMING

For a RCRA Facility Investigation (RFI) of this former BP Amoco refinery, SSP&A provided technical support in geochemistry, groundwater, and geology and participated in Collaborative Process meetings with Wyoming State agencies regarding Soda Lake, a former discharge point for refinery effluent. SSP&A's initial activities involved:

- Development of a site conceptual model of groundwater for the Soda Lake region. Soda Lake was found to be a classical discharge lake, with a deeper groundwater underflow component.
- Siting of numerous groundwater-monitoring wells in both Cretaceous sedimentary formations and unconsolidated sandy soils.
- Evaluation of the water balance and selenium biogeochemical cycle in the lake.
- Development of a probabilistic model for predicting future selenium concentrations in lake water and sediments under different management alternatives.

A goal of the RFI was to demonstrate how the Remedy Decision data were of sufficient quality and quantity to evaluate the nature and extent of contamination present or probable at the site and to support a Risk Assessment and a Corrective Measures Studies. Based on SSP&A's studies, the shallow groundwater flow system was found to discharge from the total lake periphery into Soda Lake, which lies in an enclosed basin. No groundwater was found to migrate down-gradient toward the North Platte River. This conclusion was based on the following:

- The SSP&A-generated comprehensive water-balance model demonstrated that all water loss from the Soda Lake basin is via evaporation.
- Groundwater contour maps and hydrographs documented that groundwater flows radially into Soda Lake.
- Chemical analyses of both groundwater and lake water indicated that net groundwater flow is toward Soda Lake.

ARSENIC BINDING PROCESS FEASIBILITY STUDY
WASHINGTON STATE

SSP&A performed a modeling feasibility study of an in-situ arsenic binding process for an aquifer beneath the site of an arsenic-based pesticides production facility. SSP&A assessed a geochemically engineered design for re-precipitation of iron arsenate solids as an arsenic sulfide mineral phase. The modeling of the re-precipitation mechanism used a coupled geochemical speciation and mass transfer model and a mass transport model in two dimensions specifically constructed for this evaluation.

Hydrochemical reactions were simulated in a stream tube representative of the three-dimensional flow system. The stream tube was divided into flow cells, and within each cell, the mass transfer code PHREEQE was used to model mass transfer. Equilibrium was not obtained in most cells given the relatively short residence times in each cell. The non-equilibrium condition was simulated by modifying the equilibrium constants proportional to reaction time and available reactive mass in each cell. The amount of modification was determined from batch experiments on the soils. A second-order reaction relationship was determined from the batch testing and used for predicting the degree of reaction completion. The modeling enabled simulation of several very different starting solutions at the point of recharge to the contaminated aquifer.

GEOCHEMICAL STUDIES — *continued*

PREDICTIVE WATER-QUALITY MODEL
ABANDONED MINE, WESTERN US

For this litigation project involving contamination from an abandoned mine, SSP&A developed a model for predicting changes in water chemistry with time. The purpose of the modeling was to evaluate options for treatment of contaminated surface water and for partitioning of financial responsibility among the PRPs. The geochemical model involved two steps:

- Modeling inflow of chemically-distinct water from various sources as a time-dependent mixing process using both PHREEQE and inflow data derived from a groundwater flow and transport model. The model allowed for accumulation of acid sulfate water to react with aluminosilicate minerals in the walls and floor of the mine and for formation of secondary minerals.
- Use of the code MPATH to simulate slow weathering reactions that remove protons from water by silicate hydrolysis. (MPATH allows a kinetic treatment of dissolution and precipitation reactions in water/rock systems and thermodynamic treatment of complexation, ion association, and aqueous redox reactions.) Consequently, slow processes can be modeled explicitly as a function of time. For example, simulations to 1000 years initially were made to evaluate the time scale of the weathering process.

It was found that the time scale for neutralization of the acidity of the surface water and removal of heavy metals from the water could range from several decades to a few hundred years depending on the rate of deposition of windblown dust particles to the pit surface.

URANIUM MINE WATER PURIFICATION MODEL
SOUTHWEST TEXAS

SSP&A developed a thermodynamic model for attenuation of uranium, radium, and molybdenum from uranium mine discharge waters. Application of this model to date has been at southwest Texas mines. The attenuation model involves ion complexation and mineral precipitation reactions and is solved using the U.S. Geological Survey's chemistry model PHREEQE. The thermodynamic stabilities of the mineral phases are calibrated to batch-test data. With this model, scavenging powders can be custom-blended for the specific compositions of waters encountered at each mine site. Water treatment is completed in a portable system rated at several hundred gallons per minute. The treatment process is currently undergoing EPA SITE program assessment.

GROUNDWATER MODELING AND LITIGATION SUPPORT

SSP&A, as a company, is probably best known for its work in groundwater modeling and litigation support. In this capacity, SSP&A has completed hundreds of projects which involved some component of modeling the subsurface environment. The company provides litigation support in a variety of areas including environmental insurance coverage, natural-resource damage claims, toxic tort claims, remedial-action disputes, environmental liability claims, water-rights adjudication, water and environmental permit disputes, and water-resource regulations.

NEW MEXICO ET AL. VS. GENERAL ELECTRIC ET AL.

State of New Mexico et al. vs. General Electric Company et al. The U.S. District Court for the District of New Mexico. Case No. CV 99-1254 BSJ/DJS and CV 99-1118 BSJ/LFG.

SSP&A evaluated groundwater flow, the fate and transport of contaminants, and groundwater modeling at a Superfund site in New Mexico. Mr. Steve Larson was the groundwater expert for General Electric Company. The opposing experts were disqualified, and the issues in the case were determined to be unfounded. The case was dismissed.

REDLANDS TORT LITIGATION

Superior Court of the State of California for the County of San Bernardino. Consolidated Case No. RCV 31496.

SSP&A has evaluated groundwater flow, the fate and transport of contaminants, and groundwater modeling at the Lockheed Martin Corporation (Lockheed) facility in Redlands, California. Mr. Steve Larson is the groundwater expert for Lockheed. This case is ongoing.

MICHIGAN CITIZENS FOR WATER CONSERVATION VS. NESTLÉ

Michigan Citizens for Water Conservation et al. vs. Nestlé Waters North America, Inc. et al. State of Michigan in the Circuit Court for the County of Mecosta. Case No. 01-14563-CE.

SSP&A evaluated the impact to groundwater and surface water from increased production of spring waters by Nestlé Waters North America, Inc. (Nestlé). Dr. Charles Andrews is the groundwater expert for Nestlé. This case is ongoing.

GROUNDWATER MODELING AND LITIGATION SUPPORT — *continued*

MONTANA VS. ARCO

State of Montana vs. Atlantic Richfield Company. U.S. District Court, District of Montana, Helena Division. Case No. CV-83-317-HLN-PGH.

SSP&A developed a mixing model for the origin of acidic seepage flowing at several million gallons per day near the base of an alkaline tailings pond dam in an area of historic mining adjacent to present-day heap-leach mining operations. Mr. Steve Larson was the groundwater expert for Atlantic Richfield Company (ARCO), and Dr. Remy Hennet was the geochemical expert for ARCO. From chemical analyses of the acidic seepage, natural drainage, tailings pond, and leach pad operations related waters, a mass-balance model was derived for the acid drainage using the codes WATEQ4F and NETPATH (inverse modeling approach). The mass-balance model indicated that the acidic seepage originated from a mixture of tailings pond water and leach pad effluent. The results of the mass-balance model were then used in mass-transfer simulations using PHREEQE (forward modeling approach). Tailings pond water and leach pad water were mixed incrementally and supersaturated secondary minerals were allowed to precipitate. The predicted chemical composition was in good agreement with the observed chemistry of the acidic seepage, thus confirming the thermodynamic validity of the mass-balance model.

KANSAS VS. COLORADO

(Arkansas River)

State of Kansas vs. State of Colorado and United States of America. Supreme Court of the United States. Case No. 105 Original.

SSP&A serves as a technical assistant to the State of Kansas in a legal dispute involving the availability of waters from the Arkansas River. The major case issue involves the effect of extensive groundwater pumping from alluvial aquifers in Colorado on the availability of surface-water flow in Kansas. The State of Kansas has claimed that the State of Colorado is pumping to an extent which reduces stream flow sufficiently to be in violation of the Arkansas River Compact. SSP&A conducted analyses supporting this claim, and Mr. Steve Larson testified on behalf of the State of Kansas before a Special Master of the U.S. Supreme Court. Recently, the Court found in favor of the State of Kansas when they declared the State of Colorado to be in violation of the Arkansas River Compact.

NEBRASKA VS. WYOMING

(North Platte River)

State of Nebraska, vs. State of Wyoming. Supreme Court of the United States. No. 108.

SSP&A was retained by the State of Nebraska to provide expert support on groundwater modeling in litigation involving the North Platte River in the matter of Nebraska vs. Wyoming. SSP&A reviewed the hydrologic models of the North Platte River developed by Nebraska and by the U.S. Bureau of Reclamation. Mr. Steve Larson, groundwater expert for the State of Nebraska, led this project, completing a critical analysis of the stream flow data and the use of various statistical techniques to quantify the depletions in stream flow due to groundwater use in Wyoming. The results of the analyses indicated that the variability in stream flows masked the depletions, and that the statistical techniques that were being used were not able to quantify the depletions.

NEW MEXICO STATE ENGINEER (EL PASO & MESCALERO)

Mesilla Basin Study

State of New Mexico, ex rel. S.E. Reynolds, State Engineer, and Pecos Valley Artesian Conservancy District vs. L. T. Lewis et al. United States of America, Mescalero Apache Tribe and State of New Mexico, ex rel. S.E. Reynolds, State Engineer, and Pecos Valley Artesian Conservancy District vs. Hagerman Canal Company et al. District Court for the County of Chaves, State of New Mexico. Case No. 20294 and 22600 - Consolidated.

SSP&A evaluated the impact of large-scale pumping proposed by the City of El Paso in the Mesilla Bolson and Lower Rio Grande Valley. Mr. Steve Larson was the groundwater expert for the State of New Mexico. An extensive database of water levels, water quality and pumpage were compiled. Three-dimensional numerical models were developed to calculate water-quality impacts, water-level declines, and depletions of stream and drain flows which would result from the proposed pumping.

MARTIN-MARIETTA MANUFACTURING FACILITY - DENVER, COLORADO

Martin-Marietta Corporation vs. Aetna Casualty and Surety Company et al. Superior Court of the State of California for the County of Los Angeles. Case No. C610358

SSP&A was retained to develop a quantitative framework to be used in making various management decisions concerning the remediation of contaminated groundwater on a 5,000-acre facility located adjacent to the Front Range south of Denver, Colorado. The groundwater system at this site is complex as the result of rugged topography and intricate interactions between the streams and the alluvial groundwater. No off-the-shelf groundwater models were appropriate for modeling this site. Therefore, SSP&A developed a three-dimensional finite-element linked groundwater and surface-water transport model to simulate chemical transport in the environment at this site. The modeling results and investigations completed by SSP&A were used as part of technical arguments for insurance litigation.

HARDAGE/CRINER SUPERFUND SITE - OKLAHOMA

United States of America vs. Royal N. Hardage et al., Advance Chemical Company et al. vs. Abco, Inc. et al., vs. A.C. Powell, d/b/a Powell Sanitation et al. Case No. CIV-86-1401-P; CIV-86-1401-W.

SSP&A has conducted several investigations at the Hardage/Criner site, a former hazardous waste disposal site facility in central Oklahoma, now in litigation under CERCLA. SSP&A conducted groundwater flow and transport modeling studies as part of the site Feasibility Study. A three-dimensional flow model of the site was constructed, calibrated and used to assess the groundwater flow and contaminant transport for a number of proposed remedial alternatives, eventually optimizing well locations and pumping rates for the preferred alternative.

Initial investigations at the site involved evaluation and reanalysis of existing data, design of field tests and analysis of results to determine hydraulic conductivities and piezometric heads in formations of low permeability. Other investigations included analyses to relate fracture spacings and apertures to regional hydraulic parameters; regional flow simulation to estimate hydraulic parameters and to identify potential long-term contaminant migration pathways; evaluation of the potential for dense non-aqueous phase liquid (DNAPL) migration from the waste mounds; analysis of water-quality data to determine contaminant pathways; simulations of flow and solute transport to analyze the effectiveness of various proposed source-control remedies and groundwater clean-up schemes; and, negotiations with technical representatives of the U.S. Environmental Protection Agency on source-control issues.

Work on the project has involved interaction with a technical committee representing numerous potentially responsible parties (PRPs) and with other consulting firms. Additionally, SSP&A provided coordination of the activities of an expert panel retained by the PRPs and technical support for legal counsel in charge of the defense. Expert testimony was presented by Dr. Papadopulos on behalf of the client.

LOVE CANAL - NIAGARA FALLS, NEW YORK

United States of America et al. vs. Occidental Chemical Corporation et al., Case No.CIV 79-990, United States of America, State of New York and UDC-Love Canal vs. Hooker Chemicals & Plastics Corp. et al.

Numerical groundwater models were developed to analyze the mechanisms of contaminant migration away from the Love Canal in Niagara Falls, New York, prior to 1980. The flow model developed for the site was calibrated using an inverse technique developed at SSP&A for calibration of three-dimensional transient flow models. Contaminant transport was simulated using particle-tracking methods. The modeling incorporated a large data base and enabled very detailed modeling of the area surrounding the waste source. Extensive sensitivity analyses were conducted for purposes of identifying uncertainties in the understanding of contaminant migration. The analyses conducted by SSP&A were used in support of litigation over cost recovery for implementing remedial actions at Love Canal. Mr. Larson presented expert testimony.

INTERSIL FACILITY - SUNNYVALE, CALIFORNIA

Intersil vs. Western Microwave. Case No. C-90-20701-JW.

SSP&A conducted numerical flow modeling and contaminant transport modeling at the former Intersil facility in Sunnyvale, California. A shallow plume of multiple contaminants, including PCE, TCE, and 1,2-DCE underlies the facility. The plume, which has multiple sources, is believed to have originated in part through spreading from a pool of DNAPLs located beneath a leaking underground pipeline. SSP&A used the results of the groundwater and transport modeling to evaluate the effectiveness of several alternative configurations for the pump-and-treat extraction system for groundwater remediation. The design of the system was optimized under a number of constraints, including total clean-up time and cost. SSP&A also evaluated the currently operating extraction system and devised a cost-allocation scheme between Intersil and adjacent facilities.

AGRICO LITIGATION

Bernice Samples et al. vs. Conoco, Inc., Agrico Chemical Company, Inc., and Escambia Treating Company, Inc., Circuit Court of the First Judicial Circuit in and for Escambia County, FL, Case No. 01-631-CA-01

The Agrico Chemical Company (Agrico) site in Pensacola, Florida, was listed on the National Priorities List in 1989. Superphosphate fertilizer and sulfuric acid were produced at the site starting in the early 1900s. The acidic process wastewater containing fluoride was discharged to ponds. One public supply well was shut down in the late 1950s due to low pH. At the time, operations at the Agrico site were suspected as a source of the low pH. SSP&A provided expert services for Agrico in class action lawsuits. The originally proposed class included about 6000 residential properties. SSP&A used the concentrations

of fluoride measured in groundwater downgradient from the Agrico site to define the extent of impacts from past operations that took place at the Agrico site. The plume delineation and groundwater flow regime determined by SSP&A were central to a legal motion that resulted in a substantial reduction of the initial class size. This project included detailed geochemical and hydrologic modeling, as well as an evaluation of the origin, fate, and transport of radionuclides in the subsurface environment. The lawsuits were settled in March 2004 to the satisfaction of our client.

KODAK PARK WEST - ROCHESTER, NEW YORK

SSP&A developed and calibrated a three-dimensional groundwater flow model for Kodak Park West, a section of the Kodak Park industrial complex, and used it to estimate directions and rates of groundwater flow and to evaluate remedial options. The site is an extensive industrial facility used for film manufacturing and processing and is currently under regulation as a RCRA facility. The model utilizes a finite-difference mesh of five layers and represents flow in a sequence of hydrogeologic units underlying the site. Using the model, SSP&A developed a detailed groundwater budget for Kodak Park West, determined the existing pattern of groundwater flow in each hydrogeologic unit, and tested proposed remedial measures. The model-development process and the results of hydrogeologic calculations made with the model were summarized in a detailed project report.

SAVANNAH RIVER SITE - AIKEN, SOUTH CAROLINA

SSP&A developed three-dimensional (multi-layer) numerical flow and transport models of the A- and M-Areas of the Savannah River Site, which is operated by the U.S. Department of Energy. The work performed at the site includes the development of several innovative modeling techniques, including a convolution process which allows the rapid evaluation of the migration of several chemicals with varying retardation and half-life properties. The models were used to assess the future migration of more than eighty chemical compounds assuming certain loading rates to the ground-water environment. The groundwater flow model was calibrated using state-of-the-art parameter estimation techniques based on application of the non-linear optimization techniques that were developed at SSP&A for rapid calibration of three-dimensional models. The results were integrated into an Environmental Impact Statement prepared for the operation of the site.

In addition, SSP&A developed a ground-water flow model of the A- and M-Areas and vicinity to evaluate the effectiveness of an extraction system which is presently in operation. The results of the flow model were used in conjunction with particle tracking programs developed specifically for this project to determine if the present system was effectively removing contaminated groundwater.

GIS, DATABASE, AND MAPPING

Often the databases that SSP&A receives are created from multiple sources that have heterogeneous data format and quality. Much of SSP&A's work includes resolving these discrepancies so the data can be managed efficiently and accurately. Besides basic organizational duties and creating output tables, SSP&A has experience writing custom Visual Basic modules within Access as well as creating Reports and Forms for data entry.

For more than 20 years, SSP&A has been designing, developing, and maintaining large geospatial datasets as an integral part of our project work. Environmental contamination characterization, water resource studies, and hydrologic modeling incorporate various forms of spatial data from a broad spectrum of sources, and obtaining the appropriate data and processing it into useable information is one of SSP&A's strengths.

Our personnel work with SQL-based software and are capable of customizing database routines and Input/Output interfaces through SQL and Visual Basic programming to design, compile, integrate, and maintain extensive datasets. We build robust systems that operate well in multiple user environments and maintain their functionality into the future. We deliver a final product that both meets current needs while anticipating future requirements and communicates the fundamental intermediate steps through comprehensive metadata in FGDC-compliant format. Our analysts use cutting-edge GIS software — including ESRI's ArcView® and ArcGIS™ — to improve the efficiency of our projects. We can provide custom graphical outputs, including large-format plots, 3-D visualizations, and temporal model simulations, and deliver digital products for internet-based use or on-site integration. As with our database services, GIS analysis and visualization services are an integral part of our standard project work. GIS substantially enhances the efficiency of geographic and environmental analyses and significantly improves the understanding of what entities are involved and how they interact spatially.

GIS Implementation, Design, and Creation

- Data conversion, creation, and georeferencing.
- Digitizing and data manipulation (raster to vector).
- Spatial and temporal 3-D visualizations.
- Project design including GPS field methodology, field data analysis, and custom database design.

Environmental and Engineering Support

- Remote sensing and aerial photograph acquisition and interpretation.
- Environmental database design.
- Natural resources monitoring and assessment.
- Soil and water quality analysis.
- Site density analysis.
- Utilities and transportation route selection and mapping.

Water Resource Applications

- Surface-water and groundwater modeling support.
- Geochemical site assessment.
- Regional climate and precipitation pattern mapping.
- Monitoring well site selection.
- Watershed delineation.

Land Use and Land Records Management with GIS

- Legal exhibits, publications, and courtroom graphics.
- Land use planning and zoning.
- Development strategies and regional best management practices.
- CAD-based map interpretation and creation.

Project Experience

U.S. AIR FORCE BASE
TEXAS

SSP&A was supplied a database consisting of 28 tables containing more than 2 million records for over 4,600 contaminants from 10,570 sampling points for groundwater, surface water, soil, and sediment. As part of an ongoing project, work included QA/QC of existing data; linking, manipulating, filtering, and compiling data for statistical summaries; lithologic layer-tracking; and outputting data for graphical presentation. SSP&A used MS Access, spatial analyses within ESRI's Arcview®, and GIS software to distinguish on-site versus off-site data; to visually display contaminant concentrations, lithologic layers, well information, and surrounding geographic features; and to delineate potential sources.

PUENTE VALLEY GIS & DATABASE
CALIFORNIA

As part of this project to allocate costs associated with remediation of groundwater contamination, SSP&A was retained to develop groundwater and contaminant transport models of the Puente Valley. As part of this large modeling effort, SSP&A was required to maintain historical and technical information on over 60 facilities, potential sources of groundwater contamination, over 500 wells, and other pertinent data from throughout the basin.

The U.S. Environmental Protection Agency databases formed the core of information on groundwater sampling points and groundwater quality. These databases were significantly enhanced, however, by SSP&A's staff research, data input, and QA/QC. The databases were linked to, and managed with, ESRI's ArcView® to facilitate geographic analysis of groundwater levels, topography, contaminant distribution, and other analytical data. To enhance the comparison of observed and calculated results, the output of groundwater and contaminant transport models was also processed for integration into the ArcView projects.

SSP&A used GIS to assimilate the output from both statistical and modeling tools, and to create report figures for presentation of the results in maps, tables, and charts. In addition, raster, vector and point data from varied sources were integrated using re-sampling, data projection, and feature attribution. To improve the efficiency of these operations, SSP&A wrote custom Visual Basic programs to automate complex, iterative queries necessary to develop the input to FORTRAN-based groundwater flow and contaminant transport models, and to assist in the analysis of groundwater modeling efforts.

JET PROPULSION LABORATORY
PASADENA, CALIFORNIA

SSP&A evaluated the fate and transport of chlorinated hydrocarbons and perchlorate in groundwater at this site. As part of this investigation and analysis, SSP&A compiled an extensive database and employed GIS for development of a series of maps to represent the extent and fate of the contamination. A temporal series of aerial photographs from 1952 to the present were collected, and the images were geo-referenced for use with vector datasets to perform spatial analysis within ESRI's ArcView®. Possible contamination sources were captured and noted from the imagery to verify information about holding ponds and facility features and create a backdrop for point sampling contamination data that could vary with the time of sampling events (i.e., put a November 1993 image behind mid 1990s sampling data, to match features to the data temporal as well as geographic space). The results were used in conjunction with sampling information in a database to delineate contamination plumes and track their evolution over time. ArcView GIS was used to integrate and display groundwater modeling results and to visualize spatial relationships of the sampling events.

APPLIED RESEARCH

SSP&A's reputation for innovative thinking in groundwater, geochemistry, and environmental science has led to requests for staff participation in applied research addressing such issues as:

- **Fate and Transport of PCBs in the Subsurface** — SSP&A staff served on an expert panel assembled by the Texas Eastern Transmission Corporation. The charge to this panel was to develop feasible remedial alternatives for sites where soil and groundwater have been contaminated with polychlorinated biphenyl (PCB) compounds. Dr. Charles Andrews, President of SSP&A, served as Director of this panel that defined the chemical properties of PCBs and their degradation products. The panel conducted laboratory and field studies of biodegradation, surfactant chemistry and transport, PCB transport and sorption, and DNAPL behavior in the subsurface; and evaluated field testing methods for PCB solubilization and recovery in fractured and porous media.

- **Minimum Flows & Levels** — The Southwest Florida Water Management District (SWFWMD) was directed by the Florida legislature to establish minimum flows for surface-water courses and minimum levels for aquifers and surface waters *(Section 373.042, Florida Statutes, 1996). As defined by this statute, a minimum flow for a given surface-water course shall be the limit at which further withdrawals would be "significantly harmful" to the water resources or ecology of the area. The minimum water level shall be the level of the groundwater in an aquifer, or the level of surface water, at which further withdrawals would be "significantly harmful" to the water resources of the area. The minimum flows and levels are to be based on the "best available information."*

  Part of the statute provides that prior to establishing a minimum flow or level, scientific or technical data and methodologies shall be subject to independent scientific peer review if requested by a substantially affected person. After proposing minimum flows and levels for certain lakes, wetlands, the Floridan aquifer, and the Tampa Bypass Canal, the SWFWMD received petitions requesting independent scientific peer review.

- **Pump-and-Treat Groundwater Remediation** — Dr. Chunmiao Zheng, developer of the MT3D code and liaison of SSP&A, is currently leading an interdisciplinary research team at the University of Alabama to develop a comprehensive framework for designing pump-and-treat groundwater remediation systems. The project integrates groundwater simulation, optimization, and parameter estimation techniques to design groundwater pump-and-treat systems that meet various physical, environmental, and budgetary constraints. The key components of the framework are Modflow and MT3D, two of the most popular flow and transport simulation models used in groundwater remediation designs. These simulation models are being coupled with an optimization model to automatically determine optimal well locations and pumping/injection rates under realistic field conditions.

APPLIED RESEARCH — *continued*

- **Performance Limitations of Soil-Vapor Extraction as a Remedial Technology** — SSP&A participated in a comprehensive assessment of soil-vapor extraction (SVE) as an effective technology for remediating volatile organic compounds (VOCs). The study was initiated as part of an evaluation of the effectiveness of a SVE system in operation at a Superfund site. Although the extraction system had removed a significant quantity of VOCs from the soil, clean-up levels had not been met, and the mass of contaminant remaining was found to be several thousand times greater than that predicted by the initial studies on the performance of the extraction system. Site conditions such as variability in the physical and chemical characteristics of the soils were found to have a profound influence on the performance of the SVE system. The research summarized the fundamental chemical and physical phenomena that can influence the effectiveness of SVE systems on a practical field-scale, and described the scientific basis upon which the performance of the systems can be evaluated and predicted.

GROUNDWATER MODELING SOFTWARE

SSP&A is recognized for the development of groundwater modeling software. We develop and distribute professional versions of the three leading simulation codes:

- **PATH3D** — the most versatile particle-tracking model on the market.
- **MT3D** — the most widely used groundwater contaminant transport model.
- **MODAIR AND P3DAIR** — software used in conjunction with MODFLOW for modeling air flow for Soil Vapor Extraction (SVE) system design and for simulating the movement of air and the advective transport of vapor in unsaturated soils.

SSP&A has marketed these programs since 1989, and has sold copies to groundwater modelers worldwide. To support these users, SSP&A maintains a network of users, distributes software updates for the programs, and develops advanced training courses. SSP&A also has extensive experience in the modification of these codes to add advanced capabilities, and in the development of preprocessing and post-processing utility programs.

PATH3D

A widely used particle-tracking program for *MODFLOW*.
***PATH3D* is an essential visualization and analysis tool for groundwater modeling.**

PATH3D is a particle-tracking program that calculates groundwater flow paths and travel times in transient three-dimensional flow fields generated by the U.S. Geological Survey simulator MODFLOW. The program can be used to track forwards and backwards the movement of tracer particles through steady and transient flow fields. This program is particularly useful for:

- delineating capture zones of wells in order to evaluate the effectiveness of groundwater pollution control measures under complicated hydrogeologic conditions;
- defining wellhead protection zones;
- evaluating the effectiveness of groundwater remediation scenarios under complex hydrogeologic conditions; and/or
- helping to visualize three-dimensional flow fields.

PATH3D produces output files of pathlines of individual particles, positions of displacement fronts of capture zones at desired time, and distribution of captured particles. PATH3D incorporates advanced techniques for particle capture, is straightforward to use, and is supported by leading graphical preprocessors including Groundwater Vistas. PATH3D produces output that is ready for immediate visualization in SURFER.

MT3D[99]

The world's leading solute transport simulator. MT3D has been widely accepted by regulators and the groundwater consulting and research communities and has been successfully applied at thousands of sites around the world.

MT3D99 is SSP&A's professional implementation of the most recent version of MT3DMS, the world-leading, comprehensive three-dimensional numerical simulator for solute transport in complex hydrogeologic settings. MT3D99 has a modular design that permits simulation of transport processes independently or jointly. The program is capable of simulating:

- advection in complex steady-state and transient flow fields,
- anisotropic dispersion,
- first-order decay and production reactions, and
- linear and non-linear sorption.

MT3D99 takes advantage of the multi-component structure and the generalized conjugate gradient solver of MT3DMS to offer accurate and efficient, fully implicit-in-time implementations of multispecies reaction simulation capabilities. These capabilities include straight chain decay and BIOPLUME-like instantaneous reaction kinetics. MT3D99 is completely downwardly compatible and accepts input files prepared for all previous versions of MT3D. MT3D99 includes features that make it more useful, accurate, efficient, and flexible. MT3D99 is supported by SSP&A's team of knowledgeable and helpful modelers who use the code in their own daily practice, and who have trained other groundwater professionals in its use.

MODAIR and P3DAIR

Airflow, flow-path, and capture-zone simulators developed to assist in the design and analysis of soil vapor extraction systems.

MODAIR extends the capabilities of MODFLOW for the simulation of airflow in the vadose zone. This capability is particularly useful for the evaluation of proposed and existing soil vapor extraction systems (SVE). MODAIR can be used to simulate steady and transient airflow to both discharge-controlled and pressure-controlled wells. MODAIR provides maximum flexibility for data input and for the types of conditions that can be simulated. Three types of boundary conditions at the ground surface can be represented: constant pressure, no-flow, and user-specified. MODAIR allows data to be entered in units preferred by the user, even mixed types, for length, time, mass, pressure, and air permeability. It also allows simulation of either steady-state or transient conditions. The user can prepare output files of the pressure distributions across a layer or a vertical cross-section along a row or column.

P3DAIR is a post-processing program that extends the particle tracking capabilities of PATH3D to MODAIR. P3DAIR is particularly useful for delineating contaminant capture zones and evaluating the effectiveness of SVE systems. P3DAIR produces output files of pathlines of individual particles, positions of displacement fronts of capture zones at desired time, and distribution of captured particles.

Groundwater Software Developed by SSP&A and Distributed Free ofCharge

In addition to its professional software, SSP&A also provides several useful codes that may be downloaded free-of-charge from our web site, www.sspa.com. These codes include:

ATRANS

3D analytical solution for transport from a patch boundary condition with time varying concentration.

ATRANS is a package of codes that implement three-dimensional analytical solutions for transport from a patch boundary condition in a semi-infinite aquifer. The transport processes of advection, dispersion, sorption, and transformation reactions are considered. The solution assumes the groundwater flow field to be steady, uniform, and parallel to the x-axis. The ATRANS package of solutions can represent three inflow concentration histories:

- Constant concentration;
- Exponentially decaying concentration; or
- Arbitrary inflow concentration as sets of points, or sets of steps.

LINEAR-LOG KRIGER

Water Level Kriging with A Regional-linear and Point-logarithmic Drift.

SSP&A distributes as freeware programs that implement the linear-log kriging techniques described in M.J. Tonkin, and S.P., 2002: "Kriging Water Levels with a Regional-Linear and Point-Logarithmic Drift" (Ground Water, March/April 2002). The code allows users to combine regional-linear and point-logarithmic drifts in their mapping of groundwater-level data, and can be used to account for drawdowns (or mounding, in the case of injection wells) using a logarithmic approximation for the curvature of the potentiometric surface. Because the drift model approximates the principal physical processes that govern groundwater flow and the auto-correlation of groundwater elevation data, this approach produces maps of contoured water levels that more realistically represent physical conditions and that allow for improved interpretation of measured water-level data. Additional benefits include an improved estimate of the background hydraulic gradient and generation of a grid suitable for two-dimensional particle tracking.

MPNE1D

A General Analytical Solution for One-Dimensional Solute Transport.

The code MPNE1D implements the general analytical solution for one-dimensional solute transport derived by C.J. Neville, M. Ibaraki, and E.A. Sudicky, 2000: "Solute Transport with Multiprocess Nonequilibrium: A Semi-analytical Approach" (Journal of Contaminant Hydrology, vol. 44, pp. 141-159). The code is included in the IGWMC collection of freeware for hydrogeology. The MPNE1D solution offers the ease of use, efficiency and reliability of a robust analytical solution with a flexibility that is usually only possible with numerical solutions. The solution is an ideal teaching tool, providing students with a straightforward code for exploring solute transport processes. The solution has also been applied for the interpretation of complex column tests.

ModIME

An integrated modeling environment for MODFLOW, PATH3D, and MT3D. This revolutionary pre- and post-processor is a self-contained, fully graphical system for designing models, specifying data, and visualizing model results.

ModIME supports the preparation of model input, execution of three-dimensional groundwater flow simulation codes, and post-processing of results from MODFLOW, PATH3D, and MT3D. ModIME allows users complete control over how a model is built and provides a logical and integrated tool for constructing and calibrating groundwater flow and contaminant transport models and for visualizing the model results. With ModIME, the user no longer has to assemble the formatted input files for the simulation codes. More significantly, ModIME facilitates the organization and checking of the large volumes of data typically required for a field-scale model. ModIME includes a unique zooming capability that simplifies the development of models using Telescopic Mesh Refinement.