U.S.-MEXICO TECHNOLOGY TRANSFER

BILATERAL TECHNICAL EXCHANGES FOR SUSTAINABLE ECONOMIC GROWTH IN THE BORDER REGION

A United States Department of Energy Program
National Nuclear Security Administration
Albuquerque, New Mexico

October 1, 2007

U.S.-MEXICO TECHNOLOGY TRANSFER

BILATERAL TECHNICAL EXCHANGES FOR SUSTAINABLE ECONOMIC GROWTH IN THE BORDER REGION

October 1, 2007

Final Report for work performed under contract No. DE-AC04-01AL67122

Prepared for

Mr. Jeff Lenhert
National Nuclear Security Administration
U.S. Department of Energy
Albuquerque, New Mexico

Prepared by

Dr. Richard Jimenez
Applied Sciences Laboratory, Inc.
P.O. Box 21158
Albuquerque, New Mexico 87154-1158

CONTENTS

List of Tables

List of Figures

EXECUTIVE SUMMARY

The U.S. Department of Energy (DOE) maintains a strong commitment to transfer the results of its science and technology programs to the private sector. The intent is to apply innovative and sometimes advanced technologies to address needs while simultaneously stimulating new commercial business opportunities. Such focused "technology transfer" was evident in the late 1990s as the results of DOE investments in environmental management technology development led to new tools for characterizing and remediating contaminated sites as well as handling and minimizing the generation of hazardous wastes. The Department's Office of Environmental Management was attempting to reduce the cost, accelerate the schedule, and improve the efficacy of clean-up efforts in the nuclear weapons complex. It recognized that resulting technologies had broader world market applications and that their commercialization would further reduce costs and facilitate deployment of improved technology at DOE sites.

DOE's Albuquerque Operations Office (now part of the National Nuclear Security Administration) began in 1995 to build the foundation for a technology exchange program with Mexico. Initial sponsorship for this work was provided by the Department's Office of Environmental Management. As part of this effort, Applied Sciences Laboratory, Inc. (ASL) was contracted by the DOE Albuquerque office to identify Mexico's priority environmental management needs, identify and evaluate DOE-sponsored technologies as potential solutions for those needs, and coordinate these opportunities with decision makers from Mexico's federal government. That work led to an improved understanding of many key environmental challenges that Mexico faces and the many opportunities to apply DOE's technologies to help resolve them.

The above results constituted, in large part, the foundation for an initial DOE-funded program to apply the Department's technology base to help address some of Mexico's challenging environmental issues. The results also brought focus to the potential contributions that DOE's science and technology could make for solving the many difficult, multi-generational problems faced by hundreds of bi-national communities along the 2,000-mile shared border of the United States and Mexico. Efforts to address these U.S.-Mexico border issues were initially sponsored by the DOE's Albuquerque and Carlsbad offices. In subsequent years, the U.S. Congress directed appropriations to DOE's Carlsbad office to address public health, safety and security issues prevalent within U.S.-Mexico border communities.

With ASL's assistance, DOE's Albuquerque office developed contacts and formed partnerships with interested U.S and Mexican government, academic, and commercial organizations. Border industries, industrial effluents, and public health conditions were evaluated and documented. Relevant technologies were then matched to environmental problem sets along the border. Several technologies that were identified and subsequently supported by this effort are now operational in a number of U.S.-Mexico border communities, several communities within Mexico's interior states, and in other parts of Latin America. As a result, some serious public health threats within these communities caused by exposure to toxic airborne pollutants have been reduced.

During this time, DOE's Carlsbad office hosted a bilateral conference to establish a cross-border consensus on what should be done on the basis of these earlier investigative efforts. Participating border region stakeholders set an agenda for technical collaborations. This agenda was supported by several Members of Congress who provided appropriations and directed DOE's Carlsbad office to initiate technology demonstration projects. During the following two years, more than 12 private-sector and DOE-sponsored technologies were demonstrated in partnership with numerous border community stakeholders. All technologies were well received and their effectiveness at addressing health, safety and security issues was successfully demonstrated. Several of these technologies, including those noted above and demonstrated under this effort, are now operational. Furthermore, a number of public and national security issues unique to the U.S.-Mexico border were brought to the attention of the federal government and are now being addressed, largely through the efforts of the U.S. Department of Homeland Security.

Program results demonstrated the value and effectiveness of the program's process for technology exchanges. Opportunities now exist to transition the program from its successful initial stage to one where it can more effectively address a broader spectrum of multi-disciplinary problems that impact millions of U.S. and Mexican citizens. Substantial benefits would accrue to both sides of the U.S.-Mexico border were the two countries to continue this collaboration.

1. INTRODUCTION

For several years, the Department of Energy's collaborations with Mexico's federal agencies have largely focused on energy cooperation. The common theme of this work has often included joint research and applications of innovative technologies that show potential for resolving challenges of common interest to both countries. Technologies often originate from DOE-sponsored laboratories, contractors and universities and a host of Mexico's counterpart organizations.

In the mid-1990s, DOE's Office of Environmental Management (EM) began to plan a cooperative program with Mexico's government, industry and academic sectors on the use of innovative environmental management technologies. At that time, the program was sponsored by the International Programs Division of EM's Office of Science and Technology. Work was directed by DOE's Albuquerque office. Plans called for cultivating and then implementing a bi-national cooperation program beginning with information and staff exchanges that would foster mutual-interest relationships and help focus the program's out-year activities. DOE's initial strategy called for the program to broaden beyond exchanges to include:

- U.S.-Mexico co-development of environmental technologies capable of addressing common problems
- Demonstrations of DOE-sponsored environmental management technologies that show promise for meeting Mexico's priority needs
- Joint deployment of DOE-sponsored technologies by U.S. and Mexican businesses
- Scientific exchanges that leverage the applied R&D capabilities of U.S. and Mexican academic and research institutions, and
- Technology exchanges that enhance the operations of the DOE weapons complex as well as U.S. and Mexican industry.

It was widely recognized that these DOE-Mexico technology exchange efforts must be structured to achieve near-term benefits for the U.S. and Mexican governments and their citizens. For example, by applying DOE-sponsored technologies, the environmental management infrastructure of the U.S.-Mexico border region could be improved.[1] This would, in turn, reduce health risks for both U.S. and Mexican citizens caused by exposure to pollutants from the region's expanding manufacturing industry. In parallel, technology developers would have greater opportunities to test and evaluate the effectiveness of their technologies under real-world operating conditions. Thus, the program's implementation model called for:

- Focusing on environmental management issues that are common to both the U.S. and Mexico (including problems associated with the clean-up and improved operations of DOE's weapons complex) or, at least, impact both nations

[1] Under the terms of the North American Free Trade Agreement, the U.S.-Mexico border region is defined as 100 km north and 100 km south of the international boundary.

- Identifying and evaluating DOE-sponsored technologies that show promise for addressing these needs by matching technology performance parameters against the requirements faced by the problem holders

- Demonstrating technologies in collaboration with the problem holders under realistic operating conditions that would, in turn, expand the performance database of the technologies, and

- Deploying solution technologies that satisfy the problem holders' needs within an acceptable form, schedule and budget.

It was believed that the above strategy would yield the following results:

- Successful technology demonstrations along the border that would create opportunities for greater commercialization

- Successful commercialization would generate new jobs for both countries through the manufacture, sales, distribution and maintenance of deployed technologies

- Commercialization would benefit those communities in greatest need of secure, long-term jobs and help elevate the socio-economic conditions of the border region

- Improved environmental quality of the region would reduce human exposure to toxins and trigger a host of benefits for public health and sustainable economic growth, including reduced healthcare costs and, potentially, improved academic achievement, and

- The schedule, costs and risks for clean-up of contaminated DOE, other U.S., and Mexican sites would be reduced by the availability of improved commercial technologies.

2. MEXICO'S PRIORITY NEEDS

At the outset of this program, Applied Sciences Laboratory was tasked to review and consolidate data of Mexico's priority energy, water, and environmental management needs. The results served as a starting point for identifying DOE-sponsored science and technology programs that could be applied to address the priority needs. To do so within the program's narrow budget and schedule constraints, ASL leveraged work published in the open literature and obtained the support of Mexico's university Instituto Tecnologico y Estudios Superiores de Monterrey (ITESM) (Monterrey, Nuevo Leon) to build on existing data.

Energy. During the period of the original investigation, Mexico's power consumption was growing at more than twice the U.S. rate. In order to keep up with growth, Mexico prepared to add 12,000 megawatts of electric power (MWe) to its electric power grid in the late 1990s – a 35 percent increase over the country's capacity at that time. Much of this increased power capacity is now provided by natural gas to help reduce air emissions. Also in the interest of improving environmental quality, the Mexican government emphasized energy efficiency and renewable energy programs, including: cogeneration; improved electric end-use efficiency technologies; hydroelectric power generation; geothermal power generation; wind power production; and solar power production.

Water. Water availability is one of the most critical issues of Mexico's economic development. The northern part of Mexico – which comprises almost one-third of the nation's area and includes a number of the nation's major industrial centers – has only 3 percent of the available water. The north is also the region with the greatest rate of economic growth. Even the concentrated water resources of the south are not adjacent to major population centers since the cities are located at considerably higher elevations.

Preliminary (unpublished) studies performed by ITESM's Center for Environmental Quality (CEQ) found that Mexico has an annual water deficit of about 38,000 million cubic meters. This is causing falling underground water tables. To meet daily water demands, water is transported from one place to another at enormous costs. For example, Mexico City (population more than 20 million), which faces enormous water problems, pumps about 80 percent of its water from aquifers faster than they can be replenished. The remainder of Mexico City's water supply is pumped 127 km from the Cutzumala River at a huge energy cost.

Mexico's water distribution system also has serious problems as considerable quantities of water are lost through leakage. These extensive water pumping efforts are triggering concerns over damage to Mexico's ecosystems.

Mexico's severe water supply limitation has prompted the federal government to carefully evaluate industries and determine the types that are most compatible with the long-range sustainable development of the country. Mexican officials have indicated that one way to correct the country's water supply challenges is to desalinate sea water – essentially for the mid and northern parts of the country.

Environmental management. Rapid urbanization and industrialization outpaced the development of Mexico's environmental infrastructure, particularly for municipal wastewater and solid waste collection and treatment. Mexico's priority industrial environmental needs include: air pollution control equipment; water and wastewater systems; resource recovery; hazardous and solid waste management and equipment, analytical and consulting services; instrumentation for measurement and monitoring; and pollution avoidance technologies. Mexico's 1990s market for environmental management systems was highest for water pollution control equipment and services as this represented about 40 percent of the total environmental market in Mexico. Other key markets included solid and hazardous waste management. The main sources of industrial solid waste remain manufacturing, mining, and oil processing.

Mexico's state-owned companies have some potentially staggering clean-up projects. Petroleos Mexicanos (PEMEX) (national petroleum company), Comision Federal de Electricidad (national electric utility), and the state-owned railroad company, Ferrocarriles Nacionales de México, are faced with large-scale remediation projects.

The cleaning and upgrading of storage tanks (underground and aboveground) as well as the remediation of contaminated tank sites remain priority needs throughout Mexico. For example, many of the gasoline storage tanks at PEMEX's 3,000 gas stations throughout Mexico suffer chronic leakage problems. The number of industrial storage tanks that require cleaning and remediation services may be even greater. Furthermore, PEMEX owns many properties that are contaminated with acids and spent oils. The company's refinery units have major problems with hazardous waste disposal, especially polychlorinated biphenyls (PCBs).

The remediation of unsecured municipal landfill sites where hazardous wastes have been improperly disposed of is another important remediation issue. One of the most challenging waste management problems is the disposal of used auto tires which in some cities exceeds several million tires at unsecured sites. These sites are responsible for a number of serious public health issues that have been linked by the U.S. Centers for Disease Control to mosquitoes and rodents that find haven in the tire piles. The ignition (accidental, malevolent, or by act of nature) of these tires is a serious health and safety risk. The smoke from a tire-pile fire causes large spikes in the concentration levels of hazardous byproducts. The resulting smoke threatens the respiratory health of the public.

Air quality. Air pollution is the worst environmental problem facing Mexico's largest cities. The most serious air pollution problems are in Mexico City, Guadalajara, and Monterrey. The health effects of air pollution were estimated in the mid 1990s to cost Mexico City about $1.5 billion each year in lost economic productivity alone. Combined, these three cities are responsible for about 40 percent of Mexico's total atmospheric emissions.

The transportation sector is responsible for more than 70 percent of the air pollution in these cities. Industrial sources (including power generation) are major contributors of sulfur dioxide (SO_2), nitrous oxides (NOx), particulate matter, and other regulated pollutants. Mexico's industrial sector generates 4.4 percent of the nation's air pollution and the energy sector (including the petroleum industry) generates 4 percent. Natural sources (especially wind) accounts for 15 percent of air pollution. Industrial need for improved air-pollution control technologies can primarily be found in the mining and foundry, energy, petroleum, petrochemical, pharmaceutical, chemical, steel, plastics, textile, rubber, pulp and paper, and electric-electronics industries.

Solid waste handling. Rapid urbanization and industrialization in Mexico have driven up the need for greater solid waste management infrastructure capacity. In the late 1990s, only about 4 percent of the 526,000 metric tons of solid waste generated each day in Mexico was adequately managed. This is highlighted in Figure 1 which shows the daily solid and hazardous waste generation in Mexico. As depicted, about 15,500 metric tons of Mexico's daily generation of solid wastes includes hazardous materials.

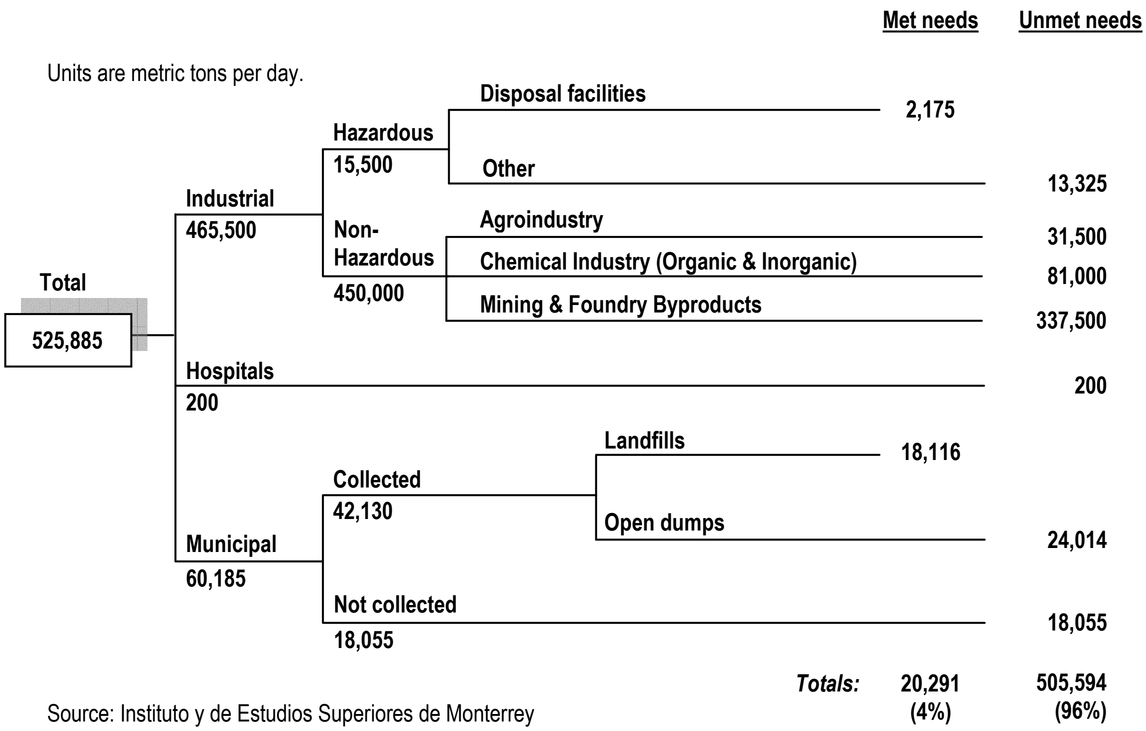

Figure 1. *Estimated daily solid and hazardous waste generation in Mexico (circa 1995).*

Of the estimated 526,000 metric tons of solid waste generated per day in Mexico, over 85 percent (465,000 metric tons) is from industry. The main sources of industrial solid waste are the manufacturing, mining and oil sectors. As shown in Figure 1, approximately 15,500 metric tons per day of hazardous waste is generated by industry, while only 14 percent of the hazardous waste generated is properly disposed. The balance of these hazardous wastes, or 13,325 metric tons per day, may be mixed with non-hazardous wastes and, perhaps, left in open dumps.

By the late 1990s, less than 20 percent of Mexico's population was served by any type of landfill infrastructure. About 50 percent of Mexico's population was served by an adequate municipal solid waste infrastructure. Only five of Mexico's 32 states had reasonably adequate facilities to dispose of municipal solid wastes. The situation was slightly better in the U.S.-Mexico border states where about 25 percent of the population was served by the landfill infrastructure. At that time, only 4 percent of the total solid waste of the country was treated or disposed of properly. This issue has been identified as one of the key challenges facing the North American Development Bank in its efforts to help improve the environmental management infrastructure of the U.S.-Mexico border region.

Hazardous waste management. Mexico has an underdeveloped domestic hazardous waste management industry. As of the late 1990s, the country had the facilities to manage only about one-third of the hazardous wastes generated each year. Mexico requires the full spectrum of hazardous waste management equipment and services. The largest sources of demand are the private sector and certain government-owned entities such as PEMEX.

Mexico City generates about 38 percent of Mexico's total volume of hazardous waste. Most of these consist of spent solvents, oils and fats, and other wastes from manufacturing. Acid, alkaline and petroleum wastes are other toxic waste streams. These are generated mostly in: southern Mexico and the Gulf Coast where PEMEX operations are located; central Mexico where a rapidly growing mineral mining industry is located; and northern Mexico where coal mining is concentrated. Because most industrial hazardous wastes are either solvents (38 percent) or oils and fats (13 percent), improved recycling technologies are needed.

The maquiladora industry is primarily situated along the U.S.-Mexico border region. Maquiladoras are in-bond facilities that were originally created by the Mexican government in 1965. They are factories that are allowed to import components into Mexico without tariffs for assembly. The components must return to the country-of-origin where they pay a nominal tariff on the "value added" to the product. As long as the imported components brought into Mexico are destined for export, no Mexican import duty is levied on the temporarily imported maquiladora inputs. Maquiladoras can manufacture a broad array of products under Mexican law. Exceptions to this allowance include such industries as petroleum, petrochemicals, and items which contain radioactive elements. The maquiladora industry was largely created to bring employment to Mexico's northern states.

3. INITIAL TECHNOLOGY EXCHANGE OPPORTUNITIES

For several years, the DOE Office of Environmental Management maintained an aggressive national program of applied research and development to improve U.S. waste management and clean-up capabilities. The program initially focused on stimulating national laboratories, universities, and private industry to develop innovative technologies and then on applied R&D and technology demonstrations to prove the readiness of technologies for transition and deployment. R&D program areas included:

- Contaminant plume containment and remediation
- Landfill stabilization
- Mixed waste characterization, treatment and disposal
- Pollution prevention
- Decontamination and decommissioning
- High-level waste tank remediation, and
- Efficient separation and processing.

DOE's investment yielded hundreds of innovative technologies to help meet its mission to clean-up the weapons complex and to prevent future environmental problems. In 1996, ASL conducted a comparison of attributes of 385 of these technologies for applicability to high-priority needs in Mexico and the U.S.-Mexico border region. Figure 2 shows the technology evaluation methodology utilized to screen the technologies.

A review of available sources of technology information was conducted. Information sources included data available on the worldwide web that was developed by DOE focus area teams, publications (e.g., DOE environmental technology catalogues) that describe the status of development of the technology and its performance, and DOE databases.

The relative merits of each of the 385 technologies were evaluated for their applicability to Mexico's environmental problems. Evaluations were based on: a technology's potential to treat specific contaminants in particular media; maturity of the technology; ease of implementation of the technology; and cost of applying the technology. Technologies that required a significant level of capital investment were often removed from consideration largely because of Mexico's limited economy. Technologies for treating high-level radioactive waste were also eliminated at the start of the evaluation because information on the extent of this type of waste was not available and not applicable to Mexico's priority needs.

Technology matches. The evaluation of DOE technologies resulted in 179 of 385 technologies having potential to meet Mexico's environmental problems. The largest percentage (58 percent) of technologies came from the Contaminant Plume and Containment and Remediation Focus Area followed by the Landfill Stabilization Focus Area (25 percent). Table 1 lists applicable technologies categorized by DOE focus area groupings.

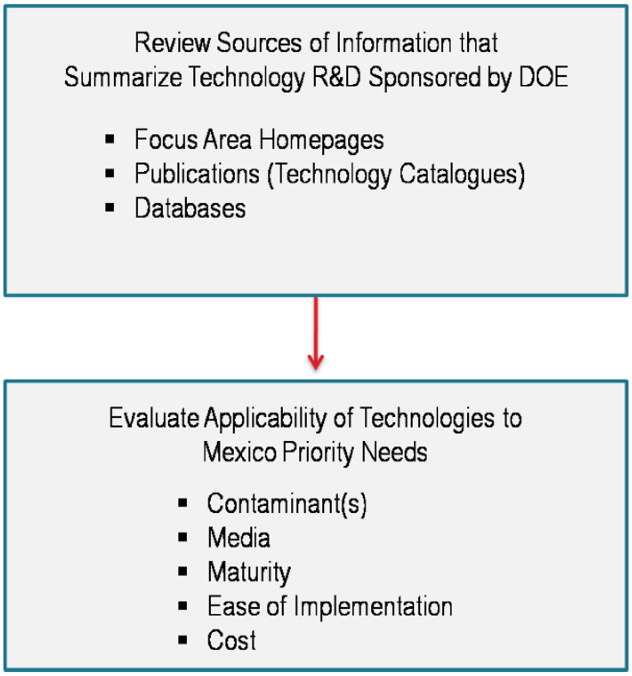

Figure 2. *Technology evaluation methodology.*

Contaminant Plume Containment and Remediation

The Contaminant Plume Containment and Remediation Focus Area had the largest number (103) of potentially applicable technologies to meet Mexico's priority needs. The majority of the technologies (76) in this group were applicable to soil contamination by industrial solid waste disposal at landfills or dumpsites, followed by surface and groundwater contamination, and finally air (emissions of soil vapor and stack gases).

Landfill Stabilization

The Landfill Stabilization Focus Area had the second largest number (44) of technologies. The majority of technologies in this group (39) were applicable to soil contamination caused by effluents to land (landfills or dump sites). Of the 39 technologies, 26 were considered non-contaminants specific because they measure geological characteristics.

Mixed Waste Characterization, Treatment, and Disposal

The Mixed Waste Characterization, Treatment, and Disposal Focus Area had 14 technologies that were relevant to Mexico's environmental needs. The majority of technologies in this group were applicable to soil contamination from Mexican industries.

Pollution Prevention

The Pollution Prevention Focus Area had eight technologies that were pertinent to Mexico's environmental needs. The technologies were evenly apportioned between application to air emissions of soil vapor and stack gases, surface and groundwater, and land media.

Decontamination and Decommissioning

Four technologies were identified that had applicability to Mexico's environmental needs from the Decontamination and Decommissioning Focus Area. Two of the technologies were applicable to contamination in pipes.

High-level Waste Tank Remediation

The High-level Waste Tank Remediation Focus Area had four technologies applicable to air contamination of soil vapor and / or stack gases, geological data generation and monitoring of remediation sites.

Efficient Separation and Processing

The Efficient Separation and Processing Focus Area had two technologies potentially applicable to Mexico's environmental needs. Both technologies were applicable to water pollution.

Table 1. *DOE technologies applicable to Mexico's priority environmental needs.*

Contaminant Plume Containment and Remediation Focus Area	
1.	Integrated Spectroscopy System for Characterization Contaminant Speciation (ISSECS)
2.	Multisorbent Arrayed Sampler
3.	Boresampler
4.	HaloSnif Fiber Optic Chemical Sensor
5.	X-Ray Fluorescence Spectroscopy for Heavy Metals
6.	Crosshole Compressional and /Shear Wave Seismic Tomography
7.	In Situ Permeable Sensor
8.	Borehole Tension Permeameter
9.	Inverting Membrane Borehole Instrumentation Techniques (SEAMIST™)
10.	Vadose Zone Monitoring System
11.	Directional Drilling
12.	Heavy-Weight Cone Penetrometer
13.	Resonant Sonic℠ Drilling
14.	Monitoring of Bioremediation Performance Using Nucleic Acid Probes
15.	TCE Degradation Demonstration Microbial Monitoring Techniques
16.	Cryogenic Drilling
17.	The Heuristic Optimized Processing System: A Technical Information System for CERCLA Waste Sites
18.	Monitoring of Microbial Population Changes
19.	Development and Testing of Water-Permeable Reactive Barrier
20.	Chemical Barriers Feasibility and Field Demonstration
21.	Chemically Enhances Barriers to minimize Containment Migration
22.	Containment of Containments Through Physical Barriers Formed From Viscous Liquids Emplaced Under Controlled Viscosity Conditions

Contaminant Plume Containment and Remediation Focus Area	
23.	Cryocell Technology Applications at Non-Arid Sites
24.	Verification of Subsurface Barriers Using Time Domain Reflectometry with Waveguides
25.	In Situ Groundwater Treatment Using Magnetic Separation
26.	Thermal Enhanced Vapor Extraction System
27.	Remediation of DNAPLs in Low Permeability Soils
28.	Resource Recovery Project
29.	Passive Soil Vapor Extraction (Barometric Pumping)
30.	In Situ Corona for in Situ Treatment of Non-Volatile Organic Contaminants
31.	NAPL – Contaminated Soil/Groundwater Remediation Using Foams
32.	In-Well Sonication Process
33.	In Situ Chemical Oxidation of Soils
34.	In Situ Redox Manipulation
35.	Tunable Hybrid Plasma
36.	In Situ Chemical Treatment for Remediation of Soils and Groundwater
37.	Demonstration of Co-Metabolic Techniques
38.	Bioremediation of PCB Contamination
39.	Adsorption/Desorption Relative to Applying Bioremediation to Organics
40.	Biomass Remediation System
41.	In Situ Bioremediation of Groundwater
42.	In-Well Vapor Stripping
43.	Mixed Chlorinated Solvent in Situ Bioremediation in the Vadose Zone
44.	Electrokinetic Remediation of Heavy-Metal Contaminated Unsaturated Soil
45.	Field Demonstration of Electrokinetic Migration Technology at Old TNX Basin
46.	Optimal Remediation Design: Methodology and User-Friendly Software for Contaminated Aquifers
47.	Six Phase Soil Heating
48.	Soil Bioreactor Studies
49.	Integrated Pulsed Ultraviolet Irradiation
50.	In Situ Radio Frequency Heating
51.	Ozone and Catalytic Oxidation
52.	Off Gas Treatment Sampling and Analysis
53.	Bioremediation of Toxic Metals
54.	Expedited Site Characterization Application to Federal Facilities
55.	Time Domain Reflectometry and Fiber Optic Probes for the Cone Penetrometer
56.	Site Characterization and Analysis Penetrometer System
57.	In Situ Measurement of Volatile Organic Compounds and Semi-Volatile Organic Compounds in the Subsurface: Development of Screening and Quantitative Field Methods Coupled with the Cone Penetrometer
58.	Miniature Pumps in the Cone Penetrometer Tip for Groundwater and Soil Gas Sampling
59.	Multi-Analytic, Single- Fiber, Optical Sensor
60.	Sol-Gel Indicator Program
61.	Miniaturized Chemical flow Probe Sensor Development-Sandia National Laboratory
62.	Flow Probe Sensor Development Center for Process Analytical Chemistry
63.	Portable Acoustic Wave Sensor Systems for Volatile Organic Compounds
64.	Surface Acoustic Wave Array Detectors
65.	Analog Site for Characterization of Contaminant Transport Through Fractured Rock
66.	Integrated Geophysical and Hydrological Characterization of Transport Through Fractured

Contaminant Plume Containment and Remediation Focus Area	
	Media
67.	Adsorption of BTEX Using Organozeolites
68.	Bio-Immobilization of Heavy Metals
69.	Bioreactors for Bioremediation
70.	Cryogenic Retrieval of Buried Waste
71.	Decision Support System to Select Migration Barrier Cover Systems
72.	Dynamic Underground Stripping of VOCs
73.	Encapsulation of Hazardous Waste
74.	High Energy Corona
75.	In Situ Air Stripping of VOCs Using Horizontal Wells
76.	Methane Enhanced Bioremediation for the Destruction of Trichloroethylene Using Horizontal Wells
77.	Polymer Gel as a Barrier for Ground Spill Contaminants
78.	Remediation of Metals Contaminated Soils Using Ligan-Based Extraction Technology
79.	VOC Off-Gas Membrane Separation
80.	VOC Recovery and Recycle
81.	Colloidal Borescope
82.	Crosswell Seismic Imaging
83.	Fiber-Optic Chemical Sensors
84.	Hybrid Directional Boring and Horizontal Logging
85.	In Situ Permeable Flow Sensor (Similar to previous description In Situ Permeable Sensor)
86.	On Site Analysis of Metals in Soils Using Stripping Voltammetry
87.	Slant Angle Sonic Drilling (SASD)
88.	Unsaturated Flow apparatus
89.	HUMASORB™: A Lignite Derived Adsorbent
90.	Road Transportable Analytical Analysis
91.	Organic Sponges for Cost Effective EVOC Abatement
92.	Soil Saw Demonstration
93.	In Situ Decontamination of Sand and Gravel Aquifers by Chemically-Enhanced Solubilization (CES) of DNAPLs with Surfactant Solutions
94.	Circulating Air Barrier System: Effective Prevention of Liquid Contaminant Movement Through Soil
95.	Lasagna™
96.	Surface-Altered Zeolites as Permeable Barriers for In Situ Treatment of Contaminated Groundwater
97.	Integrated Optic Chemical Sensor for the Simultaneous Detection and Quantifications of Multiple Ions
98.	Barometric Pumping With a Twist: VOC Contaminant and Remediation Without Boreholes
99.	A Fiber Optic/Cone Penetrometer System for Subsurface Heavy Metal Detection
100.	Stabilization and Reuse of Heavy Metal Contaminated Soil by Quicklime/Sulfate Salt Treatment
101.	Field Usable Portable Analyzer for Chlorinated Organic Compounds
102.	A Steerable Distance Enhanced Penetrometer Delivery System
103.	Acoustically Enhanced Remediation of Contaminated Soil and Groundwater

Landfill Stabilization Focus Area	
1.	Buried Waste Digface Characterization
2.	Tensor magnetic Gradiometer
3.	Inverse Scattering Imaging of Buried Objects
4.	Very Early-Time Electromagnetic System
5.	Virtual Environmental Generation of Buried Waste
6.	High Resolution Imaging Using Holographic Impulse Radar Array
7.	Imaging Infrared Interferometer
8.	Optimization of Sampling Strategies
9.	Cross Borehole Electromagnetic Imaging
10.	Magnetometer Towed Array
11.	Sandia Environmental Decision Support System
12.	Characterization of Contaminated Soils and Residues Using Electron and Ion Beam Methods
13.	Contaminated Material Excavation Handling and Retrieval System
14.	Graphite DC Arc and in Situ Real-Time Measurements
15.	Arc Melter Vitrification
16.	Secondary Treatment of Off-Gas Using Non Thermal Plasma (NTP)
17.	In Situ Encapsulation of Buried Waste
18.	Innovative Subsurface Stabilization
19.	Monolithic Confinement
20.	Containment and Stabilization of Buried Waste
21.	Migration Barrier Covers for Mixed Waste Landfills
22.	Decision Support System to Select Landfill Cover System
23.	In Situ Vitrification
24.	Develop and Demonstrate Methods of Placing a Horizontal In Situ Barrier
25.	Barriers in the Vadose Zone
26.	Subsurface Barrier Emplacement Development
27.	Remotely Piloted Vehicles and Miniaturized Sensors
28.	Remote Sensing Systems Development and Application
29.	Laser-Induced Fluorescence Imaging for Subsurface Uranium
30.	Three-Dimensional/Three-Component Seismic Surveys for Site Characterization
31.	LA-ICP-AES Using a High Resolution Fiber-Optic Interferometer
32.	Inductively Coupled Plasma-Mass Spectrometry (ICP-MS) for Analysis of Microliter Samples and Solids
33.	Secondary Ion Mass Spectroscopy Analysis: Development and Evaluation
34.	Laser-Induced Breakdown Spectroscopy
35.	Migration Barrier Covers
36.	Dry Barriers for Containment and Remediation at Waste Sites
37.	Advanced In Situ Moisture Logging System
38.	Broadband Electromagnetic for 3-D Site Characterization
39.	Rapid Geophysical Surveyor
40.	Remote Characterization System
41.	Imaging Data Analyses for Hazardous Waste Application
42.	Geophex Airborne Unmanned Survey System (GAUSS)
43.	Three Dimensional Sub-Surface Imaging Synthetic Aperture Radar
44.	High Resolution Subsurface Imaging and Neural Network Recognition

Mixed Waste Characterization, Treatment, and Disposal Focus Area	
1.	Plasma Hearth Process Development
2.	Steam Reforming
3.	Waste Stream Pretreatment for Mercury Removal
4.	Microwave Solidification
5.	Freeze Crystallization Technology
6.	Mercury Removal and Recovery From Flue Gas
7.	Diagnostic Instrumentation and Analysis Laboratory (DIAL)
8.	Laser Spark Spectroscopy for Continuous Metal Emission Monitoring
9.	In Situ Vitrification of Contaminated Soils
10.	Polyethylene Encapsulation of Radionuclides and Heavy Metals
11.	A Catalytic Wet Oxidation Process for the Treatment of Multicomponent Wastes
12.	VAC*TRAX-Mobile Vacuum/Thermal Treatment System
13.	Research and Development of an Innovative Fossil Fuel Fired Vitrification Technology for Soil Remediation
14.	Evaluation of Electrodialysis – Ion Exchange for the Separation of Dissolved Salts

Pollution Prevention Program	
1.	Chlorinated Solvent Substitution Program
2.	Spray Casting Project
3.	Waste Acid Detoxification and Reclamation
4.	Integrated Environmentally Compatible Soldering Technologies
5.	Cleaning Alternative
6.	Supercritical Carbon Dioxide Cleaning
7.	Lead Free Solder Paste
8.	B61-6/8 Electronic Assembly

Decontamination and Decommissioning Focus Area	
1.	BOA: Asbestos Pipe-Insulation Removal System
2.	Protective Clothing Based on Permselective Membrane and Carbon Adsorption
3.	Portable Sensor for Hazardous Waste
4.	Characterization of Radioactive Contamination Inside Pipes with the Pipe Explorer™ System

High Level Waste Tank Remediation Focus Area	
1.	Sensing of Headspace Gases: Continuous in Situ Monitoring of Gaseous Components in Underground storage Tanks Using Piezoelectric Thin Film Resonator Sensors
2.	Moisture Measurement by Electromagnetic Induction
3.	Infrared Analysis of Wastes
4.	Electrical Resistance Tomography

Efficient Separations and Processing Crosscutting Program	
1.	Development of Magnetically-Assisted Chemical Separation Processes
2.	Sequestering Agents for the Removal of Transuranics from Radioactive Waste (Polymer Filtration Process)

4. COORDINATION WITH MEXICO'S FEDERAL AGENCIES

Following the successful cross-matching of Mexico's priority environmental management needs versus R&D programs sponsored by the DOE's Office of Environmental Management, ASL was tasked with the coordination of these potential technology-exchange opportunities with Mexico's federal agencies. The initial basis for bi-national cooperation was the ASL-identified set of DOE-sponsored R&D programs that matched to Mexico's priority environmental management needs.

In partnership with Mexico's ITESM university, ASL and ITESM staff arranged for and held numerous detailed meetings with decision makers from Mexico's federal agencies, including the Commission for Energy Efficiency, Secretariat of Energy, Secretariat of Ecology and Public Safety, and others. Coordination meetings were also conducted with the leadership of Mexico's federal research laboratories. Key results of these coordination meetings were several formal written expressions of interest by Mexico's federal agencies to proceed with the systematic implementation of the DOE-Mexico technology exchange program. These efforts led to the following strategies for cooperation:

- Scientific staff exchanges from among U.S. and Mexican research laboratories
- Co-development of environmental technologies capable of addressing common problems
- Demonstrations of DOE-sponsored environmental management technologies at selected industrial and government sites within Mexico, and
- Joint deployment of DOE-sponsored technologies by U.S. and Mexican businesses.

This breakthrough work triggered initial steps to advance formal bi-national federal cooperation between the United States and Mexico on the resolution of hazardous waste management issues. DOE's International Programs office and the U.S. Department of State became engaged in this process. Specific research topic areas and collaborating organizations were identified, but further work was halted due to Congressional direction that altered the Office of Environmental Management's program priorities.

5. U.S.-MEXICO BORDER REGION CHALLENGES

During fiscal years 1998-99, the emphasis of this program began to shift from matching technologies and needs shared by DOE's Office of Environmental Management and Mexico to applying technologies to the environmental challenges of communities along the U.S.-Mexico border. The DOE Albuquerque and Carlsbad offices saw a common need for collaboration between the U.S. and Mexico in the interest of improving overall conditions in the border region.

Background. The U.S.-Mexico border region is the land within 100 km on each side of the U.S.-Mexico boundary. It stretches from the Pacific Ocean represented by the Ciudad Tijuana / San Diego area to the Gulf of Mexico represented by the Matamoros / Brownsville area. The region encompasses parts of six Mexican states (Baja California Norte, Sonora, Chihuahua, Coahuila, Nuevo Leon, and Tamaulipas) and four U.S. states (California, Arizona, New Mexico, and Texas). The region's 200-km wide land mass is home to more than 12 million people, with about 60 percent living and working in the United States. Circumstances peculiar to the U.S.-Mexico border region contributed to the foundation of the maquiladora program in 1965. A series of initiatives were pursued by the Mexican government to improve the economy of the region by taking advantage of Mexico's juxtaposition to the United States. One of the underlying program objectives was to improve employment in communities throughout northern Mexico.

Rapid population and industrial growth in the border region have greatly affected regional water sources and spawned other environmental problems. Growth has exceeded the original infrastructure developed to serve a much smaller population. The results have been uncontrolled and untreated wastewater discharges, unsound disposal of municipal and industrial wastes, and escalating air pollution. This has also increased demand for energy and this, in turn, has added to the region's environmental problems. As a result, the U.S.-Mexico border region has some of the most serious environmental problems in the western hemisphere. These problems can be partly attributed to the area's transnational nature. Table 2 ranks the region's major pollution problems.

***Table 2**. Major pollution problems along U.S.-Mexico border region.*

Ranking by Severity	Description
1	Shortage of clean water for drinking and potability
2	Lack of proper disposal facilities for wastewater leading to contamination of water sources, food sources and natural habitat
3	Lack of disposal facilities for municipal waste
4	Need for increased energy generation
5	Need to reduce air contaminants from vehicles and industry
6	Need to develop an infrastructure for reducing, recycling, transporting and disposing of hazardous wastes

The region's water is supplied by numerous transnational river basins and aquifers. The 14 pairs of U.S.-Mexico sister cities share common air sheds with airborne pollutants freely moving across political boundaries. There is extensive industrial pollution of water, land, and air; dangerously inadequate water treatment and supply infrastructure; and acute shortages of facilities and systems to manage solid waste. Preliminary investigations suggest that these conditions present serious health risks to the region's population. Figure 3 shows the high incidence of various diseases compared to U.S. national rates during the late 1990s. Along the Texas border with Mexico, anencephaly (serious brain disorder in newborns) was more than six times greater than the U.S. incidence levels.

	Hepatitis A	Measles	Shigellosis (gastrointestinal disease)	Tuberculosis	Neural Tube Defects *	Anencephaly *
General U.S. Population	**12.6**	**11.2**	**10.9**	**10.3**	**6.0**	**3.0**
Arizona Border	**39.4**	**9.8**	**38.3**	**6.9**	**N/A**	**N/A**
California Border	**30.7**	**61.9**	**22.1**	**12.7**	**N/A**	**N/A**
Imperial County	**23.8**	**57.6**	**37.5**	**43.0**		
San Diego	**30.8**	**47.8**	**24.7**	**13.2**		
New Mexico Border	**46.9**	**14.6**	**21.2**	**7.3**	**N/A**	**N/A**
Texas Border	**40.4**	**38.9**	**49.1**	**26.5**	**27.1**	**19.7**
Hidalgo County	**27.1**	**19.3**	**151.7**	**32.6**		

Figure 3*. Reported disease rates on the U.S. side of the border region (circa 1998).*

Many of these health issues may be attributed to the high concentration and rapid growth of industry and population in the border region, combined with relatively low rates of investment in institutional and physical capacity to handle the attending levels of pollution. Industrial growth in the border region has been driven in large part by the maquiladora program. It is estimated that over 2,000 maquiladora plants have located along the U.S.-Mexico border. Through the late 1990s, it was widely reported that many of the maquiladora plants lacked proper waste treatment or pollution prevention technology and practices.

The maquiladora industry contributes indirectly and directly to environmental degradation in the U.S.-Mexico border. Indirectly, job opportunities serve as a draw for migrants from central and southern Mexico, increasing local border populations. Maquiladoras also outsource some production to local factories that lack even rudimentary waste handling / management practices. (While research indicated that outsourcing to such plants was widespread and such plants' practices were alarming, evidence is largely anecdotal.) This has created an overload of the region's urban infrastructure and its fragile ecology. Directly, the maquiladoras adversely impact the border's environment through improper and / or inefficient disposal of waste material.

Water quality. Based on available information, the status of the water quality in the border region, specifically in the California-Baja California, Arizona-Sonora, New-Mexico-Texas-Chihuahua, and Texas-Tamaulipas regions, was summarized by examining some of the major sister cities in these regions. The results are presented below.

In the Tijuana-San Diego area, the Tijuana sewage system was originally built for a capacity of 17 million gallons of sewage per day (MGD). However, the average sewage production for 1995 was 35-40 MGD. Even today, Mexican and U.S. coastal residents in the Tijuana and San Diego areas are exposed to untreated water. 1995 California EPA data showed daily release levels of 25 MGD of undisinfected wastewater and partially-treated sewage as well as 2-3 MGD of raw sewage into the Pacific Ocean six miles south of the border. Tijuana wastewater and storm water systems are combined. Therefore, industrial waste, laden with lead and pesticide residues, may still flow in the sewage system.

In the Calexico-Mexicali area, the New River had the distinction in the late 1990s of being the dirtiest U.S. river with a flow at the border of 20-25 MGD of partially-treated domestic and industrial wastewater and about 3 MGD of untreated industrial wastewater. Previous monitoring reports revealed high levels of dichloro-diphenyl-trichloroethane (synthetic pesticide, also known as DDT), PCB, chloroform, trichlorethane, toluene, xylene and fecal coliform levels that are several thousand percent higher than the level considered potentially fatal to humans. Warnings are posted to avoid bodily contact with the water.

The Nogales sister cities are still plagued by the heavily contaminated Nogales Wash, a channel with a mixture of toxics and raw human sewage flowing through the downtown areas of Nogales, Sonora and Nogales, Arizona. There is no effective water treatment for the industrial and residential waste of Nogales, Sonora. In 1995, fecal coliform levels were often above Arizona standards by as much as 20 times.

Up until the late 1990s, there was no water treatment facility in Ciudad Juarez. Open canals may still carry "black waters" containing run-off from the city's approximately 350 factories and raw sewage dumped into the Rio Grande. The Rio Grande remains so polluted by human fecal matter in this area that skin contact threatens exposure to cholera, hepatitis and dysentery-causing organisms. This untreated water is often used for irrigation. The situation poses a threat to Mexican farmers and consumers of Mexican produce on both sides of the border.

Air quality. Throughout the 1990s, and perhaps continuing today, the sister-city pair of Tijuana-San Diego competes with Juarez-El Paso for the most polluted border air. San Diego was cited as a 1995 non-attainment zone for carbon monoxide and ozone under the Clean Air Act. Most pollution comes from automobiles in both countries and the Tijuana maquiladoras. As of 1996, very little air-quality data was available for the area nearby Mexicali / Calexico. Figure 4 shows the geographic distribution of non-attainment cities for five of the criteria pollutants.

Figure 4*. Areas of non-attainment in the border region.*

Throughout the 1990s, El Paso regularly exceeded EPA standards for carbon monoxide, ozone, and particulate matter. Maquiladora emissions, small brick factories, burning rubbish, and dust from unpaved roads comprise the extremely high level of dangerous particulate matter in the air. An ozone haze hangs over Juarez and El Paso much of the year caused by emissions reacting with sunlight. The ozone levels in El Paso steadily increased from 58 percent of the days each year having unhealthy ozone levels in 1992, to 67 percent in 1994, and 75 percent in 1995.

Hazardous waste. The increase in border industrial activity led to a companion increase in the creation of hazardous wastes. The damage to the environment and threats to public health are largely caused by illegal dumping of hazardous waste along the U.S.-Mexico border that increased throughout the 1990s.

Much of the industrial waste generated in the border region was often reported as "washed down the drain." In 1995, the newspaper *Diario de Juarez* reported that only 20 percent of industries generating hazardous waste reported proper disposal, while the disposal methods of about 44 tons of daily hazardous waste from the Juarez maquiladora zone is unknown. Oscar Canton Cetina, as Chairman of the Mexican Ecology Commission, revealed that each year, seven million tons of toxic waste is without control and illegally dumped in drains and marine waters. A spokesman for the Mexican National Council of Environmental Industrial Businessmen noted in an August 1995 *Excelsior* interview that the inspection of the maquiladora industry is virtually non-existent.

The increase in the amount of unrecorded hazardous waste and improper disposal throughout the 1990s is in direct correlation to the incentives for illegal dumping. Mexico's depressed economy was often a stimulus for illegal waste dumping by the maquiladora industry due to the high cost of proper disposal. In addition, the Mexican depression resulted in public spending being slashed and government regulators had fewer resources to investigate and prosecute illegal dumping.

Border population. Almost 90 percent of the border region's population resides in urban areas. For the most part, these urban areas include 14 sister-city communities located along the border, each composed of a U.S. and Mexican city closely related by proximity, commerce, and shared resources. These sister-city pairs are the main points of commercial and human trans-boundary movement. They are the industrial centers of the region. The U.S.-Mexico sister-city pairs are:

- San Diego-Tijuana
- Calexico-Mexicali
- Yuma-San Luis Rio Colorado
- Nogales-Nogales
- Naco-Naco
- Douglas-Agua Prieta
- Columbus-Las Palomas
- El Paso-Ciudad Juarez
- Presidio-Ojinaga
- Del Rio-Ciudad Acuña
- Eagle Pass-Piedras Negras
- Laredo-Nuevo Laredo
- McAllen-Reynosa, and
- Brownsville-Matamoros.

The population along the border has grown from 4 to over 10 million residents during 1975-2000. The EPA's U.S.-Mexico Border 2012 Program reports that the border region population has currently reached about 12 million people. The majority of population is concentrated in the 14 major sister-city pairs. A breakdown of the population levels for the period ending in the year 2000 is highlighted below.

- San Diego-Tijuana alone absorbed one third of the growth and has a combined population of more than 3.5 million people.

- El Paso-Ciudad Juarez, Laredo-Nuevo Laredo, McAllen-Reynosa, and Brownsville-Matamoros have together absorbed another one-third of the population increase. The population of El Paso-Ciudad Juarez exceeded 1.5 million in the late 1990s.

- Six other sister-city pairs have combined populations of over 150,000 each, including: Calexico-Mexicali; Laredo-Nuevo-Laredo; McAllen-Reynosa; Brownsville-Matamoros; Nogales-Nogales; and Yuma-San Luis Rio Colorado.

Table 3 is a summary of the region's population growth during the period 1990-95. The California-Baja California region, which includes the counties of San Diego and Imperial and the municipalities of Tijuana, Tecate, Mexicali, and Ensenada, makes up about 45 percent of the total border region population. The New Mexico-Texas-Chihuahua region, including the area of El Paso-Ciudad Juarez alone, makes up about 15 percent of the total. The Texas-Tamaulipas region, including the areas of Laredo-Nuevo Laredo, McAllen-Reynosa, and Brownsville-Matamoros, makes up about 13 percent of the border population.

***Table 3**. U.S.-Mexico border region population growth.*

State	1990 Population	1995 Population
California	2,607,000	2,850,000
Baja California	1,401,000	2,108,000
Arizona	235,000	287,000
Sonora	395,000	440,000
New Mexico	21,000	63,000
Chihuahua	870,000	1,085,000
Texas	1,549,000	2,030,000
Coahuila	191,000	230,000
Nuevo Leon	17,000	18,000
Tamaulipas	1,015,000	1,194,000
Total	**8,301,000**	**10,305,000**

Manufacturing industry. About half of the total registered maquiladora companies were found to have U.S. invested interests through the year 2000. Employment in Mexican maquiladoras rose over 20 percent to 811,376 workers in November 1996 from 674,693 workers in the same month in 1995. It is estimated that there are over 2,200 of these plants operating throughout Mexico. Of the maquiladora workforce, approximately 80 percent can be found in the six northern Mexican states including Baja California, Sonora, Chihuahua, Coahuila, Nuevo Leon, and Tamaulipas.

Data were collected on the distribution of maquiladora plants, the size of the workforce at the major sister-city pairs, estimates of toxic / hazardous waste effluents, and acid rain and smog precursor effluents[2]. These data, valid through the year 2000, are illustrated in Figure 5. Baja California has the largest number of plants followed by Chihuahua. The New Mexico-Texas-Chihuahua region, including Ciudad Juarez and Ojinaga, was reported to have the largest workforce. Approximately 34 percent of the region's entire maquiladora workforce is located there. Similarly, California-Baja California including Tijuana, Mexicali, Tecate and Ensenada only, followed with 28 percent of the region's maquiladora workforce. The preponderance of hazardous waste, represented in tons per year, is generated in Chihuahua, followed closely by Baja California.

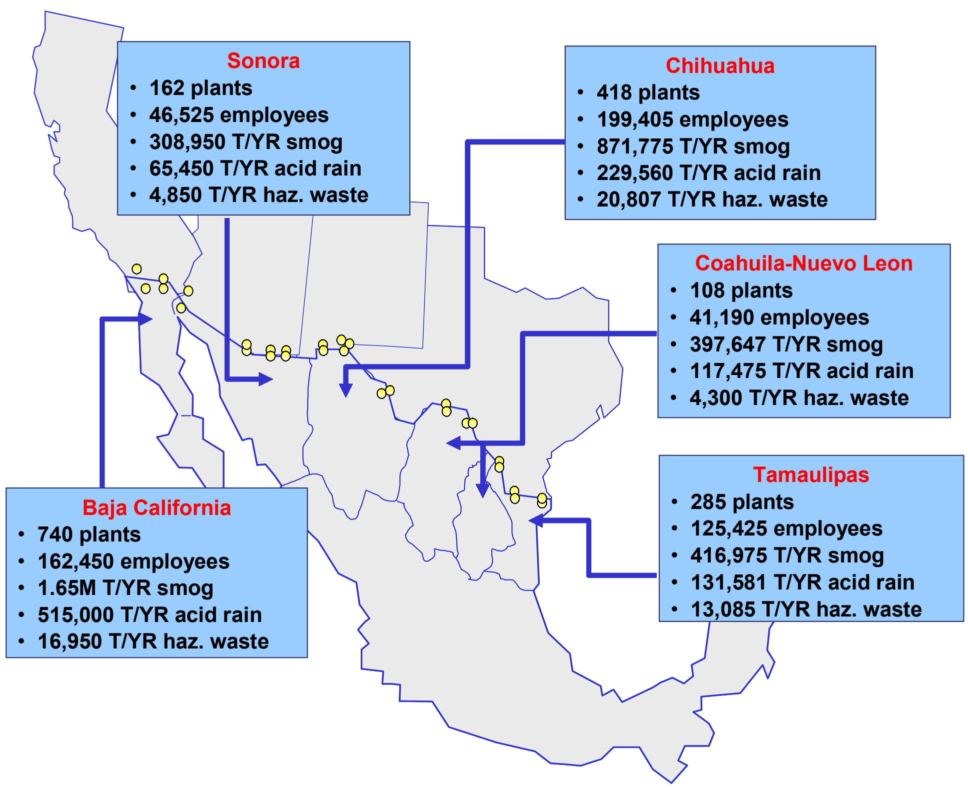

Figure 5. *Maquiladora size, distribution, and pollutant estimates.*

[2] Smog precursors are emissions of air pollutants (CO, NOx, VOCs) that undergo reactions to make smog. Acid rain precursors are SO_2 and NO_2 which combine with moisture and constitute the principal sources of acid rain.

Data, valid through the late 1990s, were then collected from the open literature on maquiladora industries in the major sister-city pairs. Major industrial groupings were assembled from these data. The waste forms produced by these major industrial groupings were identified using EPA-published data for representative U.S. manufacturers of similar products. Tables of the primary hazardous waste effluents from the maquiladora industry were then compiled. The results are shown in Figure 6. The data offers valuable insights for understanding the potential impacts of the region's waste streams on public health conditions and related learning disorders.

	Acetone	Ammonia	Chlorine	Chromium	Copper	Glycol	HCL Acid	Lead	MEK	Methanol	MIK	Nickel	Sulfuric Acid	TCA	TCE	Toluene	Xylene	Zinc
Microelectronics	▲	▲			▲								▲	▲	▲		▲	▲
Metal Products		▲		▲	▲			▲			▲			▲		▲		▲
Automobile Parts/ Accessories	▲	▲			▲	▲			▲		▲	▲				▲		▲
Apparel/Leather Goods		▲		▲	▲	▲			▲				▲		▲	▲		
Wood Products Furniture & Fixtures			▲				▲		▲	▲			▲	▲		▲		▲

Figure 6. *Major effluents from maquiladora industry.*

6. U.S.-MEXICO BORDER REGION HAZARDOUS WASTE FORUM

Among the many collaborative efforts of the DOE Albuquerque and Carlsbad offices was the implementation of the U.S.–Mexico Border Region Hazardous Waste Forum. This bi-national event was held on August 12–13, 1998 in Carlsbad, New Mexico. A "grass roots" team of community, state and national leaders was involved in the planning and coordination of the Forum under the direction of DOE's Carlsbad and Albuquerque offices.

The Forum focused on raising the awareness of elected officials to the issues of public health and environmental security risks to the border region. Breakout discussions provided specific examples of DOE technologies that could be applied to address environmental needs in the border region. The Forum achieved agreement between U.S. and Mexican participants to work together to help resolve some of the region's pressing needs. Stakeholders expressed interest in the commercialization of DOE technologies and supported approaches that would enable local business participation in product manufacturing and service provision.

The widespread participation during the Forum (132 attendees) reflected strong bi-national interest to leverage the U.S. science and technology investment to solve a number of key environmental issues throughout the U.S.-Mexico border region. A listing of the participating organizations is provided in Table 4. Participants included U.S. elected officials and their staff; representatives of U.S. and Mexican local, state and federal government offices; scientific leaders from the DOE's national laboratories and Mexico's research institutions; U.S. and Mexican university researchers; and representatives of U.S. and Mexican industries.

A clear bi-national consensus, among the participants, was that the DOE's innovative environmental management technologies offered promise for addressing the border region's needs. Other key findings and conclusions are highlighted below.

- Representatives of the U.S. Congress concurred with the importance of the Department of Energy's efforts to apply its technologies to help solve the border region's problems. The representatives encouraged the Department of Energy to continue its leadership role in this effort.

- The Mexican federal government emphasized the urgency of hazardous waste issues and requested U.S. collaboration and assistance to: 1) reduce hazardous waste generation in the border region; 2) improve the safety and efficiency of hazardous waste transportation, storage and treatment; and 3) develop better environmental regulations for the management of hazardous wastes.

- U.S. federal agency representatives from the Department of Energy, Environmental Protection Agency, and Department of Health and Human Services jointly acknowledged the need to work together on solving border regional problems. The Environmental Protection Agency stated that it would try to form an interagency alliance with the Department of Energy to leverage the Department's technologies to improve hazardous waste management throughout the U.S.-Mexico border region. This confirmed that the Department of Energy's efforts are complementary, not duplicative, of ongoing border region environmental infrastructure programs.

- Each of the Forum's six (6) working groups (listed in Table 5) independently concluded that the Department of Energy's technologies offered promise for solving the border region's hazardous waste management problems.

- A consensus was reached among the participating legal experts that there are no insurmountable legal barriers that prohibit the implementation of a joint U.S.-Mexico commercialization program for addressing the border region's needs.

Table 4. *Participating organizations of U.S.-Mexico border region hazardous waste forum.*

Type	**Organizations Represented**
Federal Government Agencies	DOE Headquarters, Albuquerque Operations Office and Carlsbad Area Office U.S. EPA Regions 6 and 9 U.S. Department of Health and Human Services / Public Health Service U.S. Department of Treasury/Customs National Institute of Ecology / SEMARNAP*
State and City Governments	Several environmental, public health, and local government offices from New Mexico, Texas and Arizona
National / Research Laboratories	Los Alamos National Laboratory, Sandia National Laboratories Pacific Northwest National Laboratory Idaho National Engineering and Environmental Laboratory Oak Ridge National Laboratory, Environmental Measurements Laboratory National Institute of Nuclear Research*
Universities	Waste Management Education Research Consortium New Mexico State University, University of New Mexico New Mexico Institute of Mining and Technology, Virginia Tech University University of Arizona, University of Texas at El Paso, Center for Environmental Quality/ITESM*, Autonomous University of Nuevo Leon*
Industry	Molzen-Corbin Inc., Waste Management Inc., Battelle Memorial Institute, Westinghouse Electric Corp., COMPA Industries Inc., SM Stoller Corp., RE/SPEC Corp., Advanced Power Technologies Inc., Jacobs Engineering Inc., Roy F. Weston Inc., Commodore/ASI, ICF Kaiser Inc. Morrison Knudsen Corp., MCT Transportation Inc., Applied Sciences Laboratory, Inc., Residuous Industriales Multiquin SA*, Delphi Packard Electric*, Servicios RACE*

* Organizations located in Mexico

The working sessions that were implemented during the forum were tasked with determining whether there is a basis for pursuing collaborative efforts to apply DOE technologies to help resolve border issues. Table 5 summarizes the results and recommendations of these working sessions.

Table 5. *Path forward recommendations of U.S.-Mexico border region hazardous waste forum.*

Session	Pathforward Recommendations
Transportation	1. Enhance the continuity of U.S. and Mexican transportation regulations. 2. Develop a memorandum of understanding (MOU) to deal with roles and responsibilities for emergencies (plan of action), liability issues, illegal transport, and shipping regulations. 3. Develop partnerships with Department of Safety, Customs, and private industry for potential funding collaboration.
Waste Minimization	1. Encourage collaboration among U.S. federal agencies (i.e., DOE, EPA and HHS). 2. Form strategic federal partnerships with Mexican agencies. 3. Involve state and local governments on both sides of the border as active strategic partners. 4. Address minimization of hazardous and toxic wastes first, then focus on other border region waste issues. 5. Focus initially on the microelectronics industry, particularly for VOC emissions. 6. Develop a fully-integrated, one-stop shop for the access to binational activities. 7. Assist in the formation of U.S. industries, particularly small businesses, to implement commercially available technologies to resolve U.S.-Mexico border waste management issues.
Characterization	1. Form partnerships with ININ and EML; DOE/EM-50 (characterization technologies) and INE to develop two-way environmental programs. 2. Establish a waste characterization issues taskforce. 3. Establish technology exchange program: fellowships, electronic and personal communication.
Final Disposition (Landfills)	1. Industry, government and universities should consider forming collaborative teams for exposing and evaluating the best commercial ideas. 2. Improve the information exchange of landfill technologies.

	3. Work with intermediate industries, rather than directly with the maquiladoras, to transfer and commercialize new technologies.
Storage and Treatment	1. Encourage the development of centralized facilities for the collection and treatment of hazardous waste generated by border region industries.
Legal Aspects	1. Work with the Autonomous University of Nuevo Leon and appropriate Mexican federal agencies to identify additional legal issues and determine plans of action for addressing them. 2. Pursue identification and resolution of legal issues in "real-world" technology transfer situations within the border region.

7. TECHNOLOGY DEMONSTRATIONS

Forum participants affirmed the value of preliminary DOE plans to demonstrate technologies under realistic operating conditions. It was determined that such served as a key first step for validating technology relevance to border conditions, as well as conditions elsewhere in Mexico. It was also agreed that demonstrations should be conducted at border sites with the participation of local stakeholders.

With the support of the New Mexico and Texas Congressional delegations, DOE's Albuquerque office initiated and DOE's Carlsbad office assumed sponsorship and led the implementation of a number of technology demonstration projects. Several of these projects required funding for additional development, test and evaluation activities prior to demonstration. Some of these projects are discussed below.

Reducing Brick Kiln Emissions

The first project was an applied technology development, test and evaluation effort conducted by New Mexico State University (NMSU), under the direction of Applied Sciences Laboratory. The resulting technology was later demonstrated and showcased. The project's origins were in materials science work that had been conducted by a scientist and student intern at Los Alamos National Laboratory (LANL). The intern later continued this work as part of his dissertation for a doctoral degree under the direction of a professor within the NMSU Chemistry Department. The candidate's work was assisted by a graduate student from Mexico who also earned a doctoral degree from NMSU in chemistry.

Background. For many generations, small groups of Mexican citizens along the border have been earning a living by making bricks that are widely used by U.S. and Mexican consumers. The traditional brick-fabrication techniques that are employed are similar to those used for centuries to make adobes. The bricks are baked at high temperatures long enough for them to "vitrify" so that the bricks achieve acceptable structural and thermal performance properties.

Traditional brick-making ovens are thermally inefficient and highly polluting. Furthermore, the brick makers' resource constraints make it necessary to use low-cost materials as fuel. These fuels normally include scrap woods, but plastics, industrial woods treated with preservatives, used auto tires, and used motor oils are often used, *despite their prohibition*, because they are cheap and readily available. The airborne by-products of each of these fuel materials are highly toxic; thus, this industry has become a very serious threat to the region's public health and to the environment.

During the late 1990s, up to 400 kilns were in operation in Ciudad Juarez while about 3,000 kilns operated along the 2,000 mile U.S.-Mexico border region. An independent study found that emissions from these kilns account for up to $150 million per year in related health care costs in Ciudad Juarez and about $15 million per year in related health care costs in El Paso, Texas. The brick makers face more immediate and direct hazards, since they must stoke the fires from above the open air kilns and losing one's balance results in severe burns or death.

Solution. Initially, efforts were undertaken to enclose the kiln using the same clay material that encompasses the kiln. While this reduced emissions dramatically and eliminated most of the hazards to brick makers, it prevented observation of temperature evenness. The solution to this was observation ports in the kiln perimeter and an ingeniously simple rod device that extended aluminum cans into the kiln. Melting of the cans confirmed adequate uniform temperatures.

The key to the technology, however, was tapping the tremendous surface areas in clays and valence in order to absorb large volumes of contaminants and trap them within the clay matrix. Essentially the same material being fired in the kiln (bricks) became the filtration media. Optimizing this materials science application involved an engineering application that also addressed a key inefficiency of the single stage kiln design. Once an enclosed, single stage kiln was fired, it still had to cool down before another batch of bricks could be baked. This wasted time and costly fuel.

By applying simple heat exchange engineering principals to the kiln design, two smaller kilns were connected to the main kiln and heat that was released was now conserved in the two secondary kilns. Unbaked bricks were staged in the secondary kilns and absorbed the airborne contaminants from the primary kiln that was being fired. Once the bricks in the primary kiln were vitrified, residual heat was channeled into the secondary kilns and those kilns were fired with a minimum of heat loss to bake the next batch of bricks.

The resulting, three-stage kiln design, named the "Marquez kiln" after its designer, was a closed-loop system that fires bricks in the central or end chambers and traps the contaminants in the system's unfired bricks. It combined high-tech materials science and engineering with low-tech materials and construction techniques. Prototype tests revealed that the design captured 97 percent of all airborne particulates, was 64 percent more efficient, reduced energy costs by 63 percent, increased productivity by 33 percent, and improved material strength by 24 percent. It also virtually eliminated all health and safety risks of operation.

The improved kiln design is also appropriate and sustainable technology. Construction of the kiln required the same clay material as the traditional kilns; a material that is both inexpensive and readily available. Construction costs increased about 60 percent due to the additional labor to make the adobe bricks and assemble the kiln. Nevertheless, the economies are evident to the brick makers and serve as the incentive to invest.

Status. The prototype kiln was constructed in Ciudad Juarez by a local brick maker who partnered with NMSU in the spring of 2000. This effort was successful largely because the development team worked in close collaboration with the region's brick makers. This helped ensure the acceptance of the technology as it was being advanced. The kiln was successfully demonstrated in August 2001. A scaled-down working model was also showcased on the Capitol Mall as part of the Smithsonian Institution's Folk Life Festival. The improved kiln design has application worldwide as the traditional Mexican brick-making process and technology is evident in many of the developing countries of Latin America, Africa, Asia Minor, the Subcontinent, and East Asia.

Following demonstration, the design was reevaluated and, with support from the U.S. Congress, additional design improvements were developed to increase brick-making capacity and recycle scarce water that is used during production. The improved design was constructed in Ciudad

Juarez and tested in 2002-03. Project costs were shared with the private sector and local governments. The Marquez kiln is now deployed at a number of U.S. border communities, in central Mexico, and in other Latin American countries. Deployment of the Marquez kiln has been steady, but slower than achievable. Deployments have been primarily funded by the private sector from the U.S. and Mexico. The resulting technology has the potential to revolutionize brick-making cottage industries throughout arid, developing regions of the world.

After completing their doctorate degrees in chemistry, NMSU researchers continue work on the Marquez kiln and are conducting further research on the use of clays for a variety of environmental and public health applications that are specific to the U.S.-Mexico border region.

Recycling Used Tires

The second project was also an applied technology development, test, and evaluation effort. The technology's original development was funded by industry and resulted in a 1990 U.S. Patent for the inventor's gasification technology. Patent award was followed by a DOE Regional Biomass Energy Program (RBEP) 1991 grant awarded to Thermogenics, Inc. (Albuquerque, NM) to demonstrate the gasification technology. Then, in 1994 Thermogenics entered into a Cooperative Research and Development Agreement with Sandia National Laboratories and the State of New Mexico Technology Enterprise Corporation for further development of the gasification technology. Thermogenics received in 1998 a second RBEP grant to develop the gas-to-liquid fuels capability of its gasification technology.

Background. In the United States, it is rare to hear of waste management and public health issues associated with used auto and truck tires. The U.S. possesses an infrastructure for the disposal and recycling of used tires. Conditions in Mexico are quite different. In fact, many used tires from the U.S. migrate to Mexico, particularly to the border communities due to the low cost of used tires and depressed economic conditions in Mexico. This drives the requirement to dispose of these tires once they are no longer usable at a much higher per-capita level in Mexico's border communities versus the conditions in the United States.

This situation has led to the accumulation of very large piles of used tires within Mexico's border communities at a rate that far exceeds the capability to dispose / recycle them. For example, Mexican authorities have provided unofficial estimates of the inventory of used tires in Ciudad Juarez exceeding 8 million tires at the city's primary tire disposal site. In Ciudad Juarez, and other border communities, these sites are simply large piles of tires above ground. These unsecured sites provide little protection against malicious acts. Accordingly, these sites present a number of concerns to border communities.

- One of the greatest concerns is a tire fire and the immediate effects on public health, the economy, commerce, and the environment. Should any of these tire piles catch fire, it is unlikely that even a bi-national fire department response would have the capability to extinguish the fire. It is common practice in the U.S. to allow tire-pile fires to burn until the fuel source (tires) is depleted. This is because tires have an enormous energy content and, therefore, burn with intense heat at levels that exceed the practical capability to extinguish them. Should this scenario be carried out, for example, in Ciudad Juarez, the impacts would be catastrophic. The region's air shed would experience very high concentration levels of toxic compounds. U.S. and Mexican citizens would experience daily challenges to their respiratory systems to varying degrees depending on their health as well as wind direction and other environmental conditions for any given day. The effects of the airborne particulate and compounds would impact crop production and quality, the meat and poultry industry, and others. One should expect this condition to last not just for days or weeks, but for months; perhaps even for more than a year.

- Tire piles are ideal breeding grounds for mosquitoes and rodents. The mosquitoes find haven in the fiber structure of tires where they re-produce. Large rodent populations are also commonly found in the tire piles. Mosquitoes and rodents are a clear threat to the Mexican public. To what degree this situation threatens Americans is dependent on the location of the tire piles and the travel distances of the mosquitoes and rodents. There is clear evidence (e.g., Centers of Disease Control) that there are escalating levels of U.S. and Mexican citizens experiencing serious health issues associated with exposure to mosquitoes. These are certainly linked to mosquitoes and perhaps linked to rodents. Under the present situation, some U.S. and Mexican citizens face these unhealthy conditions for their entire lifetimes.

- Airborne pollutants are just one of the by-products of tire fires. Tire fires will also generate hazardous and toxic liquid byproducts that will migrate from the ground surface to below ground. The extent of migration is dependent on several factors, one of which is the soil properties. Thus, this situation poses a threat to the region's aquifers. The extent of contamination of these aquifers is unknown, but it is clear that many border region communities face water shortages and can ill-afford damage to their aquifers.

Solution. Used tires are a source of useful energy. Rather than being discarded and collecting in solid waste sites, used tires are sometime recycled into several forms such as pavement materials, park benches, and other products. The cement industry recognizes the enormous heat value of used tires and often burns them in the production of cement. But, it is clear, that in some parts of the world (and certainly in the U.S.-Mexico border region) the generation rate of used tires exceeds the recycling rates. Some entrepreneurs have become aware of this situation and recognize the economic value of used tires. A few have made it their priority to advance and potentially commercialize technology that can cleanly and effectively recycle used tires into useful energy forms.

Thermogenics, Inc. has been designing and testing a tire-recycling system that converts shredded tires to a gaseous fuel for more than a decade. While the process is not yet commercially successful, Thermogenics has achieved used-tire fuel conversion in a form that can power an internal engine and, in turn, drive an electric generator that produces electric power. This end-to-end functionality has been achieved on a single platform at the company's test and evaluation facilities. Recognizing the importance of this issue and the potential contribution of the Thermogenics tire-recycling system, the Department of Energy's Albuquerque and Carlsbad offices sponsored a demonstration of the Thermogenics system during fiscal year 2000.

Status. The demonstration, held at the Thermogenics facility, included 20 participants from U.S. and Mexican government offices and the business and academic sectors. During the demonstration, the system's shredded-tire input stream was converted to a methane-based gas and the gas, in turn, successfully powered an internal combustion engine. The engine drove a generator. DOE's Carlsbad office then sponsored follow-up work that focused on further testing and improvements of tire-recycling technology. The follow-up work was completed and did not advance further due to funding setbacks for the program.

Other Technology Demonstrations

Personal Ice Cooling System (PICS). For workers who must perform their duties in thermally hot environments, the potential of heat stress is a serious occupational concern. When subject to heat stress, a worker's judgment is impaired and can quickly suffer heat exhaustion. The problem is compounded for emergency responders of U.S.-Mexico border communities who face harsh summer temperatures and who are required to wear protective clothing during the course of their duties. Consequently, they can only work in 15-minute intervals safely. In response, DOE sponsored the demonstration in 2000-01 of PICS – originally developed under DOE sponsorship to address worker health concerns in high-temperature environments associated with clean-up and decommissioning activities of the weapons complex. The demonstration was conducted in partnership with the DOE Fernald Environmental Management Project; Nogales, Arizona Fire Department; El Paso, Texas Fire Department; Laredo, Texas Fire Department; White Sands Missile Range; Fort Bliss Army Base; Nogales, Sonora (Mexico) Office of Civil Protection; and the Ciudad Juarez, Chihuahua (Mexico) Environmental and Civil Protection Departments. PICS successfully emerged as a cost-effective tool for reducing emergency responders' heat stress and was immediately deployed at seven border region communities.

Electromagnetic radiography. Many border communities are concerned about known and perceived hazardous contaminants in the soil that threaten public health. Conventional characterization methods are costly and slow. This technology was first developed by U.S. industry in collaboration with Sandia National Laboratories to detect buried waste drums and other materials. Electromagnetic radiography is routinely used to detect and characterize subsurface hazards to soil depths up to 48 feet. Demonstration of electromagnetic radiography was conducted in 2001 in the Nogales sister city community in partnership with the Nogales Economic Development Foundation, Tucson Environmental Management Division, and the Nogales, Sonora Office of Civil Protection. The demonstration team identified a potentially contaminated plume in a highly-populated residential area; at another site, the team located tunnels used for illegal operations. The demonstration confirmed the technology's value in locating and identifying subsurface contaminants within just a few hours and without extracting costly borehole samples.

Sediment Erosion Field Measurement. The El Paso Valley is heavily stressed by development and population pressures. Because the quality of surface water is so important to human health, technologies that aid in managing and protecting this valuable resource from contamination are needed. Sandia National Laboratories carried out the demonstration in 2001-02 of the Sediment Erosion Field Measurement technology for gauging erosion and the transport potential of sediments in the Rio Grande. Work was carried out in partnership with the International Boundary and Water Commission, University of Texas at El Paso, U.S. Army Corps of Engineers, and the

Autonomous University of Ciudad Juarez. The technology has since been used extensively on near-shore and river systems throughout the United States.

Radio Frequency Identification (RFID). There remains serious concern over the tremendous volumes of container and trailer ingress into the U.S. each year – estimated to be 16 million shipments. Only a fraction of shipments are inspected. In partnership with the U.S. transportation industry, DOE sponsored a 2002 demonstration of the RFID technology for its effectiveness in detecting the unauthorized intrusion and breach of a locked truck trailer or cargo container. Conducted in Laredo, Texas, the demonstration included simulated breaches into a trailer. The demonstration utilized an origin and destination chokepoint, where the system is activated and secured during each demonstration cycle. The status of the trailer, as indicated by the RFID system, revealed that the cargo container had been breached. Notification of the breached condition was successfully downloaded from the Internet in real-time and displayed. The RFID security system detected and immediately reported the time and date of the unauthorized trailer breaches. Today, RFID is widely applied by Customs and Border Protection operations.

Quick-SLAB toxic gas dispersion modeling system. Typically, following notification of a toxic release, it takes 90 minutes for trained emergency responders to gather information on the release, enter data to a software code, execute the code, and interpret results. Dense industry and population in many border communities make 90-minute predictions too long to help ensure public safety. Furthermore, the difficulty of using conventional air-dispersion codes often discourages emergency responders from using them in a crisis. To overcome these challenges, Applied Sciences Laboratory linked the SLAB air-dispersion code – developed by Lawrence Livermore National Laboratory – with an innovative user interface comprising of databases of toxic chemical inventories, their locations, and the locations of community facilities, along with an automated weather-station interface. This capability allows the emergency responder to rapidly predict, display and report toxic gas releases from industrial and municipal accidents. The resulting Quick-SLAB system was successfully developed, field tested, and deployed in 2002-03 in partnership with the Nogales, Arizona Fire Department; Nogales, Sonora (Mexico) Office of Civil Protection; and Ciudad Juarez, Chihuahua (Mexico) Environmental and Civil Protection Departments. Quick-SLAB, which cuts air-dispersion prediction time to less than 10 minutes, is now a bilingual tool routinely used to protect the binational interests of the U.S. and Mexico.

Solar water distiller. Colonias are faced with the daily challenge of securing a dependable potable water supply. Residents must haul their own water and store it in barrels. The water is often of poor quality with high dissolved solid content. DOE sponsored the demonstration in 2003 of the SolAqua, Inc. (El Paso, Texas) solar distiller system in Ciudad Juarez. The system had been advanced with the earlier support of materials and manufacturing expertise from Sandia National Laboratories with the goal of achieving affordable and effective household solar distillers for the border region's colonias. The demonstration revealed contaminant issues in the purified water. However, these issues were traced by researchers to the use of commercial water hoses that introduced additional water contaminants into the process. Recommendations focused on resolving this additional waste stream before proceeding with technology deployment.

8. RECOMMENDATIONS

This report chronicles in a summary fashion work that was initially undertaken to expand the application and impact of the Department of Energy's environmental technology development program through collaborations with Mexico. The shift in focus towards U.S.–Mexico border security and prosperity was prompted by the results of the earlier investigations and growing recognition over the course of these investigations that U.S. and Mexican interests converge most markedly along the border. Yet, from the Mexican perspective, conditions on the border, or frontera, are relatively good by comparison with other regions of the country.

Accordingly, it behooves the U.S. to assume a lead role in improving border conditions. In this regard, there needs to be a U.S. focal point that draws upon the expertise of various federal agencies, industry, academia and the communities along the border to focus on coordinated solutions. The Department of Energy, as a major science and technology organization, has much to contribute to this effort, but is not in a position to address issues outside its mission space any more than any other federal agency can.

Much has been accomplished by the Department in collaboration with U.S. and Mexican organizations. However, much more remains to be done. It is recommended that an entity be established with the mandate and resources to lead such an effort. It is also recommended that the Department of Energy continue in a support role to provide new and innovative technologies and approaches in addressing border needs.

APPENDIX I – SOURCE DOCUMENTS

Jimenez, R. and A. Bustani Adem, "Mexico's Priority Energy, Water and Environmental Needs," co-authored by Applied Sciences Laboratory and Center for Environmental Quality, Instituto Tecnologico y de Estudios Superiores de Monterrey, May 15, 1996.

Lenhert, J., "Overview of the Southwest Border Partnership," Albuquerque Operations Office, U.S. Department of Energy, 1997.

Jimenez, R. and A. Bustani Adem, "Preliminary Discussions with Mexican Agencies on Environmental Technology Collaboration," co-authored by Applied Sciences Laboratory, Inc. and Center for Environmental Quality, Instituto Tecnologico y de Estudios Superiores de Monterrey, May 23, 1997.

Jimenez, R., et al., "Leveraging DOE's Technologies to Improve U.S.-Mexico Border Health Conditions," Applied Sciences Laboratory, Inc., January 22, 1998.

Jimenez, R. and C. Esparza-Baca, "SNL-Based Technologies and Capabilities for Addressing U.S.-Mexico Border Region Environmental Needs," Applied Sciences Laboratory, Inc., March 1, 1998

Jimenez, R. and C. Esparza-Baca, "LANL-Based Technologies and Capabilities for Addressing U.S.-Mexico Border Region Environmental Needs," Applied Sciences Laboratory, Inc., April 1, 1998.

Jimenez, R., "Leveraging the U.S. Technology Base to Improve U.S.-Mexico Border Conditions," Applied Sciences Laboratory, Inc., April 20, 1998.

Jimenez, R. and R. Fong, "WERC-Based Technologies and Capabilities for Addressing U.S.-Mexico Border Region Environmental Needs," Applied Sciences Laboratory, Inc., May 1, 1998.

Carlsbad Area Office, U.S. Department of Energy, "Report of the U.S.-Mexico Border Region Forum: Application of U.S. Department of Energy Technologies to Hazardous Waste Needs," August 12-13, 1998.

Jimenez, R. et al., "Recommended U.S.-Mexico Border Region Sister Cities for Development of Hazardous Waste Management Problem Statements," Applied Sciences Laboratory, Inc., July 28, 1999.

Jimenez, R., "Leveraging Federal Science and Technology to Overcome the Challenges of the United States – Mexico Border Region," Testimony to Subcommittee on Energy, Research, Development, Production and Regulation, Committee on Energy and Natural Resources, United States Senate, Legislative Hearing on S. 397 – National Materials Corridor Partnership Act of 1999, October 7, 1999.

United States General Accounting Office, “U.S.-Mexico Border, Despite Some Progress, Environmental Infrastructure Challenges Remain,” GAO/NSIAD-00-26, Washington, DC, March 2000.

Carlsbad Area Office, U.S. Department of Energy, “Marquez Brick Kiln Demonstration, Santa Teresa, New Mexico / Ciudad Juarez, Mexico,” June 7, 2000.

Blackman, A., et al., “Tire Piles as an Environmental and Health Hazard on the U.S.-Mexico Border: A Preliminary Assessment Focusing on Paso Del Norte,” Resources for the Future, Washington, DC, September 26, 2001.

Jimenez, R., et al., “Technology Commercialization Forum, Initial Results and Path Forward,” Applied Sciences Laboratory, Inc., April 2002.

Center for Responsible Environmental Strategies, “Air Quality in the El Paso / Juarez Airshed,” Report to the Texas House Committee on Environmental Regulation, Austin, Texas, July 11, 2002.

Jimenez, R. and E. Maestas, “Recycling of Scrap Automotive Tires using Gasification Thermal Processing,” Applied Sciences Laboratory, Inc., September 4, 2002.

Jimenez, R., “Mitigating the Risk to Human Health with Technology Deployment,” Proceedings TIE Conference, Oakland, California, November 12, 2002.

Jimenez, R., “Deploying Technologies to Improve Public Health, Safety and Security of U.S.-Mexico Border Region Communities, National Border Technology Partnership Program Business Plan,” June 30, 2003.

Esparza-Baca, C. and R. Jimenez, “National Border Technology Partnership Program, Update of Problem Statements,” Applied Sciences Laboratory, Inc., September 2003.

Maestas, E. and R. Jimenez, “Demonstration of the Radio Frequency Identification (RFID) Transportation Security and Safety System,” Applied Sciences Laboratory, Inc., November 18, 2003.

Esparza-Baca, C. et al., “Innovative Technologies for Meeting High-Priority U.S.-Mexico Border Region Needs, Technology Assessments,” National Border Technology Partnership Program, Applied Sciences Laboratory, Inc., December 2003.

Corral, A. and R. Jimenez, “Clay Water Filter for Border Region Colonias, Initial Performance Evaluation,” National Border Technology Partnership Program, Applied Sciences Laboratory, Inc., February 2004.

Corral, A. and R. Jimenez, “Water Quality Investigation Ciudad Juarez Colonias,” National Border Technology Partnership Program, Applied Sciences Laboratory, Inc., March 2004.

Jimenez, R. and A. Corral, "Preliminary Performance Evaluation Oil-Fired Marquez Brick Kiln System," National Border Technology Partnership Program, Applied Sciences Laboratory, Inc., July 15, 2004.

Maestas, E., "Scrap Tires Piles in U.S.-Mexico Border Communities: A Human Health Risk Assessment," National Border Technology Partnership Program, Applied Sciences Laboratory, Inc., September 8, 2004.

Appendix II – Contributing Organizations

United States

Applied Sciences Laboratory, Inc.
Detection Sciences, Inc.
Economic Development Foundation
El Paso Electric Company
El Paso, Texas Fire Department
Fort Bliss Army Base
Laredo Development Foundation
Laredo, Texas Fire Department
Laredo Transportation Association
Los Alamos National Laboratory
New Mexico Environment Department
New Mexico State University
Nogales, Arizona Fire Department
Powers International Inc.
Rotary District 5520
Sandia National Laboratories
SolAqua, Inc.
Southwest Border Partnership
Southwest Center for Environmental Research and Policy
Southwestern Motor Transport, Inc.
Thermogenics, Inc.
TransMaritime, Inc.
Tucson Environmental Management Division
University of Texas, El Paso
White Sands Missile Range
United States Army Corps of Engineers
United States Congress
United States Department of Energy
United States Department of Health and Human Services
United States Environmental Protection Agency
United States Federal Emergency Management Agency

Mexico

Autonomous University of Ciudad Juarez
Autonomous University of Nuevo Leon
Centro Santa Catalina
Ciudad Juarez, Chihuahua, Office of Environmental and Civil Protection
Instituto Tecnologico y de Estudios Superiores de Monterrey
Maquiladora Association of Sonora
Mexico Consulate, Ciudad Juarez

Mexico Secretariat of Environment and Natural Resources
Mexico Secretariat of Health
National Institute of Nuclear Investigations
National Institute of Ecology
Nogales, Sonora Fire Department
Nogales, Sonora, Office of Civil Protection
Residuos Industriales Multiquim S.A. (RIMSA)
State of Sonora, Department of Ecology
State of Chihuahua, Department of Ecology and Environment
SUMEX (Xerox)

Binational

Border Environment Cooperation Commission
International Boundary and Water Commission
North American Development Bank
Rotary International
United States-Mexico Border Health Commission
United States-Mexico Foundation for Science
United States-Mexico Border Health Commission