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Evaluation of Potential Hydropower Sites Throughout the United States

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ABSTRACT

AMLs were used to develop a GIS layer of hydropower potential for all 50 U.S. states. This study focuses on low-head/low-power sites yielding less than 1 MW of power. The suitability of individual hydropower sites are being evaluated using GIS proximity analysis. Site evaluation factors may include land use, site accessibility, as well as proximity of the site to population centers, roads, and power lines. Site rating results will be incorporated into additional nationwide GIS data layers. The hydropower potential and site suitability map layers will be deployed on a public website using ArcIMS. These datasets will assist private and public power users to evaluate sites for potential hydropower development. In addition, this information will help the U.S. Department of Energy determine research priorities for hydropower extraction technologies.

The U.S. Department of Energy (DOE) has an ongoing interest in assessing the water energy resources of the United States. Previous assessments have focused on potential projects having a capacity of 1 MW and above. These assessments were also based on previously identified sites with a recognized, although varying, level of development potential. In FY 2000, DOE initiated planning for an assessment of low head (less than 30 ft) and low power (less than 1 MW) resources.

The Idaho National Engineering and Environmental Laboratory in conjunction with the U.S. Geological Survey recently completed assessments of all 20 hydrologic regions in the United States, which in combination provide assessment results for this entire area of the United States. Parsing of the regional assessment results using geographic information system (GIS) tools produced assessment results for each of the 50 states. The assessments provided not only estimates of the amount of low head/low power potential, but also estimates of power potential in several power classes defined by power level and hydraulic head, and an estimate of the total power potential of water energy resources in individual states and hydrologic regions and in the nation.

The method used in this study uses state-of-the-art digital elevation models and GIS tools to assess the power potential of a mathematical analog of every stream segment within each region. Only water energy resources associated with natural water courses were assessed (e.g., effluent streams, tides, wave power, and ocean currents were not included). Summing the estimated power potential of all the stream segments in the region provided an estimate of the total power potential in the region. Stream segments that had power potentials less than 1 MW and hydraulic heads less than 30 ft and power potentials less than 100 kW (microhydro) were segregated and summed to provide an estimate of total low head/low power potential in the region. Having power potential estimates in such small increments allowed the low head/low power potential to be further divided to determine the amounts of potential corresponding to the operating envelopes of three classes of low head/low power hydropower technologies: conventional turbines, unconventional systems, and microhydro.

In order to calculate the power potential of each stream segment, the hydrography in the region was derived using the U.S. Geological Survey's Elevation Derivatives for National Applications (EDNA) dataset. In addition to the hydrography, the dataset provided the elevations of the upstream and downstream ends of each stream segment, which were used to calculate hydraulic head. The dataset also allowed the calculation of the drainage area providing runoff to each stream segment. Use of the EDNA data in conjunction with climatic data provided the variables needed to calculate the annual mean flow rate for each stream segment using a regression equation or equations developed specifically for each region in the study area. Combining stream flow rate with hydraulic head provided the power potential of the stream segment.

Because the hydrography used was "synthetic," stream segments were compared to streams in the U.S. Geological Survey's National Hydrography Dataset. Unconfirmed stream segments were eliminated from the datasets that were used to estimate total power potentials. A GIS layer containing streams and areas that are excluded from development by federal statutes and policies was used to segregate excluded and nonexcluded stream segments. The amount of power potential that has already been developed in the region was derived from average annual electricity generation data provided by the Federal Energy Regulatory Commission's Hydroelectric Power Resources Assessment (HPRA) Database. Developed power potential was subtracted from the total, nonexcluded, power potential in each power class to produce estimates of "available" power potentials. No feasibility assessments were made; therefore, the results are gross numbers that do not include the elimination of "available" sites that probably would not be developed at this time. Also, "available" power potential only refers to amounts of potential that have not been developed and are not excluded from development by federal statute or policy. No assessment of actual availability for hydropower development was performed.

The study produced an engineering estimate of the magnitude of United States water energy resources on a comprehensive scale and with delineation that was not previously possible. While the results contain significant uncertainties, comparison of the relative magnitudes of power potentials within power categories, power classes, and geographic boundaries provide useful insights, such as the relative status of development and exclusion and the abundance and concentration of water energy resources. The amounts of "available" power potential are gross numbers that would be greatly reduced by a feasibility assessment accounting for the viability of resources based on such parameters as site accessibility, proximity to load centers and infrastructure, and constraints on development that have not been addressed in this study.

The assessment estimated that the total annual mean power potential of the United States is approximately 300,000 MW. Of this amount, about 90,000 MW is excluded from development. With about 40,000 MW of annual mean power already developed (corresponding to a total hydropower capacity of approximately 80,000 MW), the total available power potential is estimated to be about 170,000 MW or about 60% of the total power potential. The density of available power potential is approximately 50 kW/sq mi. Low head/low power potential makes up about 21,000 MW of the total available potential. Division of the available low head/low power potential among low head/low power technology classes showed that 34% fell within the operating envelope of conventional turbines, 16% fell within the operating envelope of unconventional systems, and 50% fell within the operating envelope of microhydro technologies. In addition to the low head/low power potential, it is estimated that there is a total of 26,000 MW of high head (30 ft or greater)/low power potential available in the 50 states.

A map of the locations of low head/low power sites by technology class shows that conventional turbine sites and unconventional system sites are numerous except in the central part of the country, arid areas of the West and where there are high concentrations of high power or high head/low power potential. Microhydro sites are abundant and exist everywhere in the country except in the plains from North Dakota to the Texas panhandle and in Hawaii, where virtually all the resources are in the high power (equal or greater than 1 MW) or high head/low power classes. A second map shows that high head/low power sites are abundant and are generally located in the mountainous areas of the country.

The regional and state potentials are compared to each other and to the total results for the 20 regions and 50 states. These comparisons show that a majority of the water energy resources in regions and states are underdeveloped compared to the national percentages of potential developed to date (12%) and potential that is available for development (57%). Available power potential is most concentrated in Hawaii, Alaska, 4 Western states and 12 states east of the Mississippi River. The states having the highest concentrations of low head/low power potential are all in the eastern United States with the vast majority being east of the Mississippi River; but in general, low power (<1 MW) sites exist in large numbers throughout the country.

The study showed that the combined amounts of available high head/low power and low head/low power power potential in the study area constitutes 30% of the total available potential. However, realizing nearly two-thirds of the low head/low power potential would require unconventional systems or microhydro technology requiring significant turbine and system configuration research and development. The fact that this source of distributed power could be realized without the need for water impoundments is a positive attribute. The greatest sources for additional hydropower lie in the combination of high power sites, high head/low power sites, and part of the low head/low power potential sites, constituting 90% of the total available power potential. This potential could be realized with conventional turbine technology, but perhaps in new configurations not requiring impoundments to be determined by future research and development.

For further details, you may download the complete study at: http://hydropower.inel.gov/resourceassessment/default.shtml

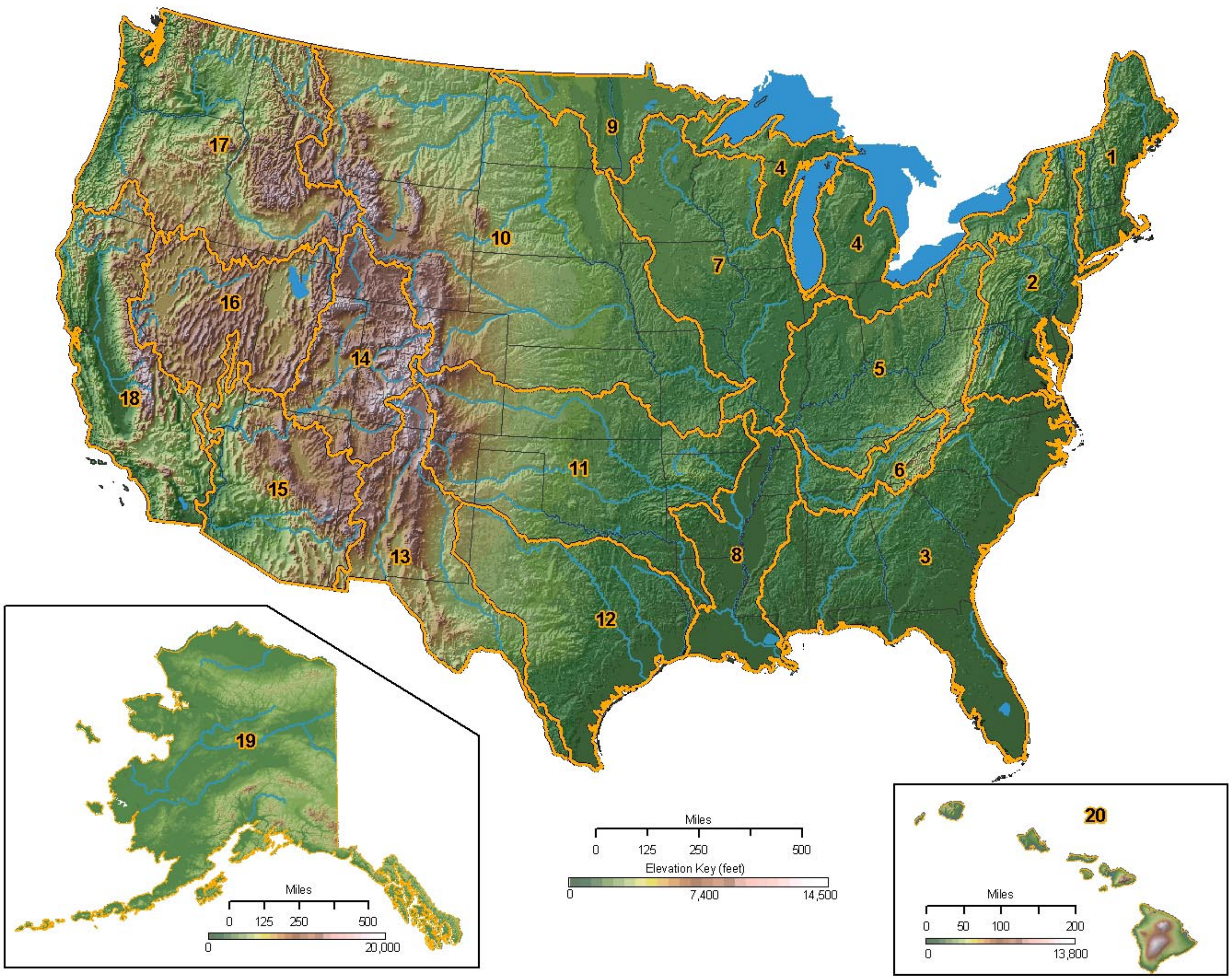

Figure 1. The 20 hydrologic regions (units) of the United States.

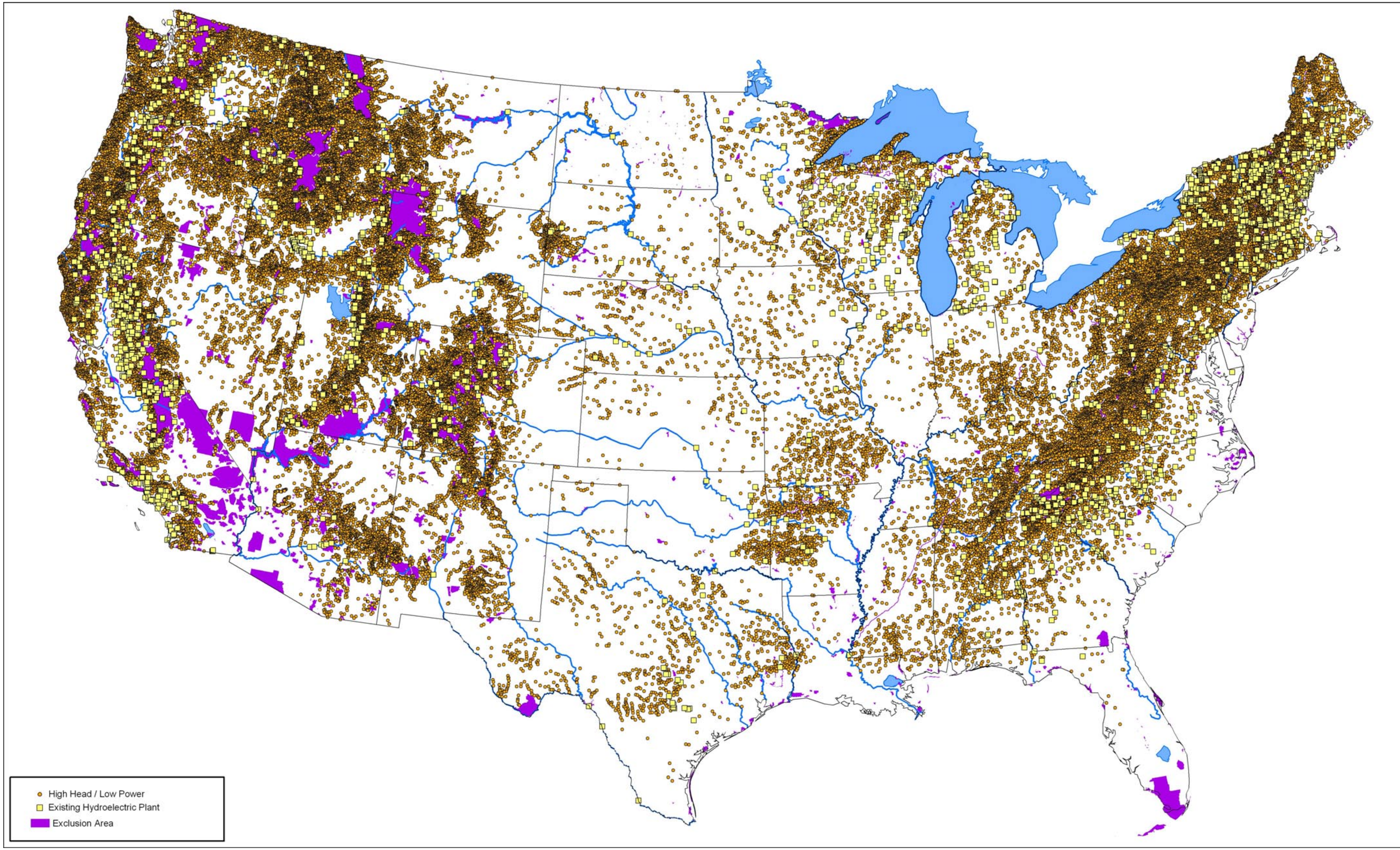

Figure 2. Existing hydroelectric plants and high head/low power water energy sites in the conterminous United States.

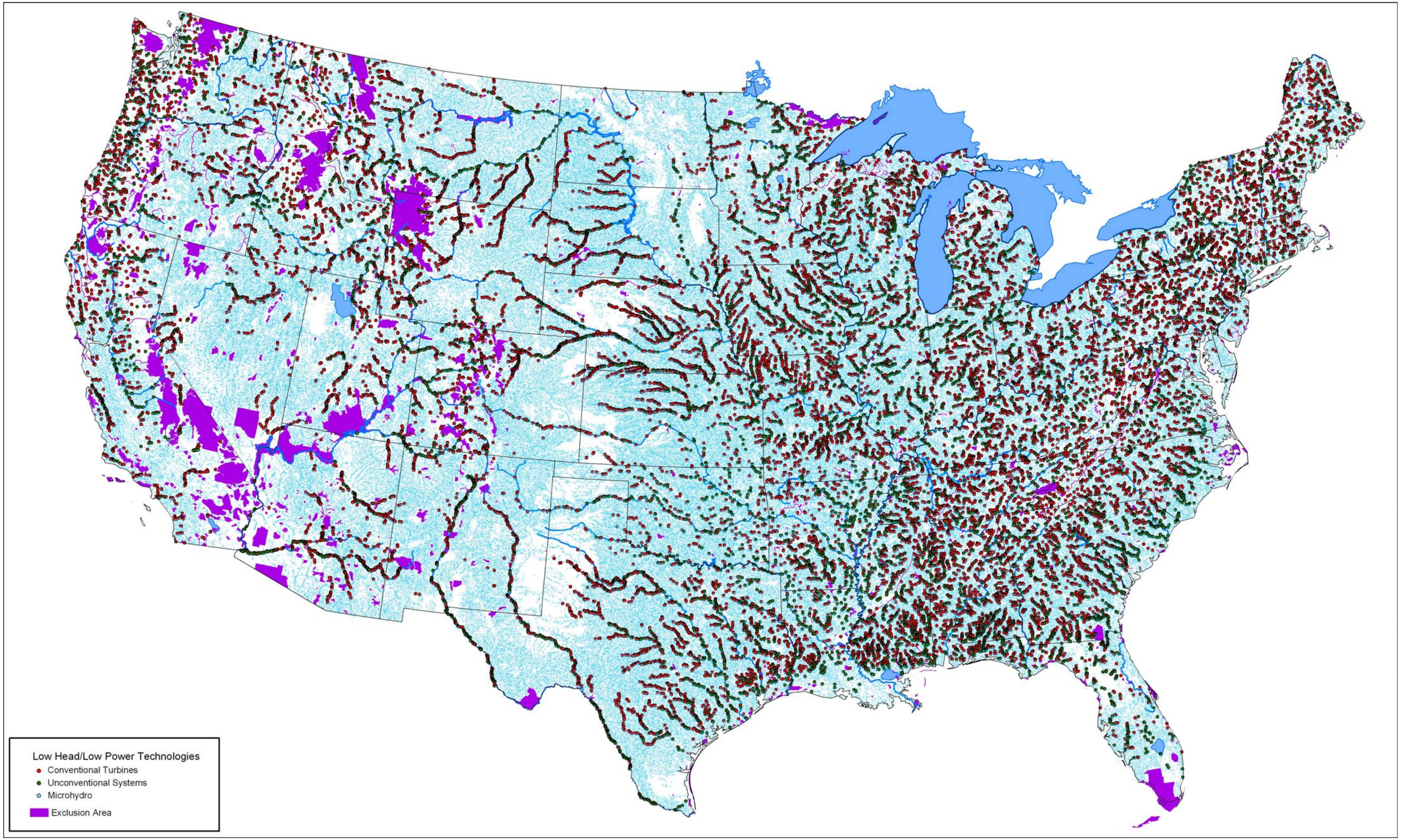

Figure 3. Low head/low power water energy sites in the conterminous United States.

CONCLUSION

This study has demonstrated that it is possible to estimate the power potential of the United States water energy resources based on the potentials of mathematical analogs of every stream segment in the country. Furthermore, stream segment potentials can be aggregated to determine the power potential in various power classes within geographic areas of interest and to locate the potential at discrete geographic coordinates.

The study has shown that over half of the power potential of the country resides in the top two hydrologic regions: Alaska (29%) and Pacific Northwest (26%); in particular, in the states of Alaska, Washington, Idaho, and Oregon. Nearly half of the available power potential also resides in the top two hydrologic regions: Alaska (26%) and Pacific Northwest (23%). Viewed from the perspective of where the greatest concentrations of available power potential are located; Hawaii, Washington, and Idaho have the highest concentrations. Oregon, Alaska, and California and 12 states east of the Mississippi make up the balance of the states in which available potential is most densely concentrated.

The estimates of available power potential produced by this study are sufficiently large to warrant further research toward realizing these additional energy resources. Such research should include at a minimum refinement of the available power potential estimates and investigation of possible locations for siting additional hydroelectric units. Low power sites are sufficiently numerous and uniformly distributed over the country to offer significant sources of distributed power without the need for reservoirs. In order to obtain a clearer estimate of the amount of power potential that can feasibly be developed and determine which sites are feasible, it is necessary to intersect the locations of potential with context parameters that govern its feasibility of development. These parameters include proximity to population centers, industry, and existing infrastructure (e.g., roads, railroads, and electric transmission lines) and locations inside or outside of nonfederal mandated exclusion areas. Because all the data generated in this project are geo-referenced and the necessary GIS tools and most of the needed context layers exist, they are suitable for such research.

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