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National Overview of Abandoned Mine Land Sites Utilizing The Minerals Availability System (MAS) and Geographic Information Systems (GIS) Technology

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INTRODUCTION

There is a growing concern and increasing consensus that abandoned mine lands (AML) pose a potential threat to the public health and environmental quality of the Nation. This concern is further complicated by a lack of agreement by land managers and public policy-makers on the dimension and scale of the abandoned mine land problem. Historically, most responses and efforts addressing abandoned mines have involved very site specific or localized studies requiring investment of large financial and human resources to complete. While locally valuable and essential in AML remediation and clean-up, these studies are expensive and give little indication of the dimension, scale, and priority at the National level. Additionally, as resources and budgets become more constrained, a new approach will be required to help planners and land managers allocate limited resources to the most serious environmental and public health priority areas.

As the steward for a large portion of Federal lands, the Department of the Interior (DOI), through the U.S. Geological Survey (USGS) and former U.S. Bureau of Mines (USBM), have compiled comprehensive national-scale mineral and natural resource databases. These databases, combined with the recent advances in spatial analysis technology, enable the USGS to address the AML issue, facilitate information flow to land use and environmental decision-makers, and provide analysis and support in the remediation of AML sites.

Presented within is an alternative methodology to the costly site-specific inventorying of abandoned mines lands. The approach demonstrates the capability of geographic information systems (GIS) technology to locate, identify, and filter mineral sites for abandoned mine land and other environmental issues; illustrates a cost-effective use of existing USGS databases to assist land managers and policy-makers; provides national-scale watershed and population comparisons allowing prioritization of AML areas; and creates an overview and framework for more specific statewide and localized watershed AML initiatives.

STUDY APPROACH

Overview

The approach utilized in this study combines the power of Environmental Systems Research Institute (ESRI) GIS software, existing minerals databases, and a logical method of filtering minerals data to locate areas or regions where significant mineral-related and mining activities have occurred. The technology combines AML information with other digital data to prioritize

sites on a National basis. Significant is a relative term and, when applied to mining activity, describes sites that contain metal or hardrock commodities as the primary commodity, and show evidence of past production. Logically, these localities, because of human activity and workings, are more likely to contain exposed physical and chemical hazards. Ultimately, these locations have potential to affect the public health and environment. Special emphasis is placed on these sites as they relate to Department of the Interior lands, watersheds, and populated regions.

The U.S. Geological Survey has numerous tabular and digital databases. By using GIS spatial processing, this information is queried and results graphically displayed. This permits rapid comparison and analysis of spatial relationships between disparate datasets and provides a means for land managers to locate, identify, and prioritize abandoned mine land areas, and affected watersheds.

Some of the mineral databases existing within the USGS include: the Mineral Resource Data System (MRDS), Rock Analysis Storage System (RASS), National Uranium Resource Evaluation (NURE) program, and the recently acquired Minerals Availability System (MAS). The focus of this report will be limited to the MAS database.

The national-scale overview takes a practical approach to scoping the AML issue. The analysis is dynamic and is presented in both tabular and graphic formats providing an effective way to characterize the AML problem. Results are a 1995 "snapshot" of AML sites from the MAS database and are heavily dependent upon spatial resolution of the digital data, its accuracy, completeness, and timeliness. Refinement of the analysis may be accomplished by including finer resolution datasets, the use of additional minerals and environmental databases, and ongoing statewide and watershed-level inventories and expertise.

Geographic Information Systems Technology

A major tool utilized to evaluate AML is geographic information systems (GIS). GIS is an integrated system of data, computer hardware, and software capable of storing, organizing, and integrating spatial information. GIS is ideal for processing, manipulating, and analyzing large, often cumbersome, tabular databases and relating this information to the surface of the earth. The strength of GIS lies in the capability to quickly, easily, and accurately describe, characterize, and display spatial relationships to facilitate informed decision-making.

The GIS hardware and software used in this study includes a UNIX-based Sun Sparcstation 2 workstation and peripherals and ESRI's Arc/Info version 6.1.1 software. The map products are

created in ARC/INFO and plotted on a Hewlett Packard HP650C inkjet plotting system.

A critical component of GIS analysis is data. Identifying and collecting existing digital data minimize the need to generate new data and avoids duplication of effort and expenditure of resources. Data availability and data resolution influence the application and type of analysis attempted. This analysis is completed at 1:2,000,000 scale resolution. The major datasets existed previously and were collected via internet.

Internet technology and data clearinghouses are important pathways to locate and access existing data. These tools are increasing in value as a mechanism for enhancing project efficiency, increasing information exchange, and fostering communication between scientists and stakeholders.

Data Layers

In GIS, ARC/INFO coverages represent themes or layers of information in the form of digital points, lines, or polygons. Coverages are mathematically registered to real-world coordinate systems and usually contain similar or related descriptive attributes. Typical examples include vegetation, hydrology, topography, and land status layers.

The major coverages used for this AML characterization include: mineral and mine site localities, Federal land management status, watershed or hydrologic unit code (HUC) boundaries, population (census) information, and national, state, and county boundaries. Each layer is described below. For additional metadata information (information about data) see Appendix A.

Mineral Localities

The mineral layer used in the analysis is the former U.S. Bureau of Mines' Mineral Availability System (MAS) database. MAS was created in the mid 1970's and is an automated tabular database for storage and retrieval of worldwide site-specific minerals information. MAS contains both proprietary and non-proprietary information and over 35 separate tables relating to location, extraction technology, economics, commodity type, and availability. MAS is one of the most comprehensive national-scale minerals databases available and contains data on over 209,000 (April 1995) sites in the United States, of which 202,000 are in the contiguous U.S.

Of particular interest is the Mineral Industry Location System (MILS) table. MILS is a non-proprietary subset of the MAS database

and contains data on location, type of operation, and status on all 209,000 locations in the U.S. When combined with commodity information from the COMMODITY table, it forms the foundation for the AML filtering methodology. Each MILS site has a unique sequence number which corresponds to Federal Information Processing Standard (FIPS) codes and is used to relate to other MAS tables. This relationship is essential for GIS integration and relational database structure. Locational reference is provided in degrees, minutes, and seconds (DMS) which are converted to decimal degrees for point generation and plotting. Since MILS is a subset of MAS, the term MAS/MILS frequently seen in the following graphics and tables, is understood to represent the MILS table.

Federal Land Management

A surface management layer called FEDLANDS is used to analyze the distribution on mine sites on Federal lands. The layer consists of boundary information for the lower 48 states and has Federal agency designations. The major land management agencies include: Bureau of Land Management (BLM), Bureau of Indian Affairs (BIA), U.S. Forest Service (USFS), National Park Service (NPS), Fish and Wildlife Service (FWS), Tennessee Valley Authority (TVA), and the Department of Defense (DOD). The land management layer originated in the USGS National Mapping Division and has an effective resolution of 1000 meters. The layer displays the Federal management responsibility and is useful for Department of the Interior AML scoping, planning, and land management activities.

Watershed Boundaries

A watershed layer called HUC2M is utilized to view the location of mineral sites in a watershed. HUC stands for hydrologic unit code and represents individual watershed boundaries. HUC codes are assigned to watersheds and respective subunits as part of a hierarchical naming convention described in U.S. Geological Survey Circular 878-A (USGS, 1982). The watershed layer encompasses the lower 48 states and was compiled in 1991 by the USGS Water Resources Division. HUC2M has an original map scale of 1:2,000,000 and effective resolution of 1000 meters.

Watersheds are common management and analysis units prevalent in many AML studies. This analysis incorporates and displays some results at the watershed level to provide consistency and utility to other watershed-based studies. In future GIS analysis of the MAS/MILS data, a finer resolution watershed coverage at 1:250,000 scale resolution has been completed for the Nation and will be incorporated.

Population Information

A critical layer for AML prioritization is the population layer. Studies of environmental and land use issues increase in value and become more effective when directly related to people and population centers. The population layer used is POP_100K. POP_100K was created by the U.S. Department of Commerce Bureau of Census and reflects 1990 census data. POP_100K contains over 523,000 point locations representing the centroids of census tracts across the country. Original scale of compilation was 1:100,000 and the data was obtained and formatted by the former USGS Branch of Resource Analysis.

National, State, and County Boundaries

Base cartographic boundary information is necessary for locational reference and effective display of a distribution or an analysis. The former USGS Branch of Resource Analysis provided the COUNTY2M coverage from which boundary layers were derived. The national, state, and county layers were created in 1991 by the USGS Water Resources Division and have an effective resolution 1:2,000,000 (1000 meters).

Data Formatting and Preprocessing

After the data are obtained, preprocessing and formatting are required to create ARC/INFO databases and perform GIS overlay and analysis. Such was the case for the Minerals Availability System.

Generic Structured Query Language (SQL) statements were designed to extract MILS and COMMODITY table information from the MAS database. Using UNIX system editors, original data were manipulated to arrange unique-id (sequence number), longitude, and latitude fields to fit the ARC Generate format. The resulting comma-delimited ASCII files and associated attributes were transferred to ARC/INFO for additional editing and processing. The ARC/INFO GENERATE command with POINT option was used to create a digital layer of mineral sites with the sequence number of each MILS point becoming a "relate item" for attribute linkage. The point attributes were merged to the mineral locations using the ARC/INFO JOINITEM command. Topology (spatial connectivity) between the points was established using the BUILD command with POINT option, resulting in a useable coverage for analysis.

Another preprocessing step involved CLIPPING the MAS/MILS mineral layer with the national boundary of the United States. The cookie-cutter procedure ensured the removal of extraneous points, including some questionable locations, and created a coupling of mineral sites to the land mass. In other words, clipping confirmed that mineral locations would be within the conterminous United

Table 1: Projection parameters for data layer registration and georeferencing.

Parameters	Values
Projection Name	Albers Equal Area
Units	Meters
Horizontal Datum	NAD27
1st Standard Parallel	29 30 00
2nd Standard Parallel	45 30 00
Central Meridian	-96 00 00
Latitude of Origin	23 00 00
False Easting	0.0 meters
False Northing	0.0 meters

States rather than offshore or in Canada or Mexico.

The other existing layers, HUC2M, FEDLANDS, POP_100K, and COUNTY2M, were procured and evaluated for consistency and compatibility with the minerals layer. Processing these layers required coordinate transformation and georeferencing the data to the same geographic coordinate system as the MAS/MILS data layer. The resulting coverages were put into an Albers Equal Area Projection (Table 1).

Data Processing and Analysis

After georeferencing, the coverages are ready for overlay and analysis. Overlay and analysis is accomplished through a series of digital unions, intersects, and statistical summaries. ARC/INFO mathematically overlays the layers and transfers attributes of one data layer to the attribute table of another. The unions create additional query capability and are fundamental in the prioritization scenarios shown in the watershed and population analysis. Typical ARC/INFO commands for these processes include UNION, MAPJOIN, INTERSECT, and IDENTITY. UNIONS are appropriate for polygon coverages while IDENTITY is mainly used for point coverages such as MAS/MILS and population.

A number of analytical layers were created. First, an IDENTITY was performed intersecting the MAS/MILS point location file with the FEDLANDS polygon file. This resulted in a MAS/MILS point coverage with Federal land management information. The minerals layer was subsequently joined to the watershed coverage, resulting in MAS/MILS point locations containing HUC codes. The STATISTICS command was used to compile the number of mineral sites per watershed and mineral locations per Federal land management category.

A similar process connected the population and watershed layers. An IDENTITY linked population information to the watershed layer creating population attributes with HUC codes. The STATISTICS command was repeated to summarize population per watershed. Both minerals and population statistics values are related by the HUC code and subsequently joined to the watershed coverage. These routines resulted in a watershed-based coverage with attributes about mineral localities, Federal land management status, and population.

The UNION process shows how the watershed coverage can quickly and easily be converted to a format capable of identifying mineral, population, management responsibility, and HUC relationships. A similar sequence can be repeated for additional layers as they become available, producing a capability to explore other prioritization scenarios and AML relationships.

Filtering Methodology and Tabular Results

The next major step involves filtering the digital minerals layer to identify a subset of priority or significant mineral sites for further detailed analysis. Logical criteria are used to define potentially hazardous sites that are summarized in subsequent tables and maps. The criteria include:

1) Analyze Federal land management responsibility in the lower 48 states emphasizing Department of the Interior (DOI) lands.

2) Evaluate hardrock commodity (metal) sites that may through alteration and chemical interaction have negative impact on the environment.

3) Filter commodity sites with evidence of past production -- assuming these areas have larger dimensions, more unreclaimed features, and higher likelihood of more physical and chemical hazards.

Federal Land Management Responsibility

At the time of this analysis, land management status information was located and obtained for all states except Alaska and Hawaii. This exclusion reduced the number of MAS/MILS sites investigated from 209,000 to approximately 202,000 (Table 2). Unless otherwise presented, the dataset analysis, statistics, and graphical displays will only include 202,000 sites for the contiguous United States. Moreover, the land management layers for Alaska and Hawaii, are probably now available and will be included in future analysis.

Table 2: General description of the distribution of sites in the Minerals Availability System (MAS) database, April 1995. Numbers are rounded to nearest thousand.

General MAS/MILS Description	MAS/MILS Sites (000's)
Worldwide	220
U.S. (50 States)	209
U.S. (Contiguous 48 States)	202
Non-federal (Contiguous 48 States)	109
Federal (Contiguous 48 States)	93

Table 2 shows a general listing and description of the MAS/MILS database. Although resolution dependent, roughly half or 49 percent of the total sites in MAS/MILS represent Non-federal ownership and management categories. Federal management responsibility is present in 46 percent of the sites in the lower 48 states. Additional Federal management statistics and summaries are displayed in ensuing graphics and tables.

Hardrock Commodities (Metals)

Although there can be chemical and physical hazards associated with industrial (sand and gravel) and energy-related (petroleum) deposits, the strength of the MAS/MILS database continues to be mineral information on base and precious metals. Hardrock and metal commodities such as gold, lead, zinc, copper, chromium and others are emphasized in MAS/MILS. These commodities, combined with their associated rock types and deposit characteristics, have the potential to generate toxic hazards that may cause environmental damage.

Another group of hardrock mineral commodities included in the analysis are uranium and phosphate. These commodities are included, because in the case of uranium, there is potential to generate radionucleide hazards, and phosphate is considered a bedded hardrock deposit.

Industrial and energy-related MAS/MILS locations are not included in this analysis. The excluded commodities are: coal, oil and gas, geothermal sites, sand, gravel, stone, clay, abrasives, silicon, perlite, and pumice (Table 3). Exclusion of these commodities reduced the number of sites in the lower 48 states for subsequent processing from 202,000 to approximately 116,000 sites. Sand, gravel, stone and coal account for the approximately 86 percent of the excluded sites.

Table 3: Summary of energy and industrial commodity sites in the Minerals Availability System (MAS) database, April 1995. Numbers are rounded to the nearest thousand.

Commodity Exclusion Screen	MAS/MILS Sites (000's)
Sand & Gravel	37
Stone	20
Coal	18
Clay	8
Geothermal	2
Pumice	1
Silicon	1
Perlite	< 1
Oil & Gas	< 1
Abrasives	< 1
No Primary Commodity Data	10

In addition, MAS/MILS contained nearly 10,000 sites with no data in the primary commodity field. Because no determination of hardrock commodity content could be made, these sites were removed from the analysis further reducing the known hardrock (metal) sites to 106,000 (Tables 3, 4).

MAS/MILS contains information on 202,000 locations in the lower 48 states. Hardrock commodities account for 106,000 or 52 percent of these locations. Of the 106,000 hardrock properties, approximately 65 percent occur on Federal lands, and 36,000 or 52 percent of these are managed by Department of the Interior (DOI) agencies. The Departments of Agriculture and Defense account for the majority of the non-Interior administered Federal sites.

By linking the MILS and COMMODITY tables from the MAS database it becomes possible for land managers interested in the specific impacts of selected mineral commodities such as lead, arsenic, or

Table 4: Summary of hardrock commodity Minerals Availability System (MAS) sites, April 1995. Numbers rounded to nearest thousand.

Hardrock Sites in the contiguous U.S.	MAS/MILS Sites (000's)
Total Sites	202
Hardrock Sites	106
Sites on Federal Lands	69
Sites on Private Property	37
Sites on DOI Administered Federal Land	36
Sites on Non-DOI Administered Federal Land	33

radionucleide contamination to pinpoint specific sites or areas for further evaluation and prioritization. Additionally, future analysis utilizing energy related databases and commodity data can and should be implemented to define their contribution to the hazardous impacts related to minerals and natural resources.

Evidence of Production

The final criterion used in the filtering process is production. The MILS table contains an attribute item called CUR which represents current status of a property or site. It has up to 10 status categories evaluating production and levels of exploration activity. The sites with evidence of past production include the following status types: producers, past-producers, temporarily shutdown operations, and intermittent producers. All other status types such as exploratory and raw prospects are excluded from the analysis. Implementing this filter reduced the total number of hardrock sites for further analysis from 106,000 to approximately 48,000 sites.

Table 5 shows data on past production. Production is associated with 45 percent or 48,000 of all hardrock properties. Of this amount, 28,000 qualify as past-producer hardrock sites on Federal lands, and 15,000 are Department of the Interior agency sites. Most of the non-Interior sites are managed by the Forest Service.

In summary, the filtering methodology has identified subsets of mineral information and abandoned mine lands. These subsets are valuable for additional AML studies and analysis in this report.

The results of the formatting, processing, filtering, and analysis clearly point to the value of GIS in manipulating large databases. The MAS/MILS database with over 209,000 locations has been quickly and easily characterized to identify and locate

Table 5: Summary of past-producer hardrock commodity Minerals Availability System (MAS) sites, April 1995. Numbers are rounded to nearest thousand.

Past-Producer Sites in the contiguous U.S.	MAS/MILS Sites (000's)
Total Sites	202
Hardrock Sites	106
Total Past-Producer Sites	48
Sites on Federal Lands	28
Sites on Private Property	20
Sites on DOI Administered Federal Land	15
Sites on Non-DOI Administered Federal Land	13

important past producing hardrock mineral sites across the conterminous United States. The subset most critical to land managers and policy-makers depends on the constituency's needs and the specific criteria of investigation. The Department of the Interior may be interested in the 15,000 sites on DOI lands, Congress may be interested in 28,000 Federal sites, and the Environmental Protection Agency may be interested in the 48,000 past-producers.

Filtering data with GIS is not only effective in saving time and money in AML inventories, it gives a new appreciation for an under-utilized minerals database by devising a new application of MAS/MILS. The power of GIS combined with a logical AML methodology add flexibility to the database and create opportunities to query other existing datasets. The results help define the AML issue, identify its scale and potential extent, and give the AML problem a new perspective for land managers and policy-makers, both at a National and state level.

One example of this flexibility resulted in analysis of the AML issue by producing state-by-state statistics. Intersecting point location information with Federal land status created attributes showing past-producer hardrock mineral sites per state. Statistical queries were utilized, and Federal and private property categories were generated (Table 6). Results of the AML filter at the state-by-state level verifies that the abandoned mine land issue, although present in the eastern United States, is mainly a western state issue. This does not diminish the focus on eastern states; it only shows there may be more areas on which to focus in the west, especially if one considers Federal land management issues and responsibility.

More importantly, this information and approach should be used as an AML planning tool and provide a foundation for local community contributions in the AML issue. State and local administrators can easily gauge the scope of the AML issue in their respective states. The methodology and results can be used to explain existing AML watershed studies, identify areas where additional focus, effort, and analysis are required, and assist planners in selecting the next area of federally-sponsored statewide AML investigation.

Additional GIS prioritization layers must be incorporated to refine this analysis. Analysis should be augmented by detailed state-by-state AML inventories, mineral production, geology, watershed, and other criteria to further assist local policy-makers. Additional criteria can generate new subsets of information from which remediation, restoration, and land management decisions can be made.

Table 6: Past-producer hardrock commodity sites by state. Compiled at 1:2,000,000 scale resolution.

STATE	FEDERAL	NON-FEDERAL	TOTAL
Alabama	51	780	831
Arizona	2941	562	3503
Arkansas	65	498	563
California	4657	1167	5824
Colorado	6310	992	7302
Connecticut	0	137	137
Delaware	0	9	9
Florida	1	122	123
Georgia	76	532	608
Idaho	1519	119	1638
Illinois	92	182	274
Indiana	12	27	39
Iowa	5	55	60
Kansas	0	56	56
Kentucky	1	100	101
Louisiana	3	55	58
Maine	1	198	199
Maryland	0	426	426
Massachusetts	0	88	88
Michigan	16	474	490
Minnesota	21	566	587
Mississippi	0	21	21
Missouri	408	5240	5648
Montana	1644	336	1980
Nebraska	0	4	4
Nevada	3644	74	3718
New Hampshire	5	115	120
New Jersey	0	226	226
New Mexico	817	467	1284
New York	2	499	501
North Carolina	612	865	1477
North Dakota	2	15	17
Ohio	0	61	61
Oklahoma	2	271	273
Oregon	1257	107	1364
Pennsylvania	1	789	790
Rhode Island	0	5	5
South Carolina	18	143	161
South Dakota	476	172	648
Tennessee	218	540	758
Texas	5	371	376
Utah	1939	205	2144
Vermont	4	39	43
Virginia	213	700	913
Washington	476	234	710
West Virginia	11	22	33
Wisconsin	2	667	669
Wyoming	632	287	919
Unknown	0	0	97
TOTALS	28,159	19,620	47,876

Graphic Results and Map Descriptions

The graphical capability of GIS is important to demonstrate the results of the spatial analysis. Colorful and informative map products provide a mechanism to display complex analysis in an understandable way. Since a map product is created, the analysis can be referenced to any "geographic" layer including political boundaries, population, quadrangle areas, or watersheds to name a few.

The following discussion focuses on map descriptions and graphic output generated in the AML overview. The plates, in Appendix B, step through a "mineral site data reduction process" similar to that described in the filtering methodology. Additional emphasis is placed on the location of mineral sites on Federal lands and the priorities established by watershed and population layers.

Land Status, Hardrock (Metals) Sites, and Past-Production Maps

Plates 1-5 display the data reduction from all MAS/MILS sites in the contiguous United States to sites on Department of the Interior lands. Plates 1 through 5 contain 202,000; 106,000; 48,000; 28,000, and 15,300 mineral sites respectively. State and county boundaries provide a locational reference. Plates 6-10 show the same reduction of mineral localities with the Federal land management layer as a locational reference and culminates in the display of mine sites on DOI administered lands.

Plate 1 shows the distribution of all MAS/MILS sites in the contiguous United States. When tabular databases are graphically displayed some previously hidden patterns and trends become evident. Observation of the dataset indicates previously unseen data anomalies or gaps which show up "stateline faults". This is the case in Nebraska, Kansas, and Texas. Kansas and Nebraska were never under contract with the U.S. Bureau of Mines to collect mineral information data in their respective states. Texas did collect mineral information under contract, but sand and gravel were ubiquitous; therefore, these commodities were never inventoried or entered into MAS/MILS (Michael Sawyer, personal communication). It points out a caveat about some databases; they may contain any number of errors, both of commission and omission.

Plate 2 shows the distribution of 106,000 hardrock commodity locations after industrial and energy-related sites are filtered from the database. This results in a 48 percent reduction from the total number of sites in the contiguous United States. Additional filtering and reduction of sites show a pattern that continues throughout the analysis; the majority of significant AML sites are in the Appalachian region in the eastern U.S., Missouri and Arkansas, and the 11 western states.

Plate 3 shows 48,000 past-producer hardrock locations and results in a 76 percent reduction from the contiguous total and a 55 percent reduction from the hardrock commodity screen. Missouri and the Appalachian region dominate the eastern U.S., whereas the Black Hills of South Dakota, Colorado Mineral Belt, Montana Belt Supergroup, and Sierra Foothill regions remain prominent in the west.

Plate 4 shows 28,000 past-producer hardrock sites on Federal lands. Data reduction is 86 percent from the contiguous United States total and 42 percent of the past-producer hardrock total. The most dramatic change on the map is the disappearance of mineral sites in the eastern United States due to a lack of Federal tracts in the region.

Plate 5 in this series displays past-producer hardrock sites on Department of the Interior administered lands, resulting in a 93 percent reduction from the original 202,000 sites. The sites are entirely located in the western U.S. Additional statistics on DOI responsibility are displayed on Plate 10.

Plates 6, 7, 8 show the Federal land management status in relation to the entire MAS/MILS database, hardrock commodities, and past-producer hardrock sites respectively. BLM and Forest Service dominate the surface management patterns, particularly in the western United States. Other agencies shown, but not previously discussed include: Bureau of Reclamation (BOR), Atomic Energy Commission (AEC), Agricultural Research Service (ARS), Department of State (DOS), and Tennessee Valley Authority (TVA).

Plates 9 and 10 characterize the past-producer hardrock sites on Federal lands. The maps contain statistics showing the major Departmental and agency responsibility. The Departments of the Interior (DOI) and Agriculture (DOA) dominate with 55 percent or 15,300 sites and 44 percent or 12,400 sites respectively. Within DOI, the Bureau of Land Management overshadows all other agencies with responsibility for nearly 94 percent of the sites. Bureau of Indian Affairs, National Park Service, and Fish and Wildlife Service contain 3, 2, and less than 1 percent respectively. The AML issue, in the case of Federal management and responsibility, is principally a western states problem.

Federal management statistics, particularly in the case of the BLM, are in need of detailed analysis. In the western United States, the BLM has a checkerboard land management pattern due to railroad land grants. The continuous management pattern shown in the 1:2,000,000 scale Federal lands layer does not reflect this pattern and can result in misleading conclusions about the responsibility and number of suspected BLM AML sites. Analysis of the land status at 1:100,000 scale with higher resolution could significantly reduce the number of sites on BLM lands.

Watershed Priority Assessment

Watersheds boundaries are used in environmental and AML studies. Unlike political boundaries, they are natural, reflect the landscape, and often control and contain the effects of AML sites and pollution. Plates 11-13 and Tables 7a-10b display watershed comparisons and statistics to help planners prioritize AML sites based upon watersheds across the Nation.

The maps illustrate the 48,000 past-producer hardrock MAS/MILS sites in watersheds by classifying the frequency of AML sites or AML "density" per watershed. AML classification ranges from zero sites per watershed to areas showing greater than 300 AML sites per watershed. Querying the formatted watershed attributes leads to a number of potential AML priority areas or "bulls-eyes" in the eastern and western United States (Tables 7a, 7b).

Plate 11 and Tables 7a and 7b describe the watersheds and their relative AML "densities" by listing the watersheds affected, HUC codes, name and location of the watershed basins or sub-basins, and the number of MAS/MILS AML sites per watershed. Plate 11 includes Federal land status and private ownership. The map provides a comprehensive look at the AML impact on Federal versus private lands. The statistics show AML pollution is more than just a Federal problem and remediation efforts have to account for

Table 7a: Watershed priority assessment based on MAS/MILS sites on Federal and Non-federal lands. Watersheds containing greater than 300 past-producer hardrock MAS/MILS sites. (Plate 11)

HUC CODES	WATERSHED NAMES AND LOCATION	MAS/MILS SITES
10030101	Upper Missouri; MT	329
4010201	St. Louis; MN, WI	308
18010211	Trinity; CA	311
7090003	Pecatonica; IL, WI	367
18020125	Upper Yuba; CA	424
10190005	St. Vrain; CO	676
10190004	Clear Creek; CO	1343
11020001	Arkansas Headwaters; CO	724
14030004	Lower Dolores; CO, UT	350
11020002	Upper Arkansas; CO	578
14030002	Upper Dolores; CO, UT	875
14030003	San Miguel; CO	519
7140102	Meramec; MO	393
7140104	Big; MO	380
14080104	Animas; CO, NM	327
11070207	Spring; KS, MO, OK	2996
6010108	Nolichucky; NC, TN	686
15050301	Upper Santa Cruz; AZ	370

potential pollution from both sources. These statistics suggest additional effort and resources should be targeted on Minnesota, Wisconsin, Missouri, North Carolina, Tennessee, Pennsylvania, Colorado, Arizona, Montana, California, and Nevada.

Plate 12 illustrates the relationship of AML sites and watersheds to Federal land management status only. A familiar pattern emerges as the majority of high AML frequency watersheds are apparent in the western United States, particularly in Colorado, California, Arizona, Nevada, and Montana. Other potential remediation target areas occur in South Dakota, Missouri, Tennessee and North Carolina (Tables 8a, 8b).

Plate 13 and Tables 9a, 9b, and 9c display important watersheds when compared to Department of the Interior administered lands. These results emphasize the need for Colorado to be a high priority area or focal point of AML remediation. Some of the identified priority areas such as the Arkansas River and Animas River watersheds in Colorado are already subject to detailed AML investigations and remediation programs. This type of analysis can highlight other watersheds and other states for additional work.

Table 7b: Watershed priority assessment based on MAS/MILS sites on Federal and Non-federal lands. Watersheds containing between 200 and 300 past-producer hardrock MAS/MILS sites. (Plate 11)

HUC CODES	WATERSHED NAMES AND LOCATION	MAS/MILS SITES
17010201	Upper Clark Fork; MT	232
10120109	Middle Cheyenne Spr.; SD	279
16040105	Middle Humboldt; NV	214
16040108	Lower Humboldt; NV	212
2040106	Lehigh; PA	285
7060005	Apple-Plum; IL, IA	257
16060001	Dixie Valley; NV	206
16040107	Reese; NV	223
18020128	North Fork American R.; CA	258
2060003	Gunpowder-Patapsco; MD, PA	245
16060010	Fish Lake; NV, CA	225
10190001	South Platte Headwaters; CO	215
14030005	Upper Colorado-Kane Spr.; CO	250
14020006	Uncompahgre; CO	290
10290109	Lake of the Ozarks; MO	230
8020202	Upper St. Francis; MO	257
18100100	Southern Mojave; CA	239
15070102	Agua Fria; AZ	238
15030105	Bouse Wash; AZ	205
3150104	Etowah; GA	222

Table 8a: Watershed priority assessment based on MAS/MILS sites on Federal lands. Watersheds containing greater than 300 past-producer hardrock MAS/MILS sites. (Plate 12)

HUC CODES	WATERSHED NAMES AND LOCATION	MAS/MILS SITES
18010211	Trinity; CA	306
18020125	Upper Yuba; CA	409
10190005	St. Vrain; CO	415
10190004	Clear Creek; CO	955
11020001	Arkansas Headwaters; CO	680
14030004	Lower Dolores; CO, UT	346
11020002	Upper Arkansas; CO	537
14030002	Upper Dolores; CO, UT	873
14030003	San Miguel; CO	512

Table 8b: Watershed priority assessment based on MAS/MILS sites on Federal lands. Watersheds containing between 200 and 300 past-producer hardrock MAS/MILS sites. (Plate 12)

HUC CODES	WATERSHED NAMES AND LOCATION	MAS/MILS SITES
10030101	Upper Missouri; MT	241
10120109	Middle Cheyenne Spr.; SD	242
16040105	Middle Humboldt; NV	210
16040108	Lower Humboldt; NV	212
16060001	Dixie Valley; NV	206
16040107	Reese; NV	223
18020128	North Fork American R.; CA	257
16060010	Fish Lake; NV, CA	225
14030005	Upper Colorado-Kane Spr.; CO,	245
14020006	Uncompahgre; CO	284
14080104	Animas; CO, NM	297
6010108	Nolichucky; NC, TN	228
18100100	Southern Mojave; CA	233
6010202	Little Tennessee; GA, NC	202
15070102	Agua Fria; AZ	215
15030105	Bouse Wash; AZ	205
15050301	Upper Santa Cruz; AZ	272

Population Priority Assessment

An additional method to prioritize watersheds and AML issues is to compare abandoned mine lands to population. Plates 14-16 provide three different ways of comparison; first, by showing the general population distribution; secondly, by comparing mineral sites to population density; and finally, by using GIS to query the watershed coverage for specific mineral and population parameters.

Table 9a: Watershed priority assessment based on MAS/MILS sites on Department of the Interior lands. Watersheds containing greater than 300 past-producer hardrock MAS/MILS sites. (Plate 13)

HUC CODES	WATERSHED NAMES AND LOCATION	MAS/MILS SITES
10190004	Clear Creek; CO	648
11020001	Arkansas Headwaters; CO	444
14030004	Lower Dolores; CO, UT	322
11020002	Upper Arkansas; CO	506
14030002	Upper Dolores; CO, UT	745
14030003	San Miguel; CO	364

Table 9b: Watershed priority assessment based on MAS/MILS sites on Department of the Interior lands. Watersheds containing between 200 and 300 past-producer hardrock MAS/MILS sites. (Plate 13)

HUC CODES	WATERSHED NAMES AND LOCATION	MAS/MILS SITES
16040105	Middle Humboldt; NV	210
16040108	Lower Humboldt; NV	212
16060001	Dixie Valley; NV	206
16060010	Fish Lake; NV, CA	214
15030105	Bouse Wash; AZ	205

Plate 14 shows 48,000 past-producer hardrock sites in the United States and a population distribution layer. Population was queried and divided into four major categories ranging from one person per watershed to over 250,000 people per watershed.

Outside of a few highly populated watersheds in and around Denver, Salt Lake City, Albuquerque, Phoenix, and Tucson the majority of population exists on the east coast, industrial midwest, and west coast. Surprisingly, there are a few watersheds with zero population. This may be due to some watershed boundaries coinciding with lakes, therefore containing no resident population, or population values represented by centroids of census tracts falling outside of watersheds areas and not overlapping or intersecting the watershed boundaries.

Population density per watershed is displayed in Plate 15. This map highlights the urban areas and major cities in the country. In addition, the 48,000 AML sites are categorized and overlaid with a hatch-pattern which identifies and compares AML locations to the cities and urban areas. Future analysis of this data combined with water-supply and water-quality data can be used to show the affect of AML sites on the public water supply to population centers.

Table 9c: Watershed priority assessment based on MAS/MILS sites on Department of the Interior lands. Watersheds containing between 100 and 200 past-producer hardrock MAS/MILS sites. (Plate 13)

HUC CODES	WATERSHED NAMES AND LOCATION	MAS/MILS SITES
10030101	Upper Missouri; MT	122
17100310	Lower Rogue; OR	126
17100308	Middle Rogue; OR	125
10080004	Muskrat; Wy	163
16060008	Spring-Steptoe Valleys; NV	145
16040107	Reese; NV	178
16020306	Great Salt Lake Desert; UT	146
18020128	North Fork American R.; CA	117
16050202	Middle Carson; NV	120
16030005	Lower Sevier; UT	119
16060011	Ralston-Stone Cabin Valleys; NV	139
16030007	Upper Beaver; UT	130
14030005	Upper Colorado-Kane Spr.; CO, UT	194
18090203	Death Valley; CA, NV	115
14070001	Upper Lake Powell; UT	154
14080104	Animas; CO, NM	164
16060015	Ivanpah-Pahrump; CA NV	143
18090206	Antelope-Fremont Valleys; CA	144
18090208	Mojave; CA	130
18100100	Southern Mojave; CA	177
15030104	Imperial Reservoir; AZ, CA	136
15050304	Brawley Wash; AZ	109
15050202	Upper San Pedro; AZ	106

Another example of the analysis and query capability of GIS is shown in Plate 16. Watersheds are selected and displayed based upon two criteria; 1) basins containing greater than 100 past-producer hardrock AML sites, and 2) specific population distributions. Population is divided into four general categories: 1-50,000 people, 50,001 to 100,000 people, 100,001 to 250,000 people, and greater than 250,000 people. The results, shown in Tables 10a and 10b, suggest the South Platte River system in Clear Creek County of Colorado and the Spring watershed in southwestern Missouri may become high priority remediation targets.

The highlighted watersheds represent one approach to identifying priority areas. Additional data, criteria and analysis can identify other watersheds of importance and will be summarized in future reports. Tremendous flexibility exists in selecting the criteria providing politicians, planners, and land managers ability to generate additional queries and develop additional insight in the AML issue.

Table 10a: Watershed priority assessment based on MAS/MILS sites and population. HUC with past-producer hardrock MAS/MILS sites greater than 100 and population greater than 250,000 people. (Plate 16)

HUC CODES	WATERSHED NAMES AND LOCATION	MAS/MILS SITES
2040106	Upper Delaware; Lehigh, PA	285
2040203	Lower Delaware; Schuylkill, PA	138
2050306	Lower Susquehanna; MD, PA	106
2060003	Gunpowder-Patapsco; MD, PA	245
10190004	South Platte; Clear Creek, CO	1343
10190002	Upper South Platte; CO	128
7140102	Meramec; MO	393
3010101	Upper Roanoke, VA	138
18090206	Antelope-Fremont Valleys; CA	188
18090208	Mojave; CA	140
3050105	Upper Broad; NC, SC	171
15070102	Agua Fria; AZ	238
3150104	Etowah; GA	222
15050100	Middle Gila; AZ	180
15050301	Upper Santa Cruz; AZ	370
15050302	Rillito; AZ	110

Table 10b: Watershed priority assessment based on MAS/MILS sites and population. HUC with past-producer hardrock MAS/MILS sites greater than 100 and population greater than 100,000 and less than 250,000 people. (Plate 16)

HUC CODES	WATERSHED NAMES AND LOCATION	MAS/MILS SITES
4010201	St. Louis; MN, WI	308
1040002	Lower Androscoggin; ME, NH	105
17100308	Middle Rogue; OR	127
7090003	Pecatonica; IL, WI	367
7060005	Apple-Plum; IL, WI, IA	257
10190005	St. Vrain; CO	676
10300102	Lower Missouri-Moreau; MO	140
11020002	Upper Arkansas; CO	578
5050001	Upper New; NC, VA	106
11070207	Spring; KS, MO, OK	2996
6010108	Nolichucky; NC, TN	686
3150105	Upper Coosa; AL, GA	101

CONCLUSIONS

GIS processing and analysis used to study the abandoned mine land issue is powerful and dynamic. The work accomplished to date characterizes significant mineral properties of a national-scale minerals database and identifies and locates 48,000 current or past-producer hardrock locations for additional study. The analysis, tables and graphics present a "snapshot" of the AML issue and allows land managers and policy-makers at the state and Federal level to quickly assess the AML issue and focus energies and resources on these areas. Population and watershed information is incorporated to assist in establishing additional priorities. Statistics generated to quantify the AML affects at the state and watershed-level establish a framework to incorporate additional detailed watershed studies.

The advantage of this methodology is that it can assimilate information from an unlimited number of tabular and digital natural resource databases. Much work remains to be done to further prioritize sites and evaluate the abandoned mine land problem. Future tasks can include:

1) Incorporate additional minerals databases such as MRDS, RASS, NURE, and other geochemical data. Add rock type, geology, and deposit model information.

2) Increase the scale (preferably 1:100,000) of the digital data and analysis, specifically land status, state and county boundaries, and watersheds.

3) Summarize Alaska and Hawaii AML information.

4) Include detailed statewide and watershed-level AML inventories currently in progress. Present additional statistics from these data for local community evaluation, interaction, and partnership development.

5) Identify additional prioritization and ranking layers. These may include mineral production data, precipitation, hydrology buffers, vegetation, slope and aspect, topography, biodiversity, water quality, ecosystem, and demographic information.

6) Determine energy and industrial mineral contributions into AML and perform specific commodity analysis; integrate with the Environmental Protection Agency "superfund" and toxic release databases.

7) Add 3-Dimensional visualization and remote sensing capability and analysis to investigate AML priorities.

8) Investigate physical hazards associated with past mining activities.

Because the AML issue is complex and has many parameters that influence the type of hazards, pollution, and acid mine drainage, GIS becomes a preferred tool to evaluate these complexities. Utilizing GIS and augmentation of this analysis by completing these additional tasks can lead to and enhance informed decision-making, create additional insights, focus limited resources, and provide an integrated and comprehensive approach to remediating AML sites.

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Goklany, I.M., Coppa, L.V., Kaas, L.M., and Ferderer, D.A., 1996, Watersheds Most-at-Risk Due to Abandoned Mines on Federal Lands, Paper in Proceedings of the American Water Resources Association Annual Summer Symposium, Syracuse, NY, July 14-17, 1996, 12 p.

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Ryder, J.L., 1994, Active-, Inactive-, and Abandoned Mine Information and Selected Geochemical Data for the state of Colorado: U.S. Geological Survey Open File Report 94-579 Diskette Version, 6 p.

Sawyer, M., 1995, Personal communication, Former U.S. Bureau of Mines Minerals Availability System (MAS) Database Analyst.

U.S. Geological Survey, 1982, A U.S. Geological Data Standard: Codes for the Identification of Hydrologic Units in the United States and Caribbean Outlying Areas: U.S. Geological Survey Circular 878-A, 115 p.

Appendix A: Metadata Documentation for Digital GIS Coverages

State and County Boundaries

Doc-Rev	0.9.6
Create-Date	910319.131547
Update-Person	Mark Negri
Update-Date	920214.083409
Cover	COUNTY2M
Workspace	/dsdl/datalib/cusa/tiles/cusa
Extent	-2369407, 250819, 2264015, 3176391
Precision	Single
Tolerances	30,20
Number-Arcs	12365
Number-Segs	272116
Number-Polys	5062
Number-Points	5061
Number-Tics	197
Number-Annos	0
Theme	1:2,000,000 Base Maps
Description	Counties in Conterminous United States
Contact Person	Doug Nebert
Contact-Inst.	Doug @FTS959-5691, M. Negri @FTS959-5613
Organization	USGS-Water Resources Division
Cover-Rev	unknown
Location	Conterminous United States
Resolution	approximately 1 km.
Scale	1:2,000,000
Archive	Maintained on line on DIS2QVARSA, library CUSA
Pub-Status	For USGS and Cooperator use only
Citation1	USGS Files: 1:2,000,000 scale digital map of counties and county equivalents in the conterminous U.S.

HUC - Watershed Boundaries

Doc-Rev	0.9.8
Create-Date	910429.145710
Update-Person	K. Lanfear
Update-Date	930406.142001
Cover	HUC2M
Workspace	/srv1/nws/cusa
Extent	-2362603, 269207, 2264015, 3175350
Precision	Single
Tolerances	2,20
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Number-Segs	476096
Number-Polys	4093
Number-Points	4092
Number-Tics	197
Number-Annos	0
Theme	Hydrologic Units
Description	1:2,000,000 Hydrologic Units map of the U.S

HUC - Watershed Boundaries (continued)

Contact Person	Kenneth J. Lanfear
Contact-Inst.	lanfear@qvarsa.er.usgs.gov, 703-648-6852
Organization	USGS
Cover-Rev	1.1.1
Location	Conterminous United States
Resolution	approximately 1 km.
Scale	1:2,000,000
Archive	National Water Summary DSDL
Pub-Status	Internal
Citation1	USGS Files: 1,200,000 scale map of hydrologic units in the conterminous U.S.

Population Layer

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Create-Date	910926.11104
Update-Person	Mark Negri
Update-Date	920214.082246
Cover	Pop_100K
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Precision	Single
Tolerances	460,0
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Number-Segs	0
Number-Polys	0
Number-Points	523,205
Number-Tics	4
Number-Annos	0
Theme	1990 U.S. Census Population
Description	Point coverage containing 1990 Census data
Contact Person	Doug Nebert
Contact-Inst.	Doug @FTS959-5691, M. Negri @FTS959-5613
Organization	USGS-Water Resources Division
Cover-Rev	unknown
Location	Conterminous United States
Resolution	variable
Scale	1:100,000
Archive	Maintained on line on DIS2QVARSA, library CUSA
Pub-Status	Not reviewed
Citation1	U.S. Department of Commerce, Bureau of Census: 1990 Census of Population and Housing Public Law 94-171.

Federal Land Management Boundaries

Information regarding the Federal land boundaries is incomplete at this time. Data originated in the USGS National Mapping Division and provided by the former USGS Branch of Resource Analysis, Reston, VA.

Minerals Availability System (MAS)

Doc-Rev	6.694
Create-Date	941201
Update-Person	D. Ferderer
Update-Date	941201
Cover	US_MILS
Workspace	/dk3/data/us/general
Extent	-3244262, -1997932, 3533413, 5963403
Precision	Single
Tolerances	5,0
Number-Arcs	0
Number-Segs	0
Number-Polys	0
Number-Points	205,096
Number-Tics	4
Number-Annos	0
Theme	Various mineral base maps
Description	Mineral locations and properties in the U.S.
Contact Person	Bill Ferguson, Don Bleiwas
Contact-Inst.	(303) 236-8747 or (303) 236-5200
Organization	USGS-Mineral Information Team (MIT)
Cover-Rev	unknown
Location	Conterminous United States
Resolution	variable
Scale	variable
Archive	Maintained on MAS2 server, MIT, Denver CO
Pub-Status	Portions are Public Domain
Citation1	Former U.S. Bureau of Mines Minerals Availability System Database. Numerous inputs and table criteria. For additional information see: Deposit Information Manual and Data Dictionary, Version 6.694.

Appendix B: Plates showing the distribution and analysis of abandoned mines, MAS/MILS locations, Federal lands, watersheds, and population for the contiguous United States.

1) MAS/MILS Locations in the Contiguous United States

2) Hardrock Commodity MAS/MILS Locations in the Contiguous United States

3) Past-Producer Hardrock MAS/MILS Locations in the Contiguous United States

4) Past-Producer Hardrock MAS/MILS Locations on Federal Lands in the Contiguous United States

5) Past-Producer Hardrock MAS/MILS Locations on Department of the Interior Lands

6) Federal Lands and MAS/MILS Locations in the Contiguous United States

7) Federal Lands and Hardrock MAS/MILS Locations in the Contiguous United States

8) Federal Lands and Past-Producer Hardrock MAS/MILS Locations in the Contiguous United States

9) Past-Producer Hardrock MAS/MILS Locations on Federal Lands in the Contiguous United States

10) Past-Producer Hardrock MAS/MILS Locations on Department of the Interior Lands

11) Watershed Priority Assessment Based on Past-Producer Hardrock MAS/MILS Locations in the Contiguous United States

12) Watershed Priority Assessment Based on Past-Producer Hardrock MAS/MILS Locations on Federal Lands in the Contiguous United States

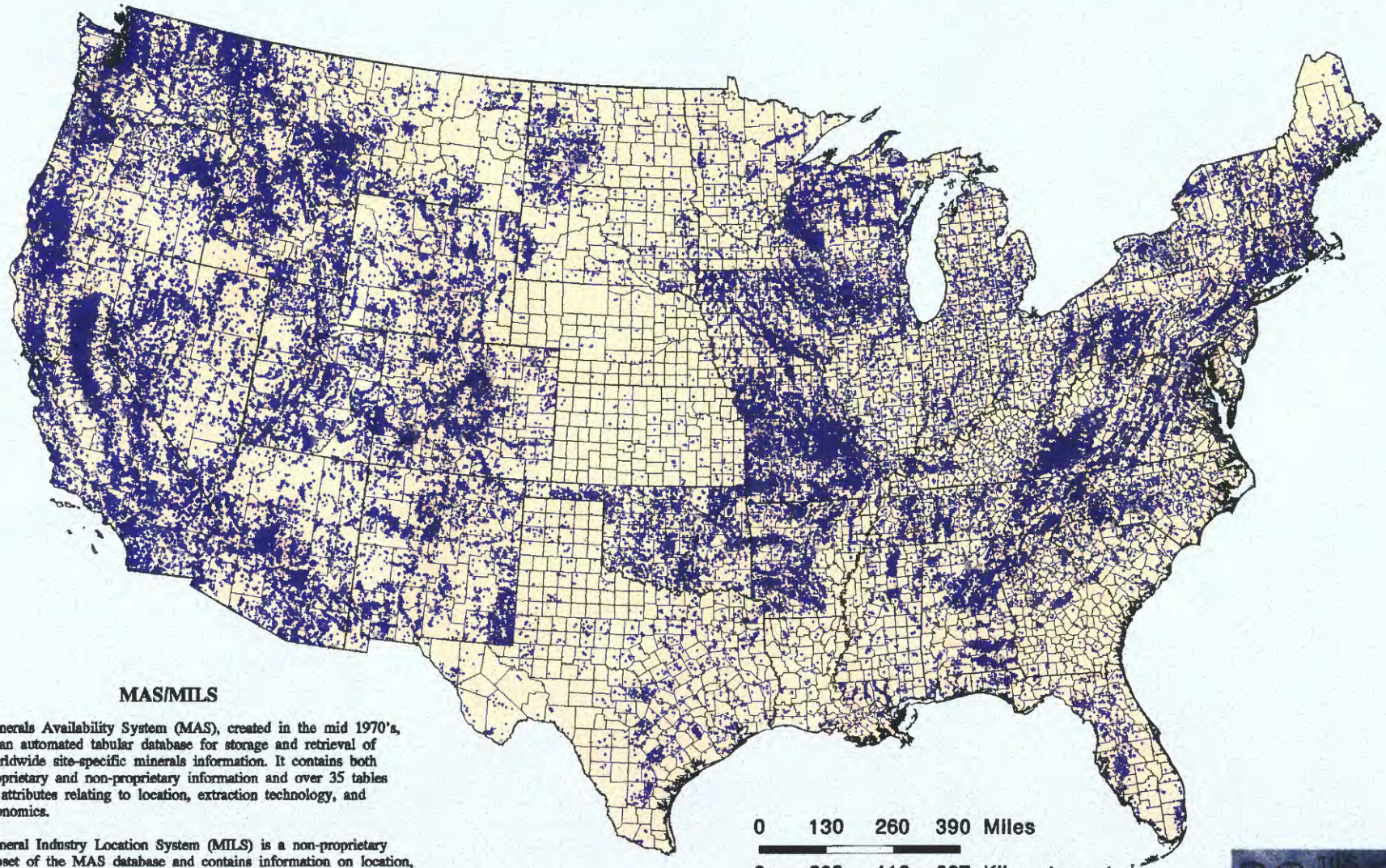
13) Watershed Priority Assessment Based on Past-Producer Hardrock MAS/MILS Locations on Department of the Interior Lands in the Contiguous United States

14) Population Per Watershed Compared to Past-Producer Hardrock MAS/MILS Locations in the Contiguous United States

15) Population Density Per Watershed Compared to Past-Producer Hardrock MAS/MILS Locations in the Contiguous United States

16) Watershed Priority Assessment Based on Population and Past-Producer Hardrock MAS/MILS Locations in the Contiguous United States

MAS/MILS LOCATIONS IN THE CONTIGUOUS UNITED STATES



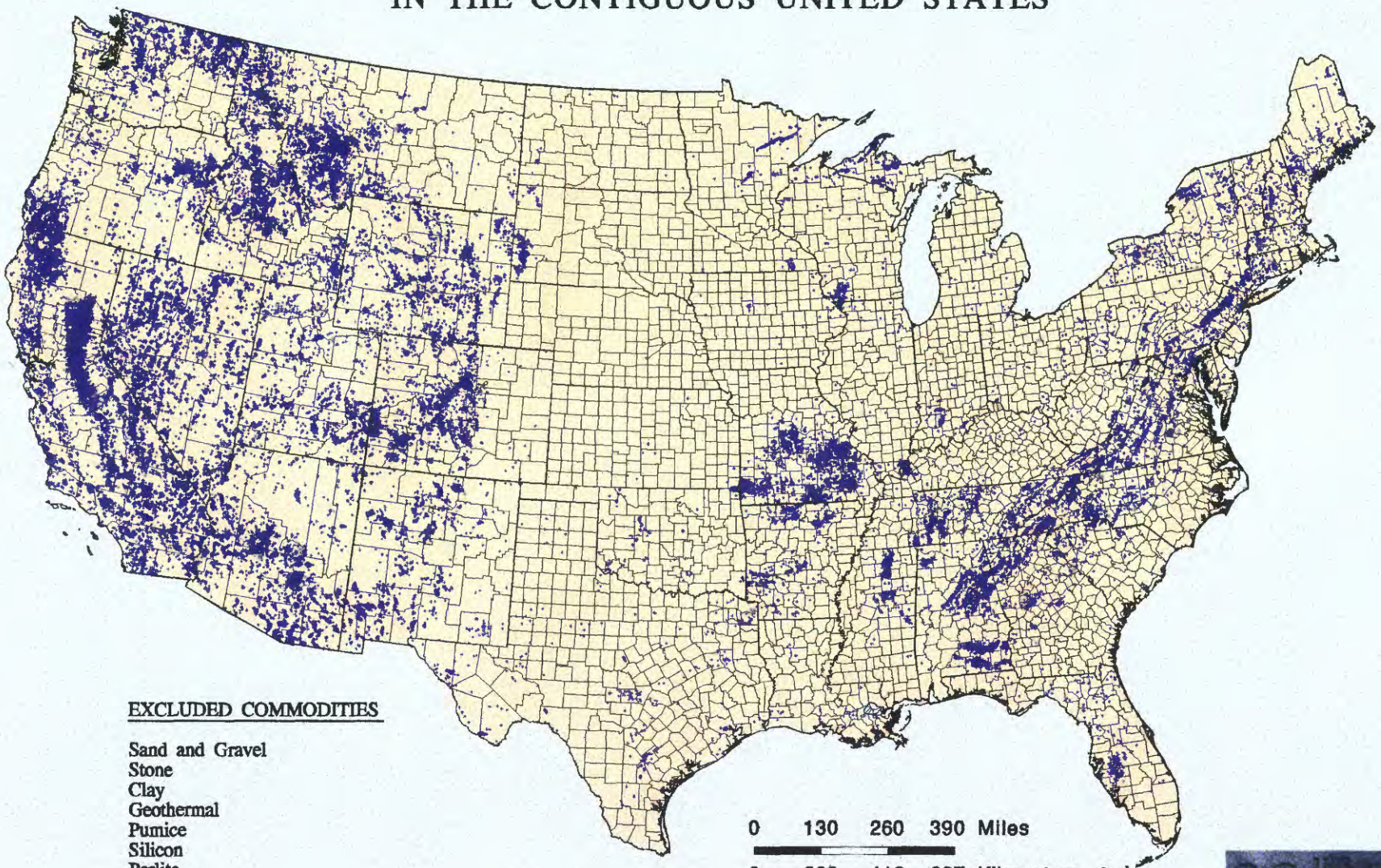
MAS/MILS

Minerals Availability System (MAS), created in the mid 1970's, is an automated tabular database for storage and retrieval of worldwide site-specific minerals information. It contains both proprietary and non-proprietary information and over 35 tables of attributes relating to location, extraction technology, and economics.

Mineral Industry Location System (MILS) is a non-proprietary subset of the MAS database and contains information on location, type of operation, and status. Each MILS site has a unique sequence number corresponding to Federal Information Processing Standards (FIPS) codes and used to relate to other MAS tables.

Maps and analysis completed by David Fenster at the U.S. Geological Survey, Denver. For additional information call: (303) 236-5611 or via e-mail at dfenster@glovr1.cr.usgs.gov.

HARDROCK COMMODITY MAS/MILS LOCATIONS IN THE CONTIGUOUS UNITED STATES



EXCLUDED COMMODITIES

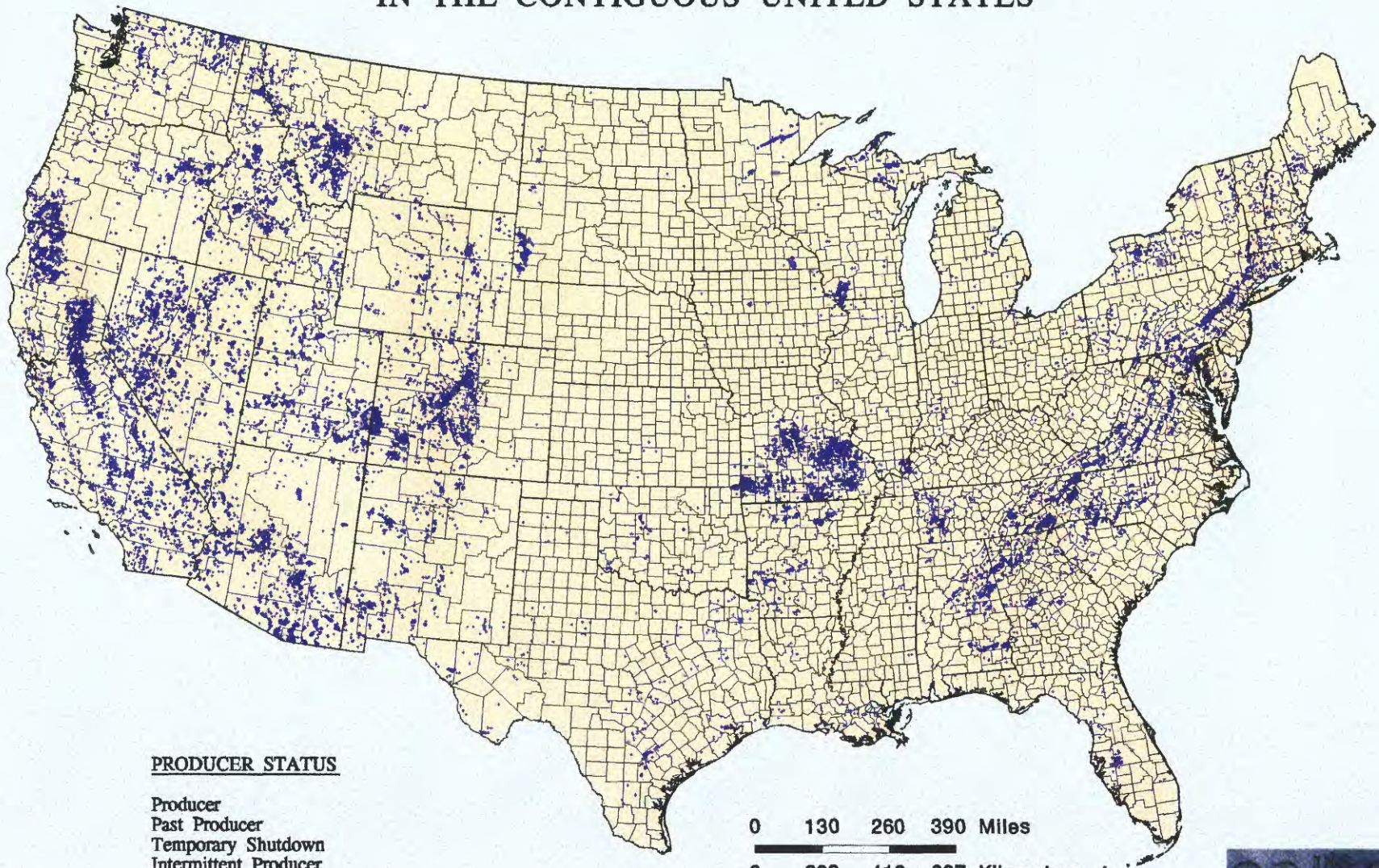
Sand and Gravel
Stone
Clay
Geothermal
Pumice
Silicon
Perlite
Abrasives
Coal
Oil and Gas

0 130 260 390 Miles

0 209 418 627 Kilometers

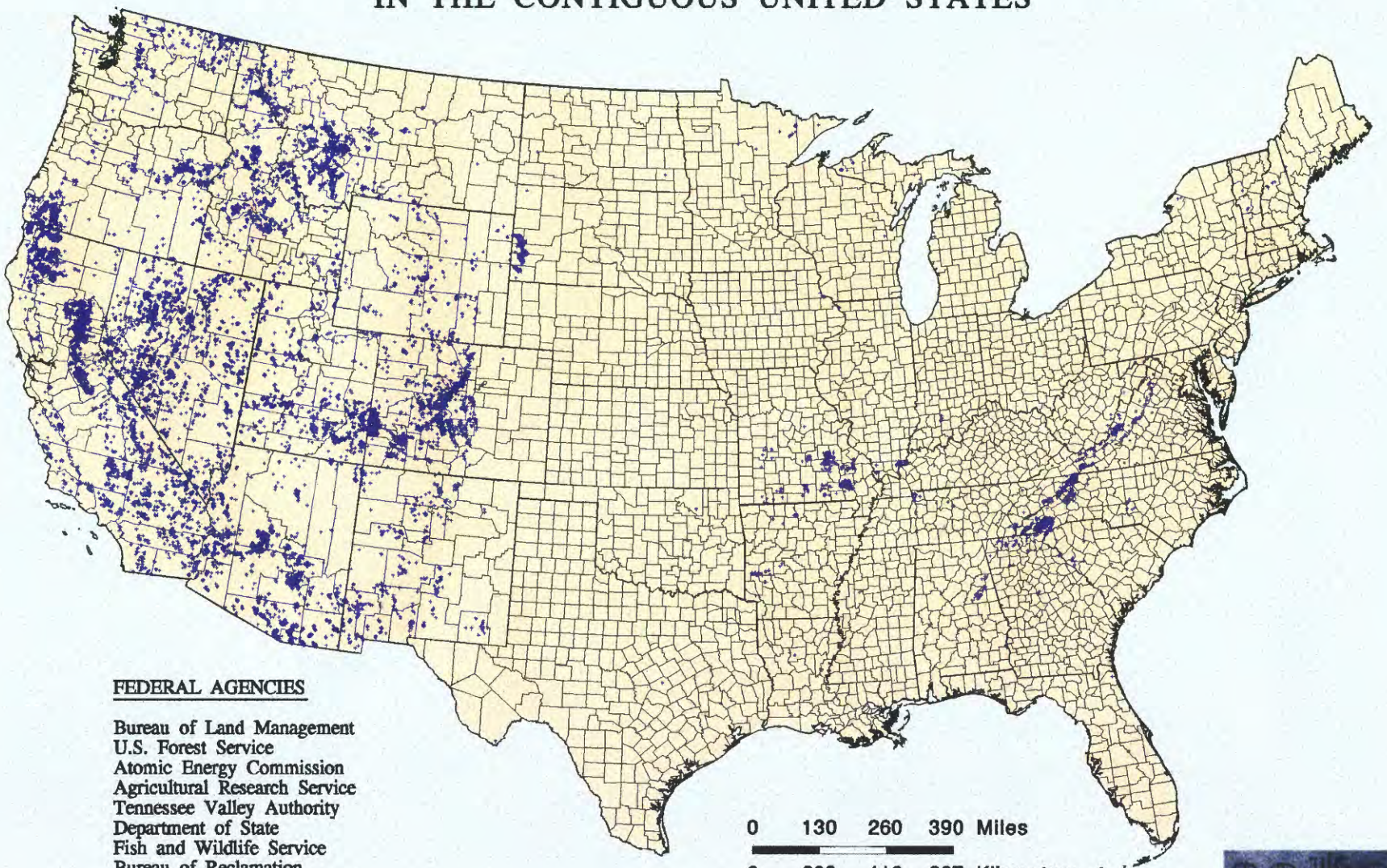
Maps and analysis completed by David Fenstermaker at the U.S. Geological Survey, Denver. For additional information call: (303) 236-5611 or via e-mail at dfenster@gdwrl.cr.usgs.gov.

PAST-PRODUCER HARDROCK MAS/MILS LOCATIONS IN THE CONTIGUOUS UNITED STATES



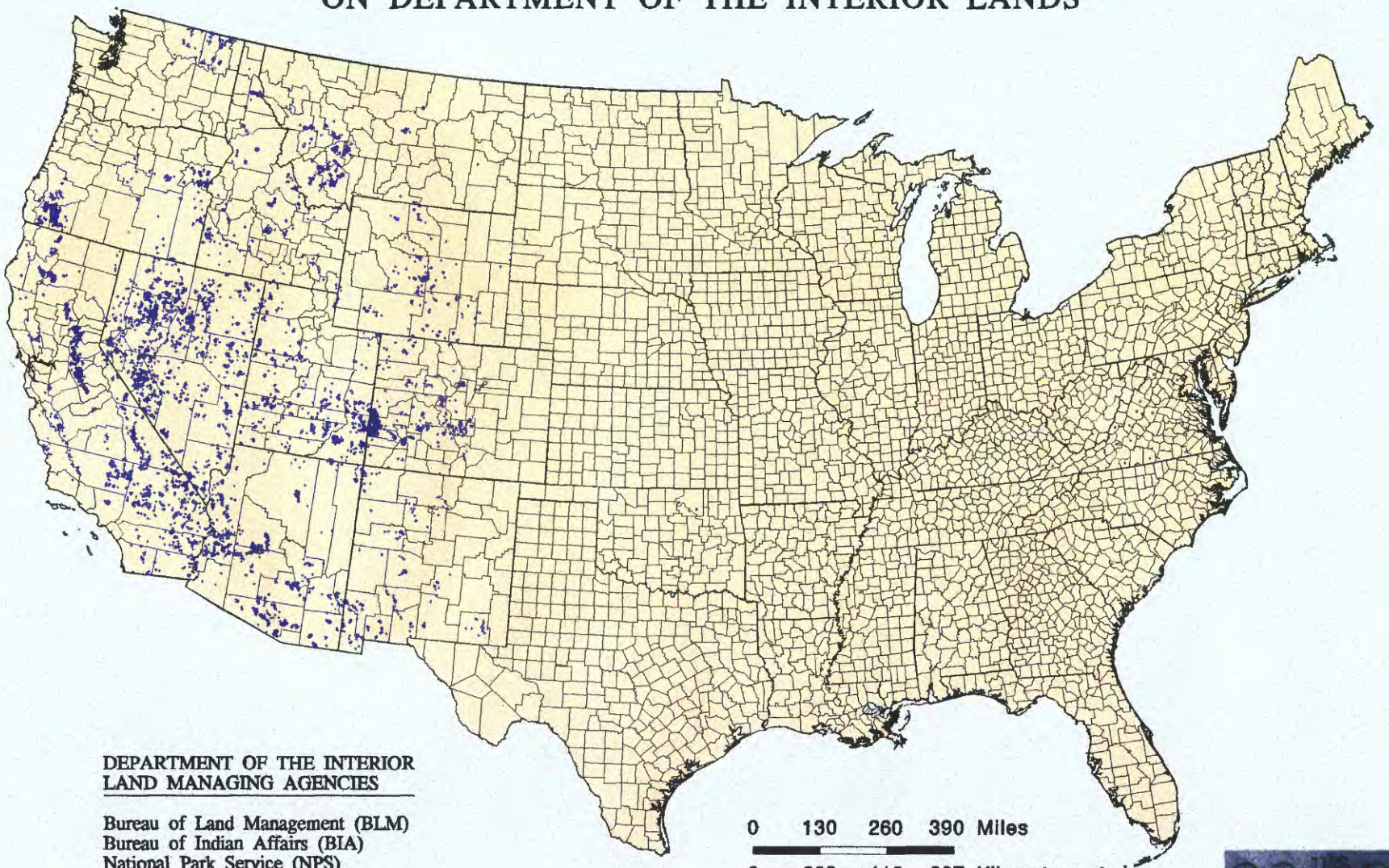
Maps and analysis completed by David Postmer at the U.S. Geological Survey, Denver. For additional information call: (303) 236-5611 or via e-mail at dlordorc@gdsvr1.cr.usgs.gov.

PAST-PRODUCER HARDROCK MAS/MILS LOCATIONS ON FEDERAL LANDS IN THE CONTIGUOUS UNITED STATES



Maps and analysis completed by David Fenderson at the U.S. Geological Survey, Denver. For additional information call: (303) 236-5611 or via e-mail at dfenders@gdesvr1.cr.usgs.gov.

PAST-PRODUCER HARDROCK MAS/MILS LOCATIONS ON DEPARTMENT OF THE INTERIOR LANDS



DEPARTMENT OF THE INTERIOR
LAND MANAGING AGENCIES

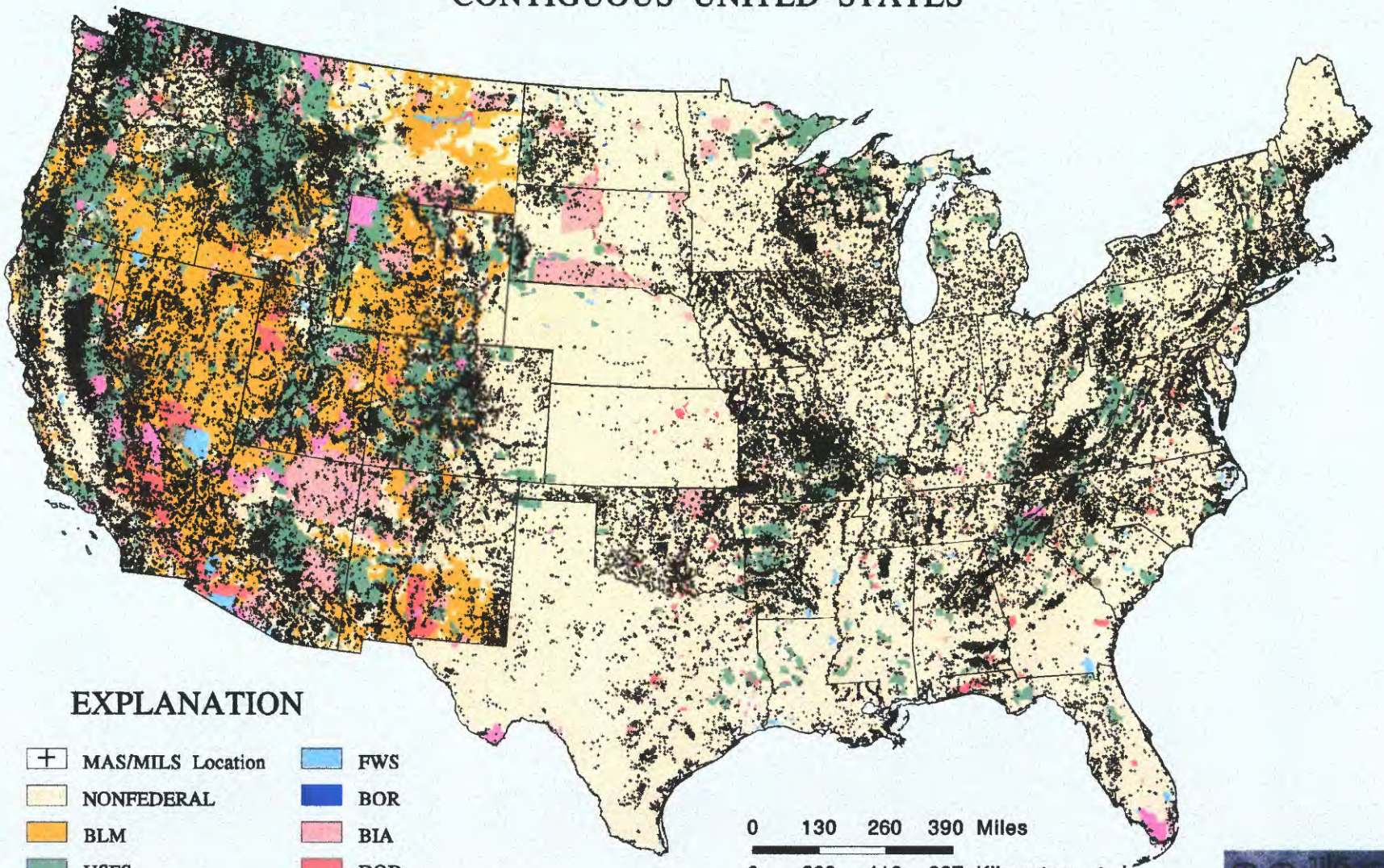
Bureau of Land Management (BLM)
Bureau of Indian Affairs (BIA)
National Park Service (NPS)
Fish and Wildlife Service (FWS)
Bureau of Reclamation (BOR)

0 130 260 390 Miles

0 209 418 627 Kilometers

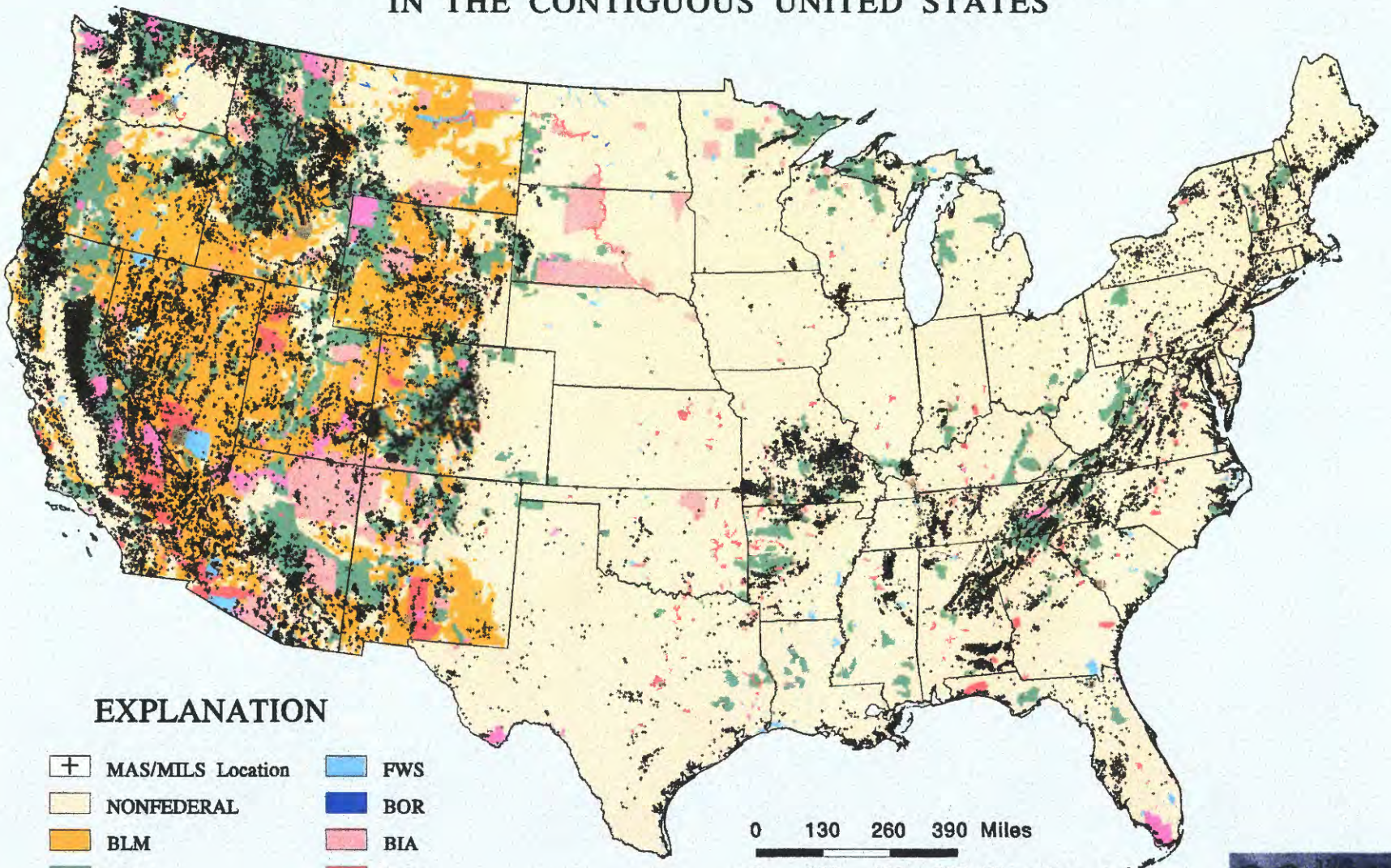
Maps and analysis completed by David Fenster at the U.S. Geological Survey, Denver. For additional information call: (303) 236-5611 or via e-mail at dfenster@gldevz1.cr.usgs.gov.

FEDERAL LANDS AND MAS/MILS LOCATIONS IN THE CONTIGUOUS UNITED STATES



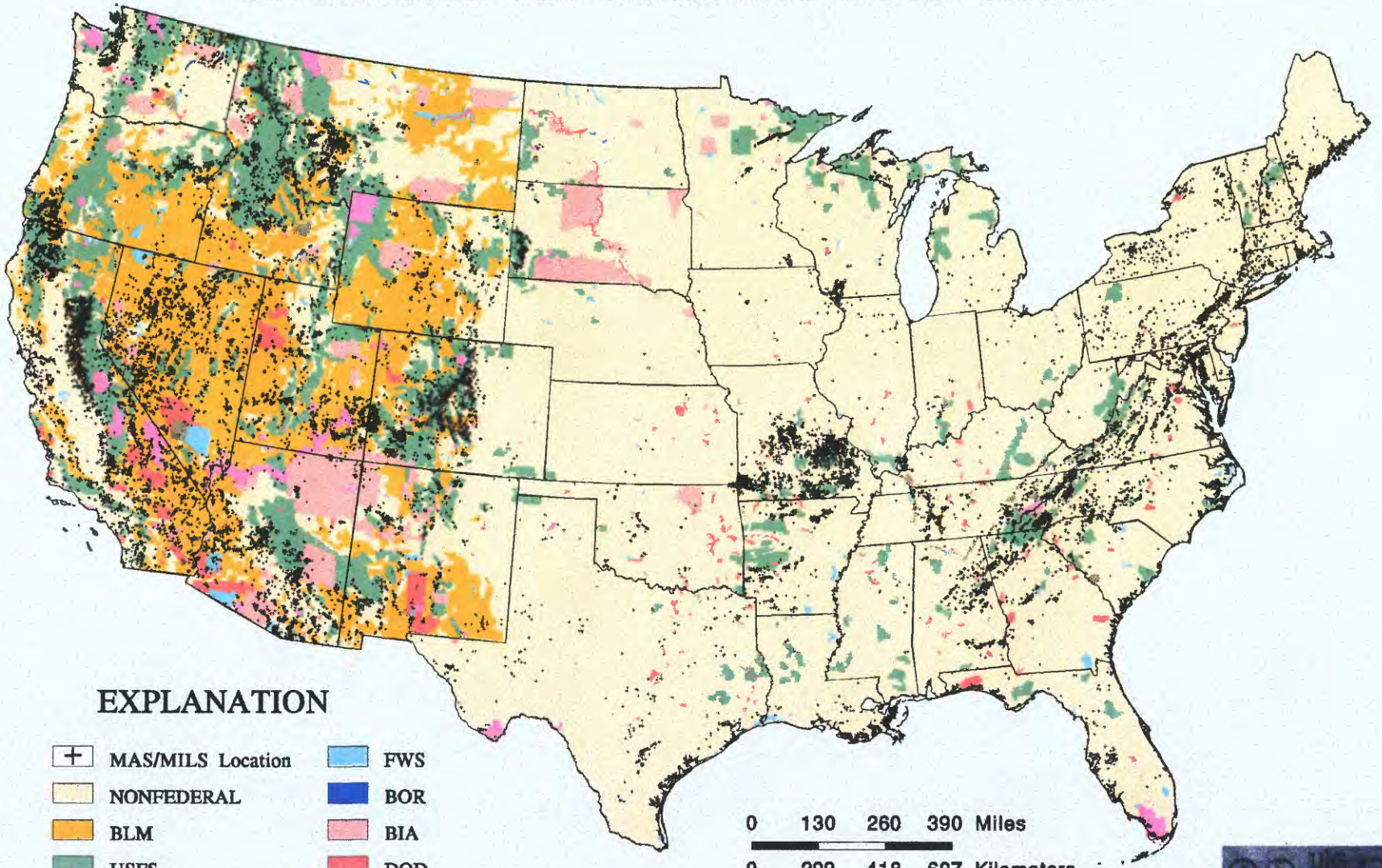
Maps and analysis completed by David Pershour at the U.S. Geological Survey, Denver. For additional information call: (303) 236-5611 or via e-mail at dfarlan@glovr1.cr.usgs.gov.

FEDERAL LANDS AND HARDROCK MAS/MILS LOCATIONS IN THE CONTIGUOUS UNITED STATES



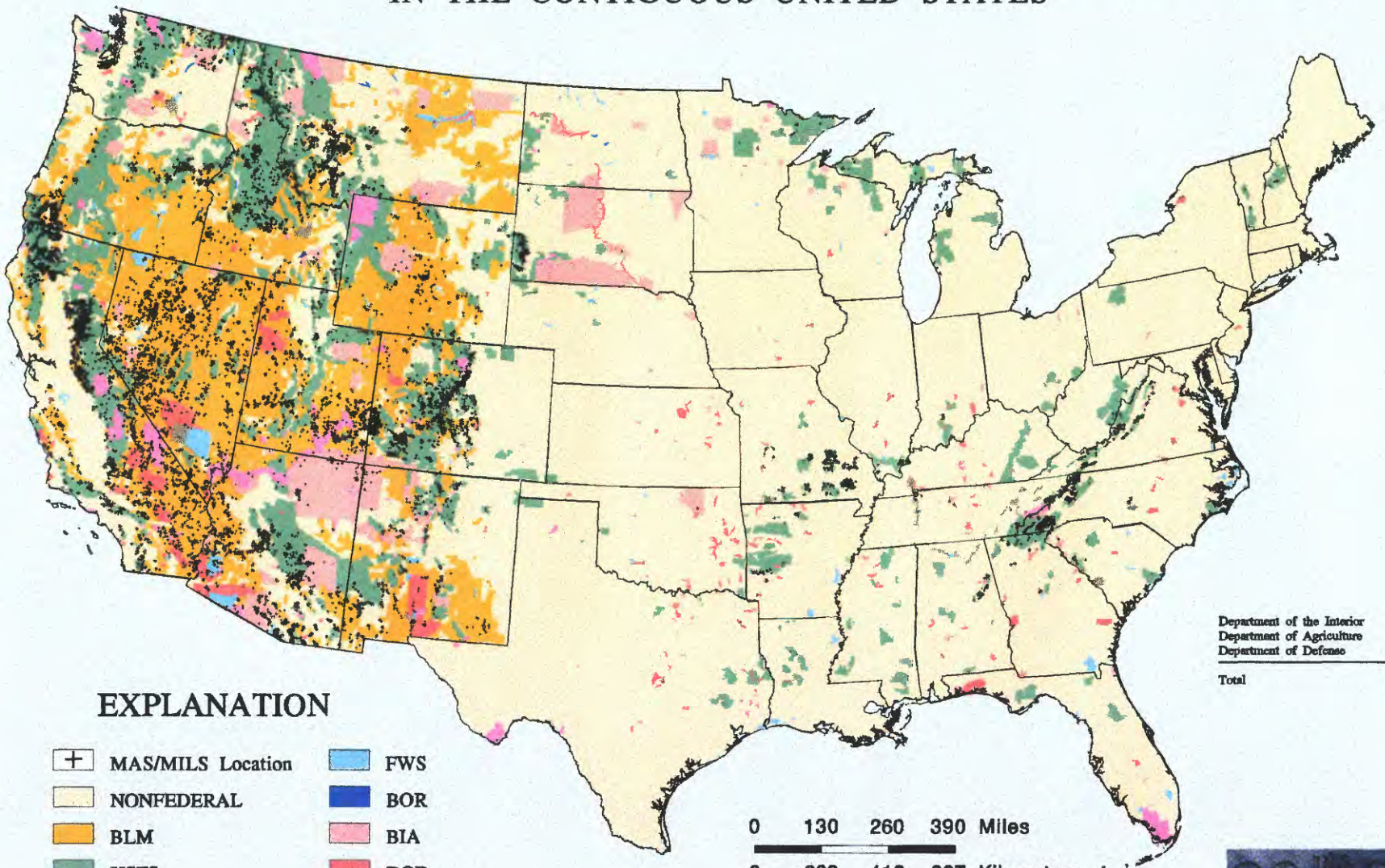
Maps and analysis completed by David Fenster at the U.S. Geological Survey, Denver. For additional information call: (303) 236-5611 or via e-mail at dfenster@gdsvr1.cr.usgs.gov.

FEDERAL LANDS AND PAST-PRODUCER HARDROCK MAS/MILS LOCATIONS IN THE CONTIGUOUS UNITED STATES



Maps and analysis completed by David Fenster at the U.S. Geological Survey, Denver. For additional information call: (303) 236-5611 or via e-mail at dfenster@gdsvr1.cr.usgs.gov.

PAST-PRODUCER HARDROCK MAS/MILS LOCATIONS ON FEDERAL LANDS IN THE CONTIGUOUS UNITED STATES



EXPLANATION

- MAS/MILS Location
- NONFEDERAL
- BLM
- USFS
- AEC, ARS, TVA, DOS
- FWS
- BOR
- BIA
- DOD
- NPS

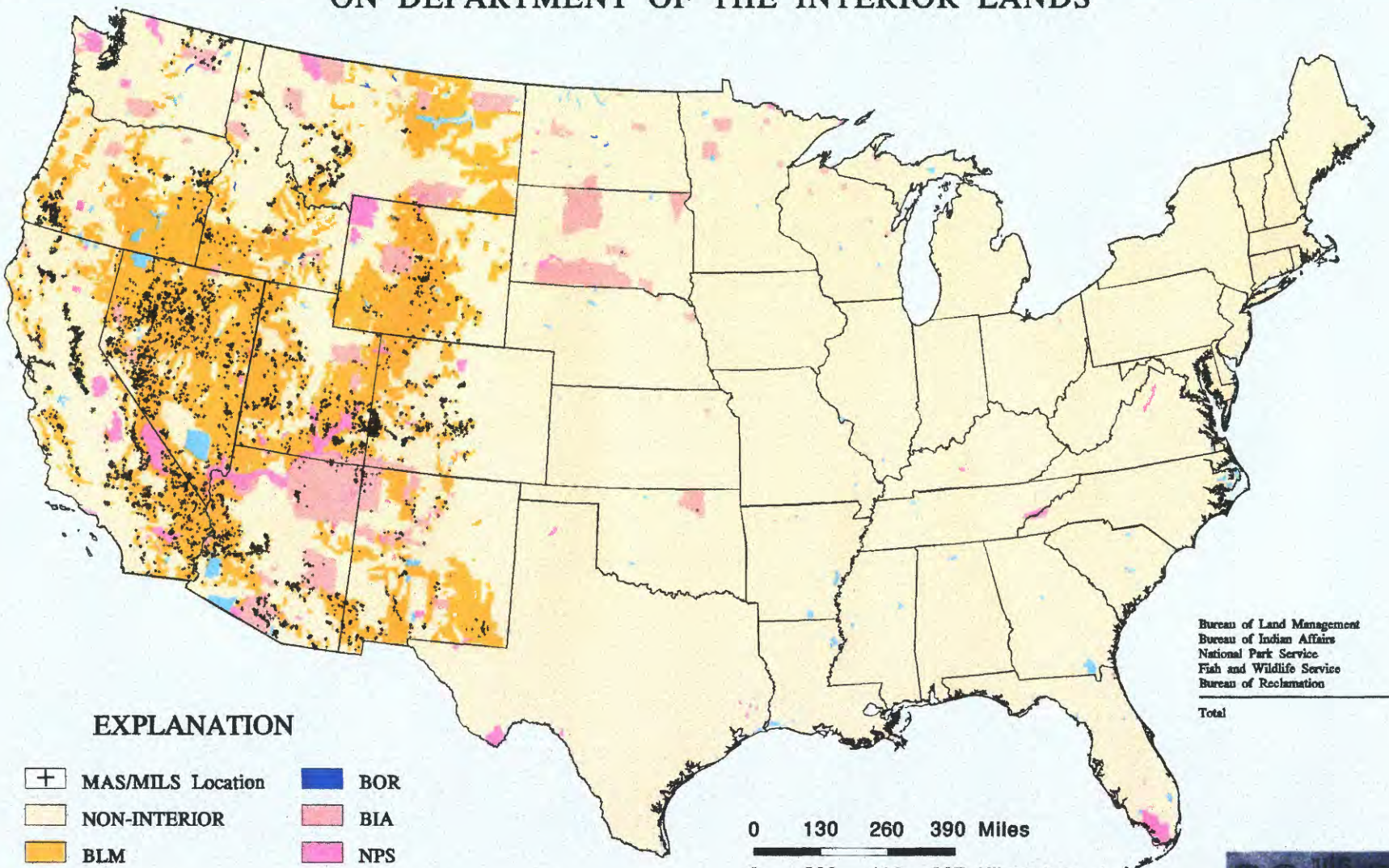
0 130 260 390 Miles

0 209 418 627 Kilometers

Department of the Interior	15,300
Department of Agriculture	12,400
Department of Defense	300
Total	28,000

Maps and analysis completed by David Pantaw at the U.S. Geological Survey, Denver. For additional information call: (303) 236-9611 or via e-mail at dfordorc@gdsvr1.cr.usgs.gov.

PAST-PRODUCER HARDROCK MAS/MILS LOCATIONS ON DEPARTMENT OF THE INTERIOR LANDS



Bureau of Land Management	14,356
Bureau of Indian Affairs	518
National Park Service	312
Fish and Wildlife Service	101
Bureau of Reclamation	13
Total	15,300

EXPLANATION

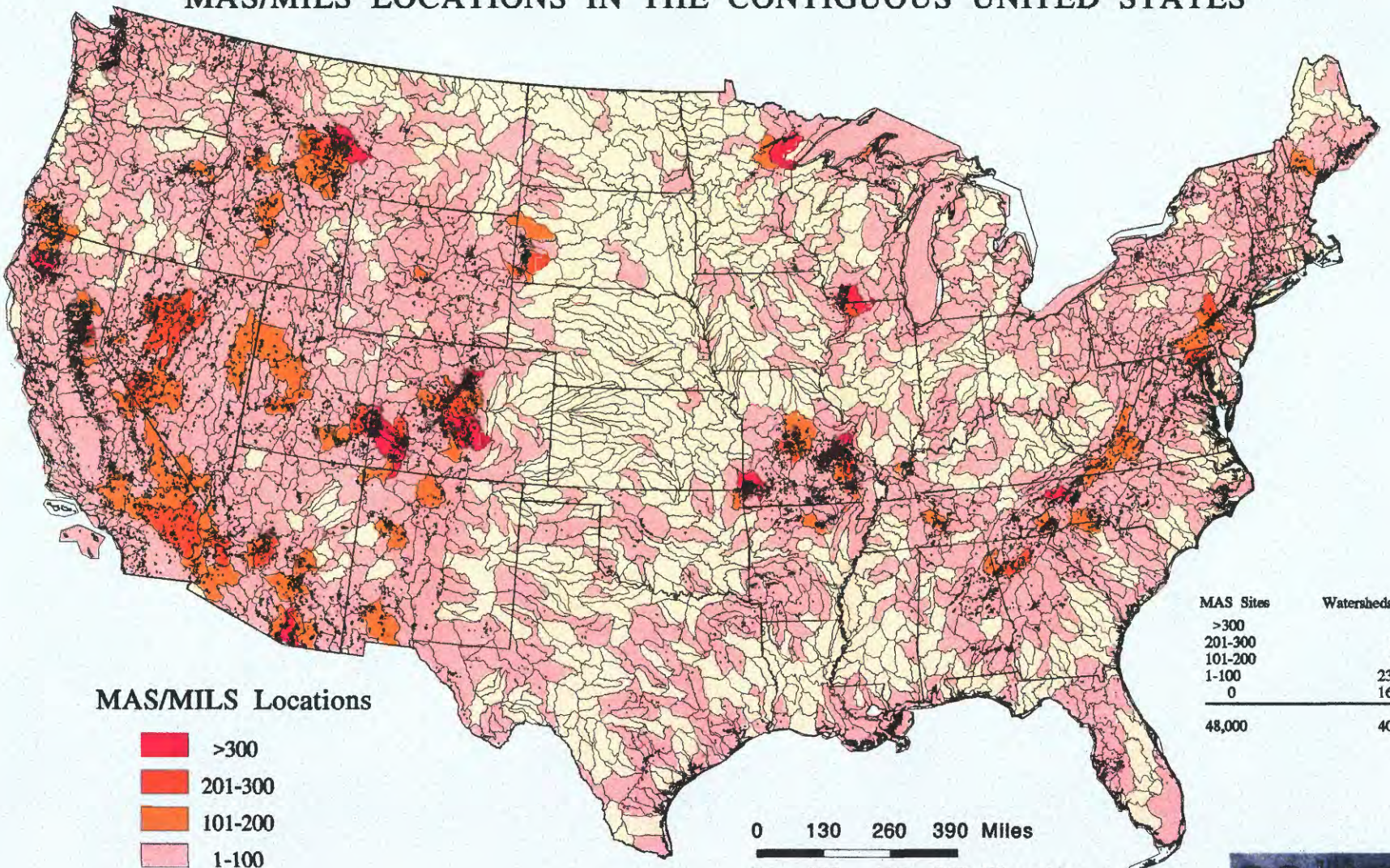
- MAS/MILS Location
- NON-INTERIOR
- BLM
- FWS
- BOR
- BIA
- NPS

0 130 260 390 Miles

0 209 418 627 Kilometers

Maps and analysis completed by David Fenderer at the U.S. Geological Survey, Denver. For additional information call: (303) 236-5611 or via e-mail at dfenderer@gdesvr1.cr.usgs.gov.

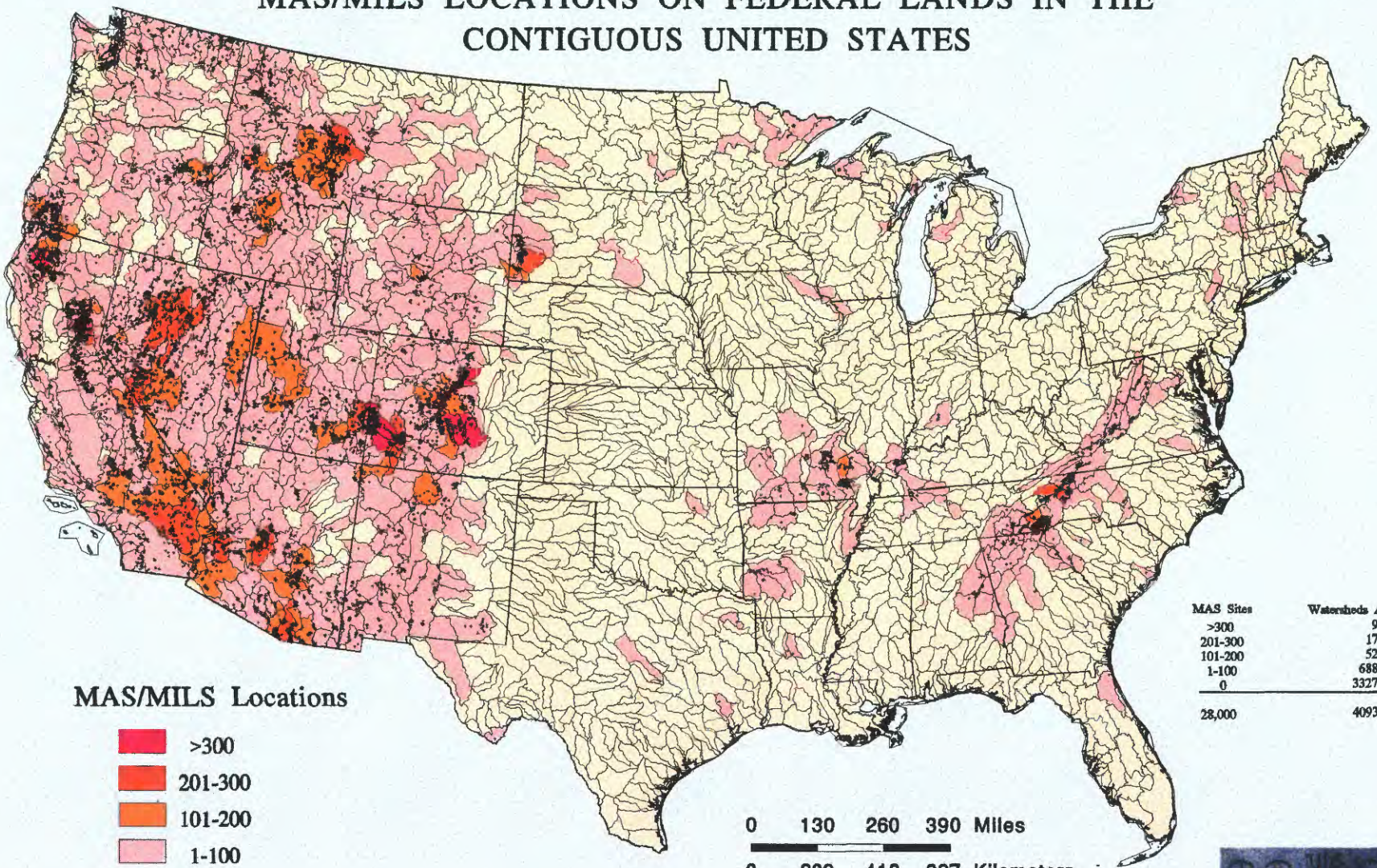
WATERSHED PRIORITY ASSESSMENT BASED ON PAST-PRODUCER HARDROCK MAS/MILS LOCATIONS IN THE CONTIGUOUS UNITED STATES



MAS Sites	Watersheds Affected
>300	18
201-300	20
101-200	74
1-100	2374
0	1607
48,000	4093

Maps and analysis completed by David Fenderson at the U.S. Geological Survey, Denver. For additional information call: (303) 236-5611 or via e-mail at dfenders@glovrl.cr.usgs.gov.

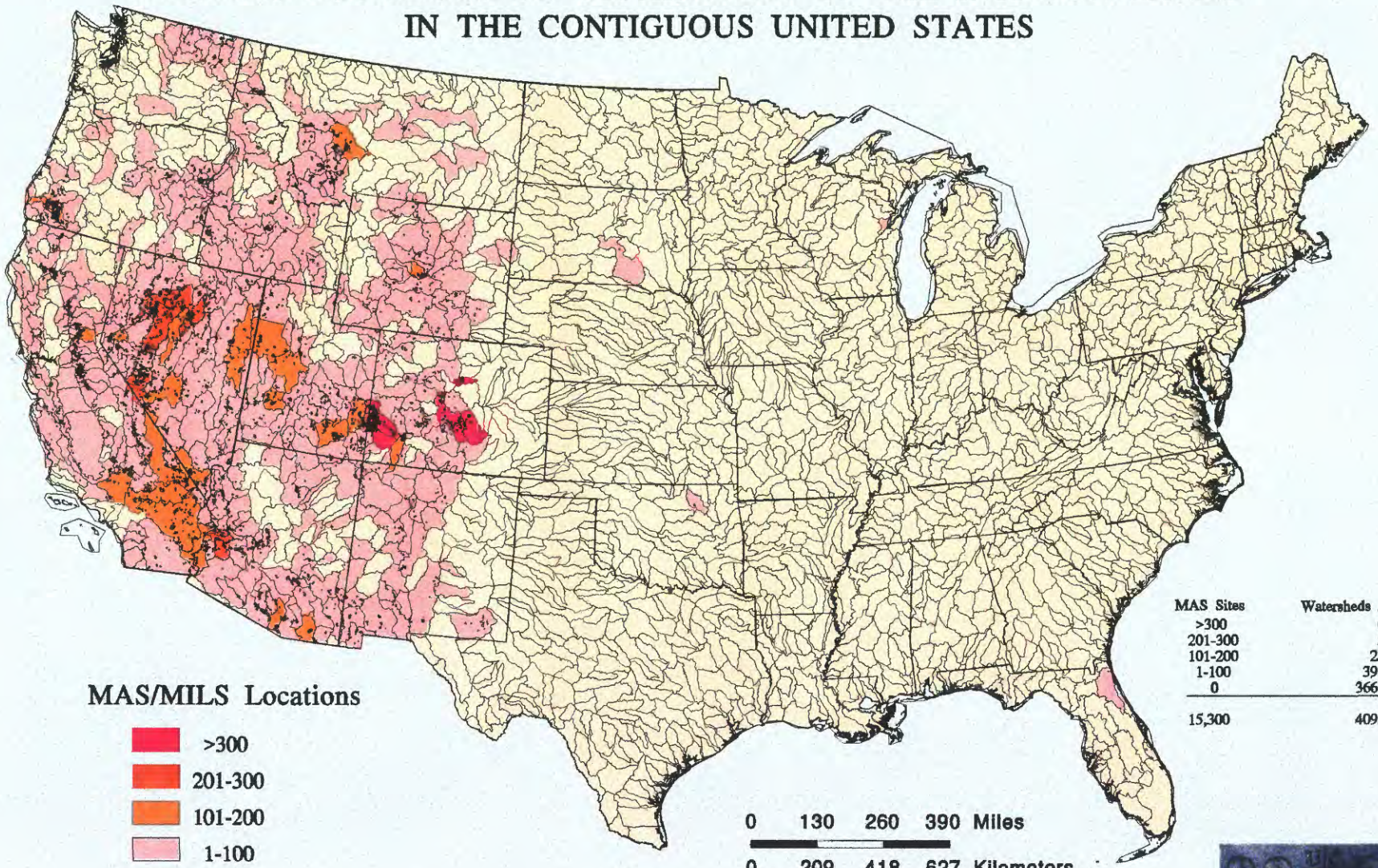
WATERSHED PRIORITY ASSESSMENT BASED ON PAST-PRODUCER HARDROCK MAS/MILS LOCATIONS ON FEDERAL LANDS IN THE CONTIGUOUS UNITED STATES



MAS Sites	Watersheds Affected
>300	9
201-300	17
101-200	52
1-100	688
0	3327
28,000	4093

Maps and analysis completed by David Fenstermacher at the U.S. Geological Survey, Denver. For additional information call: (303) 236-5611 or via e-mail at dfenster@gdenvr1.cr.usgs.gov.

WATERSHED PRIORITY ASSESSMENT BASED ON PAST-PRODUCER HARDROCK MAS/MILS LOCATIONS ON DEPARTMENT OF THE INTERIOR LANDS IN THE CONTIGUOUS UNITED STATES



MAS Sites	Watersheds Affected
>300	6
201-300	5
101-200	23
1-100	398
0	3661
15,300	4093

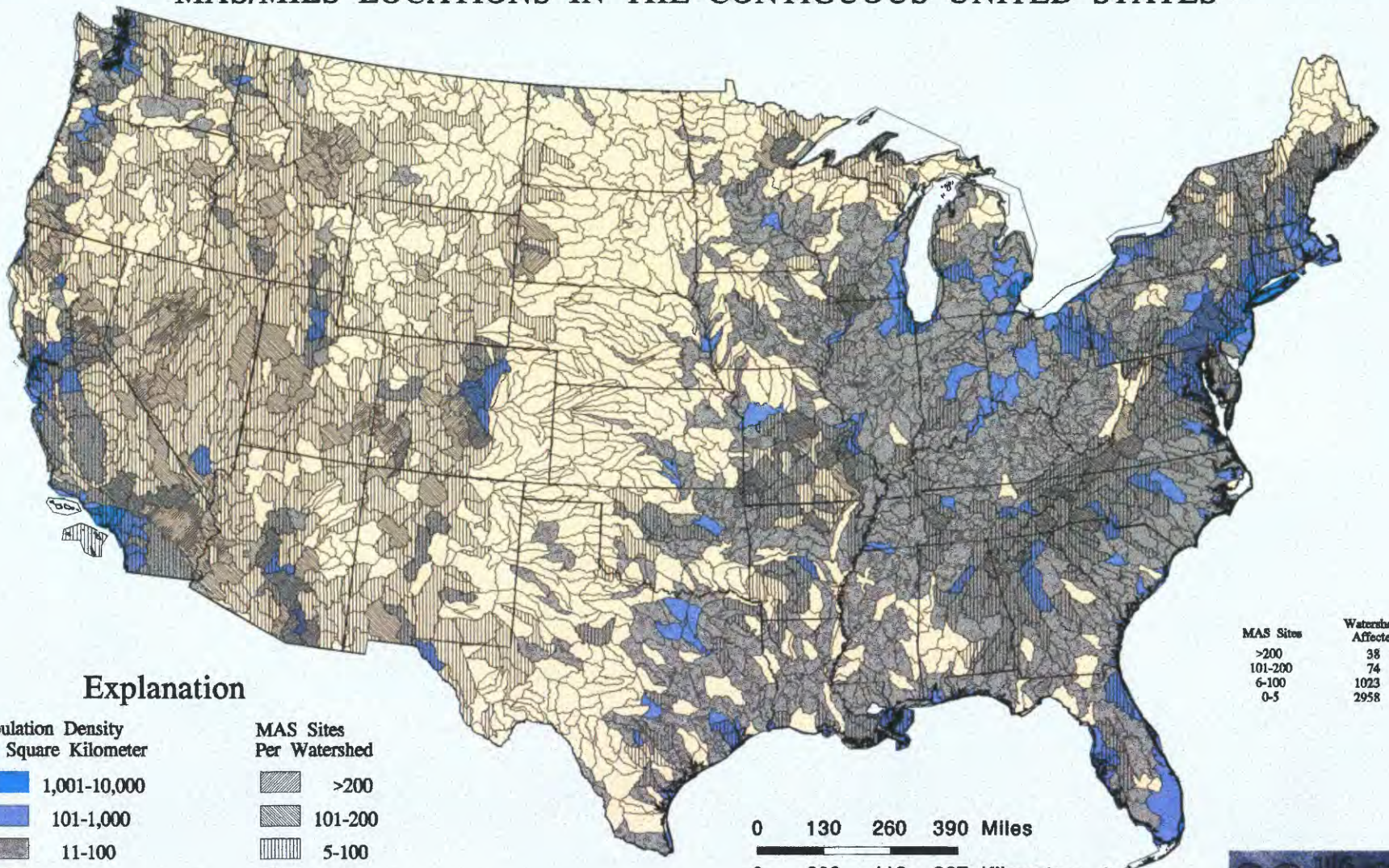
Maps and analysis completed by David Ferderer at the U.S. Geological Survey, Denver. For additional information call: (303) 236-5611 or via e-mail at dferderer@gdenvr1.cr.usgs.gov.

POPULATION PER WATERSHED COMPARED TO PAST-PRODUCER HARDROCK MAS/MILS LOCATIONS IN THE CONTIGUOUS UNITED STATES

Population	Watersheds
>250,000	811
100,001-250,000	623
50,001-100,000	590
1-50,000	2009
0	60
Total	4093

Maps and analysis completed by David Ferderer at the U.S. Geological Survey, Denver. For additional information call: (303) 236-5611 or via e-mail at dferderer@gdsvr1.cr.usgs.gov.

POPULATION DENSITY PER WATERSHED COMPARED TO PAST-PRODUCER HARDROCK MAS/MILS LOCATIONS IN THE CONTIGUOUS UNITED STATES



Explanation

Population Density
Per Square Kilometer

- 1,001-10,000
- 101-1,000
- 11-100
- 0-10

MAS Sites
Per Watershed

- >200
- 101-200
- 5-100
- 0-5

MAS Sites	Watersheds Affected
>200	38
101-200	74
6-100	1023
0-5	2958

0 130 260 390 Miles

0 209 418 627 Kilometers

Maps and analysis completed by David Ferderer at the U.S. Geological Survey, Denver. For additional information call: (303) 236-5611 or via e-mail at dferderer@gdmrl.cr.usgs.gov.

WATERSHED PRIORITY ASSESSMENT BASED ON POPULATION AND PAST-PRODUCER HARDROCK MAS/MILS LOCATIONS IN THE CONTIGUOUS UNITED STATES