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U.S. Hydropower

Resource Assessment

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U.S. Department of Energy, Idaho Operations Office

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**Uniform Criteria for
U.S. Hydropower Resource Assessment**

**Hydropower Evaluation Software
Status Report**

**James E. Francfort
Kevin M. Moore^a
Bennie N. Rinehart**

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**Idaho National Engineering Laboratory
EG&G Idaho, Inc.
Idaho Falls, Idaho 83415**

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a. Morgantown Energy Technology Center, Morgantown, West Virginia 26505

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ABSTRACT

The Department of Energy is estimating the hydropower development potential in this country. The Hydropower Evaluation Software is a computer model that was developed by the Idaho National Engineering Laboratory for this purpose. The Hydropower Evaluation Software estimates the potential hydropower resources available in the United States, using uniform criteria for measurement. The software was developed and tested using hydropower information and data provided by the Southwestern Power Administration. It is a dBASE, menu-driven software application. Hydropower Evaluation Software allows the personal computer user to assign environmental attributes to potential hydropower sites, calculate development suitability factors for each site based on the environmental attributes present, and generate reports based on these suitability factors.

This status report details Hydropower Evaluation Software's development, its data requirements, and its application to the 12 states assessed to date. This report does not discuss or present the various user-friendly menus of the Hydropower Evaluation Software. One is referred to the User's Manual for specifics. This report focuses on data derivation, summarization of the 12 states (Arkansas, Colorado, Kansas, Louisiana, Missouri, Montana, North Dakota, Oklahoma, South Dakota, Texas, Utah, and Wyoming) extracted into the software to date, and plans for future assessments.

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CONTENTS

ABSTRACT	iii
ACKNOWLEDGMENTS	v
INTRODUCTION	1
Need for Uniform Criteria	1
Model Development	2
Model Testing	2
Model Goal	2
DATA SOURCES	3
Primary Data Sources	3
Secondary Data Sources	4
Data Sources for Threatened and Endangered Species	5
DATA REQUIREMENTS	6
Basic Site Data	6
Environmental Attribute Definitions	7
SUITABILITY FACTOR DETERMINATION	11
Suitability Factor Values	11
Dam Status	11
Overall Project Suitability Factor	12
LIMITATIONS AND APPLICABILITY	14
ASSESSMENT PROCESS AND ASSUMPTIONS	15
SUMMARY OF STATES COMPLETED TO DATE	16
PLANS FOR FUTURE ASSESSMENTS	22
OBTAINING INDIVIDUAL STATE INFORMATION	23
ADDITIONAL HYDROPOWER EVALUATION SOFTWARE INFORMATION	24
REFERENCES	25

FIGURES

1.	Sample printout of resource database listing	10
2.	Number of potential hydropower sites by states	19
3.	Total potential hydropower capacity by states	19
4.	Total potential hydropower capacity by site status	20
5.	Percent of total potential hydropower capacity by site status	20
6.	Average potential hydropower capacity by site status	21

TABLES

1.	Valuation of environmental attributes	11
2.	Suitability factors by dam status for environmental attributes	12
3.	Overall project suitability factor computation	13
4.	Hydropower capacity summary modeled by the Hydropower Evaluation Software	17

Uniform Criteria for U.S. Hydropower Resource Assessment Hydropower Evaluation Software Status Report

INTRODUCTION

In June 1989, the U.S. Department of Energy initiated the development of a National Energy Strategy to identify the energy resources available to support the expanding demand for energy in the United States. Public hearings conducted as part of the strategy development process indicated that potential hydropower resources were not well defined. As a result, the Department of Energy established an interagency Hydropower Resource Assessment Team to ascertain the country's hydropower potential. The team consisted of representatives from each power marketing administration (Alaska Power Administration, Bonneville Power Administration, Western Area Power Administration, Southwestern Power Administration, and Southeastern Power Administration), the Bureau of Reclamation, the Army Corps of Engineers, the Federal Energy Regulatory Commission, the Idaho National Engineering Laboratory, and the Oak Ridge National Laboratory. The interagency team drafted a preliminary assessment of potential hydropower resources in February 1990. This preliminary assessment indicated that there were about 52,900 MW of potential hydropower energy in the United States.

Partial analysis of the potential hydropower resource database by groups in the hydropower industry indicated that the hydropower data included redundancies and errors that reduced confidence in the published estimates of developable hydropower potential. The Department of Energy continues assessing hydropower resources in order to correct these deficiencies, improve estimates of developable hydropower, and determine future policy. To support these efforts by the Department of Energy, the Idaho National Engineering

Laboratory designed the Hydropower Evaluation Software.^a

This report considers and discusses conventional hydropower resource potential. This does not include pumped storage hydropower potential.

Need for Uniform Criteria

The Idaho National Engineering Laboratory's Hydropower Evaluation Software considers a uniform set of possible site-specific environmental attributes to assess the likelihood of developing the potential hydropower resources of regions and states. These site-specific environmental attributes, derived from the Nationwide Rivers Inventory, include whether a site has Wild and Scenic Protection or is on a tributary of a site with such protection; whether cultural, historical, fishery, geologic, recreational, scenic, or wildlife values are present; and whether threatened or endangered fish or wildlife are present. The attributes are based on the potential project's location, including whether the site is within a national park, national grasslands, national wildlife refuge, or other federal lands. Hydropower Evaluation Software's use of uniform criteria allows personal computer users nationwide to identify environmental attributes present at potential hydropower sites, calculate development suitability factors for each site based on the attributes present, and generate uniform reports based on these factors.

a. Detailed information about the Idaho National Engineering Laboratory's Hydropower Evaluation Software may be found in the User's Manual (Francfort, Matthews, and Rinehart 1991).

The Hydropower Evaluation Software was developed as a tool to measure hydropower potential by regional power marketing administrations and state energy agencies, because they were the most likely to need accurate hydropower information. Hydropower Evaluation Software was not intended to provide precise development factors for individual sites, but to provide regional or state capacity totals. Because the software was developed as a generic measurement tool encompassing national issues, regional and state totals must be considered judiciously; various local issues may skew hydropower potential totals. Employing Hydropower Evaluation Software as a national measurement tool will smooth any local anomalies.

Model Development

Hydropower Evaluation Software, both a database and a probability-factor computer model, is a dBASE, menu-driven software application that is intended to be user-friendly. Computer screens and report generation capabilities were developed to meet the needs of users nationwide. The software uses environmental attribute data to generate an overall project suitability factor between 0.1 and 0.9. A combination of attributes results in a lower suitability factor because multiple environmental considerations reduce the likelihood that a site may be developed to its physical potential.

The Hydropower Evaluation Software was developed in conjunction with the Oak Ridge National Laboratory, which provided the essential environmental evaluation support (Sale 1990). The Idaho National Engineering Laboratory also received valuable assistance from the Southwestern Power Administration, which defined the database requirements and the reporting capabilities required by a power marketing administration.

Model Testing

The Idaho National Engineering Laboratory used the Hydropower Evaluation Software to assess the developable hydropower potential in the Southwestern Power Administration area during the Hydropower Evaluation Software testing stage. The states in this area include Arkansas, Kansas,

Louisiana, Missouri, Oklahoma, and Texas. Hydropower Evaluation Software identified about 250 sites with hydropower potential. After the Hydropower Evaluation Software computer model analysis was completed, the estimated Southwestern Power Administration hydropower resources were reduced 33.5%. This reduction resulted from the influence of various environmental attributes on the reality of successfully developing a hydropower site.

After successfully developing and testing the Hydropower Evaluation Software in conjunction with the Southwestern Power Administration, it was recognized that a process was necessary to successfully integrate the evaluation process between the individual states and the Department of Energy's Hydropower Program. With administrative relationships already in place with the individual states, it was believed that using the Department of Energy's Support Offices to coordinate the assessment process might prove to be a practical method to assess the entire United States. The Denver Support Office coordinated a test assessment of the individual states within their administrative region (Colorado, Montana, North Dakota, South Dakota, Utah, and Wyoming). This test assessment, including obtaining individual state input, proved to be a viable method that could be used to assess hydropower potential throughout the United States.

Model Goal

The goal of the Hydropower Evaluation Software is to assemble an accurate database of all potential hydropower sites in the United States for use as a planning tool to determine the viable national hydropower potential. Potential hydropower is not limited to the development of new sites; it also includes the development of additional hydropower generation capabilities at sites that currently have hydropower but are not developed to their full potential. This hydropower potential is a source of nonpolluting, renewable energy available to meet the growing power needs of the United States. The Hydropower Evaluation Software should make this goal obtainable and help ensure a set of uniform criteria for national assessment.

DATA SOURCES

Primary Data Sources

The Federal Energy Regulatory Commission's Hydropower Resource Assessment database and the National Park Service's Nationwide Rivers Inventory database are the two main information databases used for hydropower site data. State input is used to validate the Hydropower Evaluation Software modeled results.

Hydropower Resource Assessment. This database is maintained by the Federal Energy Regulatory Commission and contains the best available national inventory of hydropower potential. It contains information about all sites that have been subject to any Federal Energy Regulatory Commission hydropower licensing action and information on project sites that have been identified by the Federal Energy Regulatory Commission, or other agencies, as having development potential even if no licensing action has taken place. This database lists project sites and corresponding basic site data. Approximately 4,500 sites with hydropower development potential are listed in the Hydropower Resource Assessment database.

Nationwide Rivers Inventory. The Nationwide Rivers Inventory was completed in 1982 by the National Park Service. Park Service regional offices systematically collected information on rivers and identified those with outstanding resources. Uniform procedures for identifying rivers for the Nationwide Rivers Inventory—including field and map verification of each river's values—were applied throughout the country. Specific outstanding resources were identified for those river reaches selected for inclusion in the Nationwide Rivers Inventory. Reaches were identified if outstanding fisheries, wildlife, geologic features, historical resources, cultural resources, recreation resources, scenic values, or other resources were present. The Nationwide Rivers Inventory also indicates the presence of threatened and endangered species (classified as fish or terrestrial wildlife) and whether the reach is part of, or considered for, inclusion in a state or federal wild and scenic rivers program.

Although the National Park Service used uniform procedures to consider rivers throughout the United States for inclusion in the Nationwide Rivers Inventory, it would be incorrect to assume that if a potential site is not on a reach listed in the Nationwide Rivers Inventory there would be few environmental impediments to development: significant changes, such as new fisheries or increased recreational use, may have occurred since the Nationwide Rivers Inventory was compiled.

State Resource and Energy Agencies.

After the information contained in the Federal Energy Regulatory Commission's Hydropower Resource Assessment and the National Park Service's Nationwide Rivers Inventory databases were entered into the Hydropower Evaluation Software, the modeled results were presented to the natural resource departments or energy offices of Colorado, Montana, North Dakota, South Dakota, Utah, and Wyoming. (This interaction was coordinated by the Southwestern Power Administration for the other six states within their power marketing administrative area). Each state was then able to provide input, validating and in many cases updating the environmental attributes present at potential hydropower sites as well as the individual site physical information. Additionally, the individual states were able to add previously unlisted sites that were known to state agencies as having undeveloped hydropower potential.

State input is often the result of coordinated canvassing between several state agencies within each state. For instance, water management agencies may identify sites with undeveloped hydropower potential that were not listed in the Federal Energy Regulatory Commission's Hydropower Resource Assessment database. Or state agencies may be aware of state historical sites such as archeological sites of early Indian societies or other historical values that would impact the probability of developing a hydropower site. This state input often results in an adjustment of a site's overall project suitability value. In the case of the addition of previously unidentified sites with undeveloped hydropower potential, a state's sum of undeveloped hydropower potential may be increased. The value of state

input to the modeling of undeveloped hydropower potential cannot be overstated. Each state is the best source of local site knowledge.

Secondary Data Sources

Other data sources can also be used to identify project locations and to assign environmental attributes to these locations. Some of these data sources are national in coverage, while others are available only for smaller areas such as individual states. Each additional database used will need to be obtained from its source, and the environmental attributes it lists will need to be extracted.

Power Marketing Administrations. Power marketing administrations possess significant information that is of primary importance to the successful application of the Hydropower Evaluation Software. Each power marketing administration can verify any outside sources of data that are used; but, of greater importance, each power marketing administration can provide significant information about anything affecting potential hydropower development within its region. Power marketing administrations will be aware of possible state opposition and any local action regarding a specific project.

State Environmental Databases. Many states keep inventories of aquatic and riparian resources. These inventories can include lists of high-quality and possibly protected streams, natural areas, and recreational resources. State plans for waterway development, filed by a state with the Federal Energy Regulatory Commission, can limit potential hydropower sites. State data is often very useful for determining the environmental feasibility of hydropower sites, but the data may require a great deal of manipulation before it can be incorporated into a regional database for hydropower evaluation. Because little state information is available in digital format, it is difficult to input state data into the Hydropower Evaluation Software database.

An example of a state database is the California Department of Fish and Game Wild Trout Program inventory, which lists streams identified as outstanding trout fisheries; such streams are protected

from development under California law. As another example, the state of Utah has rated each of its streams by the following categories: (a) type of fishery, (b) productivity, (c) reproductive success, (d) spawning habitat, and (e) aesthetics. Projects on streams with high ratings in these categories will have greater environmental concerns.

American Rivers Outstanding Rivers List. During 1988, an organization named American Rivers published its Outstanding Rivers List. This list is a comprehensive, nationwide compilation of rivers that possess some outstanding ecological, recreational, natural, cultural, or scenic values. Rivers protected by legislation and rivers currently unprotected are included. The list contains an estimated 15,000 river reaches, totalling about 300,000 river miles. Each river reach is described in terms such as its upriver and downriver end points, its total length, its significance, and the source of information. Some of this information is redundant with the Nationwide Rivers Inventory, which is included within the Outstanding River List, but much of it is additional information.

Northwest Power Planning Council. Streams under the jurisdiction of the Bonneville Power Administration have been studied by states and rated by the Northwest Power Planning Council for the suitability of additional hydropower development. Streams were rated for values such as anadromous fish presence, resident fish populations, wildlife, natural features, cultural features, and recreation. In 1987, the Northwest Power Planning Council published a list of streams deemed unsuitable for hydropower development, which generally includes all streams containing anadromous fisheries. For projects proposed in the Bonneville Power Administration marketing area, the stream ratings are an important source of environmental attributes.

Wetlands Inventories. The presence of wetlands that could be affected by a potential hydropower project is an important environmental attribute because wetlands are protected under the Clean Water Act. The U.S. Fish and Wildlife Service has inventoried wetlands in some regions, and maps of

these inventoried wetlands are available. Wetland inventories are also available from some states.

Data Sources for Threatened and Endangered Species

U.S. Fish and Wildlife Service Threatened and Endangered Species Database. Geographic information in this database is given by county and hydrologic unit—and sometimes at finer resolutions. Species information includes locations of species, life histories of species, legal histories of the designation as threatened and endangered species, habitat use, bibliographies, contact people, and key words that identify species as aquatic, wetland, or riparian species. The database has been in transition between in-house devel-

opment and contracted management (by the Nature Conservancy) for several years. It appears that a wealth of information exists but may be difficult to access.

Nature Conservancy. The Nature Conservancy has a national database of all species that identifies threatened and endangered species. This database organizes geographic information by county.

U.S. Fish and Wildlife Service Gap Analysis Project. This is a state-by-state project designed to identify species-rich areas that are not legally protected. Three databases are being developed for each state: (a) locations of all species, (b) vegetative coverage, and (c) land ownership. Aquatic species are not yet included in the project.

DATA REQUIREMENTS

Basic Site Data

The Idaho National Engineering Laboratory obtained basic site data for the Hydropower Evaluation Software from the Federal Energy Regulatory Commission's Hydropower Resource Assessment database. Additional data can be converted to dBASE format and downloaded, or the data can be entered manually. The following data fields were copied into the Hydropower Evaluation Software from the Hydropower Resource Assessment database for each project site. The names used are the actual structural names assigned to each field in the database. (Note: "_" is used in dBASE as a separator character.)

PROJNUM. The number assigned to each project by the Federal Energy Regulatory Commission. When a PROJNUM is not assigned for a project, the user is strongly encouraged to provide a pseudo number (see *Hydropower Evaluation Software User's Manual*).

PLANT_NM. Name of the project.

STREAM. Name of the stream where the project is located.

STATE_NM. Name of the state where the project is located.

LAT_U. The latitude of the site.

LONG_U. The longitude of the site.

CLASS_C. The owner class code:

- C = Cooperative
- F = Federal
- I = Industrial
- M = Municipal and other nonfederal
- P = Private utility
- R = Private nonutility.

OWNER_NM. Name of the project owner.

KWRATE_P. The Hydropower Resource Assessment database estimated potential nameplate rating (KW) of the project. This is not the current capacity

at a developed site. It is the potential capacity at an undeveloped site or a site without power, or the potential *additional* capacity of a site that already has power.

GEN_AA_P. The Hydropower Resource Assessment database estimated potential Average Annual Generation (MWh) of a site. This is *not* the current average annual generation at a developed site but the potential average annual generation at an undeveloped site or a site without power, or the potential *additional* average annual generation of a site that already has power.

UNITYP_P. Type of unit:

- C = Conventional
- R = Reversible
- Z = Missing.

PLANTTYP. The project type or type of operation:

- CMB = Combined conventional and reversible units
- DIV = Gravity diversion (powerhouse on different stream)
- PDV = Pumped diversion (one-way pumped storage)
- PMP = Pure (recycled) pump storage
- RES = Reservoir only
- ROR = Run-of-river (dam 10 ft high with minimal storage)
- RRG = Reregulating
- STG = Storage, conventional (dam > 10 ft high with significant storage)
- TID = Tidal conventional hydropower.

STATUS_C. Project status code:

- DJ = Disclaimer of Federal Energy Regulatory Commission jurisdiction
- EA = Exemption applied for
- FA = Federally authorized
- FR = Federally recommended
- LE = License exception
- LJ = Lack of Federal Energy Regulatory Commission jurisdiction
- MA = Federal Energy Regulatory Commission major license application
- MO = Federal Energy Regulatory Commission major license outstanding

NA = Federal Energy Regulatory Commission minor license application
 NO = Federal Energy Regulatory Commission minor license outstanding
 PA = Federal Energy Regulatory Commission preliminary permit application
 PO = Federal Energy Regulatory Commission preliminary permit outstanding
 XX = No status
 YO = Federal Energy Regulatory Commission minor part license outstanding
 ZZ = Missing.

BASIN_NM. The river basin where the project is located.

CNTY_NM. The county where the project is located.

Not all of the above 15 variables are present for each site in the Hydropower Resource Assessment database, and the information the database provides is not always accurate. Each state or power marketing administration should review these data and verify their authenticity.

Environmental Attribute Definitions

The Idaho National Engineering Laboratory derived the following 19 environmental attributes from the Nationwide Rivers Inventory. The corresponding suitability factors are fully explained in the Suitability Factor Determination section (p. 11).

Wild/Scenic Protection. This attribute identifies project sites that are included in the federal wild and scenic rivers system, under consideration for inclusion in the federal system, included in a state river protection program, in a designated wilderness area, or protected from development under another program. Relatively few sites have this status, but those that do are highly unlikely to be developed. Projects at undeveloped sites on state or federally protected wild and scenic rivers, or in wilderness areas, must be assumed to be legally protected from hydropower development. Also, projects at sites under consideration for protection are highly likely to be opposed by state and federal resource agen-

cies, and protection will be approved at many such sites before hydropower development could occur. Since it is possible, but highly unlikely, that development could occur at a site with wild and scenic river protection, the suitability factor assigned to all such projects at undeveloped sites is 0.1.

It is highly unlikely that a project at an existing dam would be on a wild and scenic river since rivers are usually designated as wild and scenic only if they are free of developments such as dams. A suitability factor of 0.5 is assigned for such unusual cases.

Wild and Scenic Tributary or Upstream or Downstream of a Wild and Scenic Location.

This attribute is assigned to a project if it is at the upstream or downstream end of a wild and scenic river reach or is on a tributary of a wild and scenic river. A project at a developed site would affect a downstream wild and scenic river if additional alterations to the flow regime resulted. A suitability factor of 0.75 is assigned for such projects. Projects at undeveloped sites are highly likely to alter the flow regime and may cause changes in downstream water quality, so a suitability factor of 0.5 is assigned to undeveloped sites.

Cultural and Historic Values. Project impacts on cultural and historic resources can often be mitigated (for example, by excavating archeological sites or relocating historic structures). Projects at existing dams are unlikely to affect such resources unless an increase in reservoir pool elevation occurs or major new structures are built. A suitability factor of 0.75 is assigned to such projects. Development of undeveloped sites is more likely to affect cultural and historic resources, so a suitability factor of 0.5 is assigned.

Fish Presence Value. A stream reach may or may not have legally protected fisheries. In either case, however, strong state opposition to new development must be expected if a valuable fishery resource exists. Relatively high instream flow release requirements can mitigate the impact on fisheries, but a high instream flow release would reduce the economic viability of the project. Projects at developed sites could have some impact, such as increased turbine mortality. A suitability

factor of 0.75 is assigned to projects at developed sites. Development at undeveloped sites could have a major impact on aquatic habitat through inundation, migration blockage, turbine mortality, water quality, and altered flows. Some of these can be mitigated, but such mitigation could be expensive. A suitability factor of 0.25 is assigned to undeveloped sites.

Geologic Value. Geologic values such as rock formations are rarely protected legally and are not generally affected by small projects. Development at existing sites is not affected by geologic resources, so a suitability factor of 0.9 is assigned. Development at undeveloped sites may inundate geologic features, so a suitability factor of 0.5 is assigned.

Recreation Value. River recreation users tend to be effective opponents of hydropower development. Development at any storage dam would affect recreation by altering flow releases; mitigation typically includes higher flow releases during periods of high recreation use. Such releases can be made through turbines, but higher flow releases tend to occur when power demands are low. Projects at existing dams would have little effect on recreation besides flow alterations, so they are assigned a suitability factor of 0.75. Projects at undeveloped sites would inundate reaches, block the passage of boats, and reduce aesthetics. Because projects at undeveloped sites are likely to be strongly opposed, a suitability factor of 0.25 is assigned.

Scenic Value. Scenic values are not legally protected but must be considered in assessing the impact of a project. Scenic values are also important to recreational river users. The addition of power to existing dams would alter scenic values only through the addition of new structures and perhaps by reducing visually attractive spillage, so a suitability factor of 0.9 is assigned. New projects at undeveloped sites would have important effects on scenic resources because views would be altered by the project. Undeveloped projects are assigned a suitability factor of 0.5.

Wildlife Value. Terrestrial wildlife and wildlife habitat are protected by fish and game agencies that

are influential in determining mitigation requirements for hydropower projects. Development at existing sites would have little effect on wildlife unless reservoir pool elevations are altered or construction of major facilities is required. A suitability factor of 0.75 is assigned for projects at existing sites. Development at undeveloped sites could inundate wildlife habitat, and construction would cause a great deal of disturbance. It is difficult to mitigate for such impacts, so opposition to such a project could be strong. Undeveloped projects are assigned a suitability factor of 0.25.

Other Value. The effects of other values, such as the presence of rare wetland communities or consideration for wilderness designation, are assigned by using the most commonly assigned suitability factor for the other values. For projects at developed sites, the suitability factor is 0.75. For projects at undeveloped sites, the suitability factor is 0.5.

Threatened and Endangered Fish or Wildlife. The presence of threatened and endangered species near a project site requires additional consultations with wildlife agencies and can result in additional studies and mitigation requirements. The presence of threatened and endangered fish species may preclude development of new storage projects because new projects can involve the greatest alteration of aquatic habitat. Terrestrial threatened and endangered species are unlikely to be highly affected by run-of-rivers projects, but storage reservoirs could affect terrestrial habitat. For existing sites, a suitability factor of 0.75 is assigned when threatened and endangered species are present. For projects at undeveloped sites, a suitability factor of 0.5 is assigned when threatened and endangered species are present.

Federal Land Code 103: National Park, Monument, Lakeshore, Parkway, Battlefield, or Recreation Area. These lands are legally protected from development. A suitability factor of 0.1 is assigned for such projects.

Federal Land Code 104: National Forest or Grassland. These lands are not legally protected from development, but the managing agency has the right to impose additional mitigation requirements on projects. A suitability factor of

0.75 is assigned to projects at existing sites, since these projects typically have fewer impacts. A suitability factor of 0.5 is assigned for undeveloped sites.

Federal Land Code 105: National Wildlife Refuge, Game Preserve, or Fish Hatchery. These lands are managed for fish and wildlife habitats, and hydropower development would almost always be incompatible. A suitability factor of 0.1 is assigned for such projects.

Federal Land Code 106: National Scenic Waterway or Wilderness Area. These lands are legally protected from development. A suitability factor of 0.1 is assigned for such projects.

Federal Land Code 107: Indian Reservation. These lands are not legally protected from development, but Indian tribes have the right to impose additional mitigation requirements on projects. A suitability factor of 0.75 is assigned for

projects at developed sites, and a suitability factor of 0.5 is assigned for projects at undeveloped sites.

Federal Land Code 108: Military Reservation. These lands are not legally protected from development, but the managing agency has the right to impose additional mitigation requirements on projects. A suitability factor of 0.75 is assigned for projects at developed sites, and a suitability factor of 0.5 is assigned for projects at undeveloped sites.

Federal Land Code 198: Not on Federal Land. This variable indicates that the project is not on federal land, so there are not any development constraints based on Federal Land Codes. The value for this variable is 0.9.

Figure 1 delineates all of the data requirements presented above in a report menu option from the Hydropower Evaluation Software. The cultural, fish presence, historic, and scenic values combine to give the sample site a project suitability factor of 0.25.

RESOURCE DATABASE LISTING

DATE: 03/26/93

PAGE NO: 1

FERC NUMBER SW0006	PLANT NAME Kirkland	STREAM NAME Smackover Cr, Ouachita R	STATE NAME AR
	COUNTY NAME Ouachita	RIVER BASIN Ouachita-Black River Basin	
	CLASS P	OWNER NAME Downhill Water Associates	
NAME PLATE RATING (KW) 4000.00	ANNUAL ENERGY PESF 0.25	PESF * KW 1000.00	PESF ANNUAL RATING (MWh) 6000.00
			Energy Rating (MWh) 1500.00
Unit Type C	Plant Type STG	Project Status ZZ	Dam Status U
			Latitude 0.00 Longitude 0.00

<u>Factor</u>	<u>Exist</u>	<u>Prob</u>	<u>Factor</u>	<u>Exist</u>	<u>Prob</u>
Wild/Scenic Protection		0.90	Wildlife Value		0.90
Wild/Scenic Tributary or			Threatened/Endangered Fish		0.90
Upstream/Downstream of a			Threatened/Endangered Wildlife		0.90
Wild/Scenic Location		0.90	Federal Land Code 103		0.90
Cultural Value	Y	0.50	Federal Land Code 104		0.90
Fish Presence Value	Y	0.25	Federal Land Code 105		0.90
Geologic Value		0.90	Federal Land Code 106		0.90
Historic Value	Y	0.50	Federal Land Code 107		0.90
Other Value		0.90	Federal Land Code 108		0.90
Recreation Value		0.90	Federal Land Code 198		0.90
Scenic Value	Y	0.50	PROJECT SUITABILITY FACTOR:		0.25

Figure 1. Sample printout of resource database listing.

SUITABILITY FACTOR DETERMINATION

Suitability Factor Values

Suitability factors depend on the environmental attributes of the potential project site. They reflect the probability that environmental considerations can make a project site unacceptable, prohibiting its development. The suitability factors were developed in conjunction with the Oak Ridge National Laboratory staff who are experienced in hydropower licensing cases. Five potential values were selected, as shown in Table 1. *These suitability factors are appropriate only for the regional analysis of overall hydropower development potential and are not useful for determining the ultimate viability of developing a specific project site.*

Dam Status

The effects of environmental attributes vary by dam status. The dam status classifications follow the Federal Energy Regulatory Commission standard, which is

W = Developed hydropower site with power.

W/O = Developed site without power generation (the site has some type of

developed impoundment or diversion structure).

U = Undeveloped site (the site does not have power generation capability, a developed impoundment, or a diversion structure).

The best way to explain the influence dam status has on a project's environmental suitability factor is to provide an example: development at an undeveloped site will have a greater impact on recreation than additional development at a site that is already developed. So if a recreation value is present at an undeveloped site, a probability of 0.25 is assigned to reflect the decreased likelihood of development. If a recreation value is present at a developed site (either with or without power), then a value of 0.75 is assigned because development of a site already having a structure, either with or without power, is less likely to be impacted by any recreation value. These factors and all the other factors used are shown in Table 2.

The "not applicable" column in Table 2 assigns the default value of 0.90 if the user indicates the attribute is not present or if the entry is left blank. Environmental concerns will exist even if no environmental attributes are assigned, so a default value of 0.90 (rather than 1.0) is used to reflect this reality.

Table 1. Valuation of environmental attributes.

Effect of environmental attributes	Value of suitability factor
Little effect on likelihood of development	0.90
Minor reduction in likelihood of development	0.75
Likelihood of development reduced by half	0.50
Major reduction in likelihood of development	0.25
Development prohibited or highly unlikely	0.10

Table 2. Suitability factors by dam status for environmental attributes.

Environmental attribute	Suitability factors		
	Existing dam with or without power	Undeveloped site	Not applicable
Wild/Scenic Protection	0.50	0.10	0.90
Wild/Scenic Tributary or Upstream/Downstream Wild/Scenic Location	0.75	0.50	0.90
Cultural Value	0.75	0.50	0.90
Fish Presence Value	0.75	0.25	0.90
Geologic Value	0.90	0.50	0.90
Historic Value	0.75	0.50	0.90
Other Value	0.75	0.50	0.90
Recreation Value	0.75	0.25	0.90
Scenic Value	0.90	0.50	0.90
Wildlife Value	0.75	0.25	0.90
Threatened/Endangered Fish	0.75	0.50	0.90
Threatened/Endangered Wildlife	0.75	0.50	0.90
Federal Land Code 103	0.10	0.10	0.90
Federal Land Code 104	0.75	0.50	0.90
Federal Land Code 105	0.10	0.10	0.90
Federal Land Code 106	0.10	0.10	0.90
Federal Land Code 107	0.75	0.50	0.90
Federal Land Code 108	0.75	0.50	0.90
Federal Land Code 198	0.90	0.90	0.90

Overall Project Suitability Factor

The final step in evaluating the environmental suitability of each project site is to combine the suitability factors for the individual environmental attributes into a single factor for each project site. This overall suitability factor is an estimate of the probability of a project's successful development, considering only the attributes identified in Table 2 and their effects on site development. The project environmental suitability factors will be used to predict the contribution that each individual project makes to the aggregate potential energy supply for a state or region.

The overall suitability factor is a function of the suitability factors for the individual environmental attributes. The presence of more than one environmental attribute means that more than

one environmental concern affects a project. The overall suitability factor should obviously be no greater than the lowest factor for individual attributes, and it should be less than the lowest factor if multiple significant environmental constraints are present. For example, if an undeveloped project has both fish values (suitability factor = 0.25) and recreation values (suitability = 0.25), the cumulative effects of these two concerns will make its overall suitability even less than 0.25; so an overall suitability factor of 0.1 is assigned.

If the environmental suitability factors for individual environmental attributes were truly the probability of the project's being developed, then the overall probability of development could be mathematically calculated. And if the individual suitability factors were true and independent probabilities,

then the probability of developing the project site because of environmental concerns would be equal to the product of all the individual factors. However, the Federal Energy Regulatory Commission's licensing process is not a statistical probability function, and it cannot be assumed that suitability factors can be handled as independent probabilities (for example, there is a strong correlation between the scenic, recreational, and fishing values of a stream). In addition, environmental attributes not considered by the Hydropower Evaluation Soft-

ware would bias the value of the overall suitability factor if it were calculated as a probability.

The procedure outlined in Table 3 is used for assigning overall suitability factors. This procedure assumes that the lowest suitability factor dominates the likelihood of a project's development. However, it also considers the reduced likelihood of development resulting from the occurrence of multiple low suitability factors.

Table 3. Overall project suitability factor computation.

Individual environmental suitability factors	Project suitability factor
No environmental attributes assigned	0.90
Lowest individual factor(s) = 0.90	0.90
Lowest individual factor = 0.75	0.75
Two or more lowest individual factors = 0.75	0.50
Lowest individual factor = 0.50	0.50
Two or more lowest factors = 0.50	0.25
Lowest individual factor = 0.25	0.25
Two or more lowest individual factors = 0.25	0.10
Lowest individual factor(s) = 0.10	0.10

LIMITATIONS AND APPLICABILITY

The Hydropower Evaluation Software is not intended to model the likelihood of development of any specific hydropower project. To perform this function, the Hydropower Evaluation Software would have had to encompass the many site-specific factors affecting a distinctive site. With so many unique sites in the nation, an unmanageable number of single-site-specific attributes would be required, and the database and software would become burdensome and unmanageable, and it would fail to provide a uniform nationwide evaluation. In the Pacific Northwest, for instance, if the Hydropower Evaluation Software incorporated single-site-specific criteria it would have included any outcomes from the "Salmon Summit"—the attempt to aid the migration of salmon and steelhead. This consideration would have been unique to the Northwest area only, not to the majority of the United States. Additionally, if a single state decreed that there would be no additional hydropower development within its boundaries, the Hydropower Evaluation Software would fail in its

mission if it included an attribute unique to that single state but not pertinent to the remaining 49 states. If there is significant state opposition, it will most likely be based on factors such as fish and recreation values, which the Hydropower Evaluation Software is designed to model; and if the site is undeveloped and fish and recreation values are present, then the Hydropower Evaluation Software would assign an overall project suitability factor of 0.1. Tests conducted with the Southwestern Power Administration, and through them several states, indicated that the Hydropower Evaluation Software does satisfactorily model local concerns affecting hydropower development when environmental, legal, and institutional constraints to development are present. The model provides a uniform evaluation of hydropower potential, and it should be used to accumulate regional potential, not individual project potential. Summing the regional totals provides a national aggregate of the potential hydropower resources available.

ASSESSMENT PROCESS AND ASSUMPTIONS

The assessment process uses a logical extraction of data from the two primary data sources discussed previously: the Nationwide Rivers Inventory and the Hydropower Resource Assessment databases. The basic site data is relatively easy to download. However, extracting the environmental attributes data is somewhat tedious because of the cross-referencing needed between the two database sources and the interpretation of narrative descriptions of outstanding environmental attributes.

Environmental attributes for sites on river reaches listed in the Nationwide Rivers Inventory can be assigned several ways. The first and simplest is to assign the environmental attributes of a Nationwide Rivers Inventory reach to any project in the same state, county, and river basin as the listed reach. This method relies on the county and river basin identifiers in the Hydropower Resource Assessment database for location; these identifiers are unlikely to be inaccurate.

A second method for assigning Nationwide Rivers Inventory attributes to projects is to (a) use the river mile designations for Nationwide Rivers Inventory reaches to locate the reaches on Federal Energy Regulatory Commission river basin maps, (b) use the Geographic Information System to map the projects at the same scale, and (c) overlay the

project maps on the Nationwide Rivers Inventory reach maps to see which projects fall on Nationwide Rivers Inventory reaches. This method is potentially more accurate since only the projects actually on the Nationwide Rivers Inventory reach would be identified. Sites within a specified distance upstream or downstream of the Nationwide Rivers Inventory reach could also be identified and assigned the environmental attributes of the Nationwide Rivers Inventory reach. The main disadvantage of this method is that it uses the latitude-longitude coordinates of projects from the Hydropower Resource Assessment database, which are occasionally missing or inaccurate.

The application of suitability factors is straightforward once all of the environmental attributes have been identified. One simply follows the specifications in Table 2.

The underlying assumption in the evaluation process is that the suitability factors being assigned to environmental attributes represent the degree to which these attributes will decrease the likelihood of developing a site. One must also assume that the combination of suitability factors is not multiplicative but can be represented by the weighing scheme shown in Table 3.

SUMMARY OF STATES COMPLETED TO DATE

This status report reviews the 12 states whose undeveloped hydropower capacity has been assessed with the Hydropower Evaluation Software. As stated in the Introduction, the Southwestern Power Administration was used for model testing. The six states in this power marketing administration are Arkansas, Kansas, Louisiana, Missouri, Oklahoma, and Texas. An additional six states—Colorado, Montana, North Dakota, South Dakota, Utah, and Wyoming (located within the Department of Energy Denver Support Office region)—have also been assessed. These latter states have, with the exception of Utah and Colorado, provided input and verification of the site data. Utah and Colorado are currently reviewing their state information.

Using the hydropower summary report menu feature of the Hydropower Evaluation Software, the 12 states are summarized in Table 4. Figures 2 through 6 elaborate on the capacity adjustments presented in Table 4. They show that the Hydropower Evaluation Software will adjust potential capacity downward due to the effects of environmental attributes. They also demonstrate the wide variation in individual state site numbers and potential capacity.

Figure 2 summarizes the number of potential hydropower sites in each of the 12 states. The number of sites does not change after the Hydropower Evaluation Software adjustments are made. Colorado has the highest total (251 sites) with the most undeveloped sites (156) and the most developed sites without power (93). North Dakota has the lowest total (14 sites) with the fewest undeveloped sites (2) and the fewest developed sites without power (10). Texas has the most developed sites with power (23), and Louisiana and Wyoming have none. The total number of sites for the 12 states is 922. Developed sites with existing power (75) account for less than 10% of the total number of sites (432 undeveloped sites and 415 developed sites without power). Over 60% of the sites are less than 5 MW in unadjusted potential capacity, and over 86% are less than 30 MW.

Figure 3 summarizes unadjusted and Hydropower Evaluation Software adjusted total potential

hydropower capacity for the 12 states. Montana has the highest unadjusted potential capacity, but it is surpassed by Colorado and Texas after adjustment for environmental attributes using the Hydropower Evaluation Software. Montana also has the biggest adjustment decrease (2,657 MW, or 72%). Louisiana shows the smallest capacity decrease (25 MW, or 11%). North Dakota remains the state with the least potential capacity with or without adjustment. Overall capacity for the 12 states decreases from 14,636 to 7,479 MW (a 49% decrease).

Figure 4 is a bar chart comparison of unadjusted and adjusted total potential hydropower capacity by site status. As expected by the probability weighing scheme, the capacity associated with an undeveloped site has the biggest reduction from 7,461 to 3,019 MW, or a loss of 4,442 MW (60%). Developed sites with (75 sites) or without (415 sites) power have similar (38%) reductions in potential capacity, from 1,878 to 1,162 MW (a loss of 716 MW) and from 5,298 to 3,298 MW (a loss of 2,000 MW) respectively. Developed sites without power have the greatest overall potential after adjustment (3,298 MW). The potential for developed sites with power remains considerably less at roughly one-third (1,162 MW) of the other potentials.

Figure 5 presents these same totals by site status as overall percentages in pie charts. Developed sites without power have increased from 36% to 44% overall after adjustment, while undeveloped sites have decreased from 51% to 40% overall. Developed sites with power increased from 13% to 16% percent overall.

Weighing the potential capacities by the number of sites provides further perspective to this summary. Figure 6 shows the unadjusted and adjusted average potential hydropower capacity by site status. The greatest unadjusted and adjusted average potential is for developed sites with power. The lowest unadjusted average potential is for developed sites without power, but the lowest average changes to undeveloped sites after adjustment for environmental attributes.

Table 4. Hydropower capacity summary modeled by the Hydropower Evaluation Software (HES).

State	Category	Number of projects	Name plate capacity (MW)	HES adjusted capacity (MW)
Arkansas	With Power	13	193	174
	W/O Power	28	378	332
	Undeveloped	20	638	231
	State Total	61	1,209	737
Colorado	With Power	2	67	55
	W/O Power	93	830	515
	Undeveloped	156	1,449	760
	State Total	251	2,346	1,330
Kansas	With Power	1	.06	.03
	W/O Power	12	53	45
	Undeveloped	5	100	38
	State Total	18	153	83
Louisiana	With Power	0	0	0
	W/O Power	14	78	67
	Undeveloped	8	148	133
	State Total	22	226	201
Missouri	With Power	6	116	104
	W/O Power	12	203	181
	Undeveloped	11	378	38
	State Total	29	697	323
Montana	With Power	7	470	235
	W/O Power	72	1,129	502
	Undeveloped	79	2,073	277
	State Total	158	3,671	1,014
North Dakota	With Power	2	86	43
	W/O Power	10	13	7
	Undeveloped	2	.04	.04
	State Total	14	100	50
Oklahoma	With Power	9	274	179
	W/O Power	18	78	68
	Undeveloped	6	190	94
	State Total	33	542	341

Table 4. (continued).

State	Category	Number of projects	Name plate capacity (MW)	HES adjusted capacity (MW)
South Dakota	With Power	5	569	285
	W/O Power	25	548	405
	Undeveloped	3	6	5
	State Total	33	1,124	695
Texas	With Power	23	56	46
	W/O Power	26	164	140
	Undeveloped	40	1,014	834
	State Total	89	1,234	1,019
Utah	With Power	7	46	42
	W/O Power	69	902	462
	Undeveloped	66	758	288
	State Total	142	1,707	792
Wyoming	With Power	0	0	0
	W/O Power	36	920	574
	Undeveloped	36	708	320
	State Total	72	1,628	894
Totals	With Power	75	1,878	1,162
	W/O Power	415	5,298	3,298
	Undeveloped	432	7,461	3,019
	Grand Total	922	14,636	7,479

Currently, over 4,500 sites in the United States are identified in the Hydropower Resource Assessment database as having additional conventional hydropower potential. Unadjusted capacity for the United States is estimated by the Hydropower Resource Assessment database to be over 70,000 MW. A simple extrapolation of the evaluated 12 states (51% of original unadjusted capacity) would suggest that the actual developable potential, in light of environmental constraints, is likely to be in the 35,000 MW range.

Summary. There will always be a decrease in potential hydropower capacity when environmental attributes are factored into the suitability for development. After loading hydropower data for 12 states into the Hydropower Evaluation Software

and checking the data with the respective states, the analysis indicates that potential hydropower capacity will drop nearly in half. The greatest decrease for any state is always with undeveloped sites. This result changes the greatest potential capacity to developed sites without existing power, though developed sites with existing power still have the greatest average potential hydropower capacity per site.

The results of the Hydropower Evaluation Software can be used by developers as a preliminary means for identifying developable sites. Sites with an overall project suitability factor of 0.1 have significant constraints to development. These constraints may include wild and scenic legislative protection that would literally require an act of

Figure 2. Number of potential hydropower sites by states.

(Undeveloped sites do not have any power or civil structures in place; developed sites without power do not have any power generation capability but do have some type of civil structure such as a dam or water diversion structure; and developed sites with power have current generation and a civil structure onsite with additional, undeveloped hydropower potential.)

Figure 3. Total potential hydropower capacity by states.

Figure 4. Total potential hydropower capacity by site status.

(Undeveloped sites do not have any power or civil structures in place; developed sites without power do not have any power generation capability but do have some type of civil structure such as a dam or water diversion structure; and developed sites with power have current generation and a civil structure onsite with additional, undeveloped hydropower potential.)

Figure 5. Percent of total potential hydropower capacity by site status.

(Undeveloped sites do not have any power or civil structures in place; developed sites without power do not have any power generation capability but do have some type of civil structure such as a dam or water diversion structure; and developed sites with power have current generation and a civil structure onsite with additional, undeveloped hydropower potential.)

Figure 6. Average potential hydropower capacity by site status.

(Undeveloped sites do not have any power or civil structures in place; developed sites without power do not have any power generation capability but do have some type of civil structure such as a dam or water diversion structure; and developed sites with power have current generation and a civil structure onsite with additional, undeveloped hydropower potential.)

Congress before development could occur. Other constraints could include fisheries, wildlife, or recreation attributes that members of the public value significantly. Any development at sites with these attributes would likely encounter delays and costs that would make the licensing process tedious and the economics unthinkable. Similar conditions, though perhaps not as overwhelming, would likely be encountered if development of a site with a value of 0.25 were attempted.

The actual probability of development of individual sites with values of 0.5, 0.75, and 0.9 could also depend on nonsite events such as regional electrical capacity surplus margins, political philosophies, or other external factors such as oil shortages and resulting legislative incentives. Development

probability of a site with a value of 0.9 is not a known certainty because unknown interest groups or environmental attributes may make development implausible. In spite of possible unknowns, Hydropower Evaluation Software modeled results can be used as a "first-cut" vehicle to identify individual developable sites. It is useful as a regional and national power planning tool.

The results of the Hydropower Evaluation Software are obtained in a viable, low cost manner. These results provide a peerless means for identifying the undeveloped hydropower potential whose development is essential for ensuring continued energy growth, which is necessary for the continued viability of the economic strength of the United States.

PLANS FOR FUTURE ASSESSMENTS

Depending on future funding allowances, the resource assessment of hydropower potential should continue for the remaining states in order to obtain an informed estimate of national hydropower potential. The administrative aspect of coordinating individual state review and input of the hydropower potential assessment through Department of Energy support offices should be continued given the pre-existing relationships between the support offices and the individual state energy agencies. These close relationships greatly expedite the administrative coordination when several agencies are cooperating on the resource assessment endeavor. If the assessment does not continue, other regional data, especially east of the Mississippi, must be extracted and loaded into the Hydropower Evaluation Software before any extrapolation can be made to a national level. In addition, feedback from users may warrant other data fields or an updated User's Manual.

Application of the Hydropower Evaluation Software to current data significantly reduces calculations of state and regional totals for potential new hydropower. An abundance of potential sites remains that, as a result of this assessment, have been identified as more likely to be developed given current environmental awareness and geopolitical constraints. Strategies may need to be formulated to further assess those sites with the most potential for development. For example, developers would need to know if transmission lines are nearby and easily accessible.

The value of the Hydropower Evaluation Software lies in the interaction among state and regional entities for the planning and development of hydropower, a nonpolluting, renewable energy resource. It is a tool for state and regional entities to customize their database inventories of hydropower sites, thereby helping decision makers and developers assess economic viability and national priorities.

OBTAINING INDIVIDUAL STATE INFORMATION

The Hydropower Evaluation Software results for the 12 states assessed to date are available and can be obtained by writing or calling the National Technical Information Service (NTIS). Reports of Department of Energy sponsored projects or reports received on foreign exchange agreements can be ordered from Oak Ridge, Tennessee. Reports are available in paper, microfiche, computer disks, and magnetic tape formats.

Telephone Orders. (703) 487-4650. NTIS sales desk and customer services are available between 8:30 a.m. and 5:00 p.m., Eastern Standard Time.

Fax. (703) 321-8547. Customers may fax their orders to NTIS. These orders may be charged to an NTIS deposit account, American Express, VISA, or MasterCard.

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For Help Tracing an Order. Call (703) 487-4650 and request the customer service option.

ADDITIONAL HYDROPOWER EVALUATION SOFTWARE INFORMATION

Additional information concerning the Hydro-power Evaluation Software can be obtained by contacting Ben Rinehart or Jim Francfort at the

addresses provided below. Copies of the software and the User's Manual may also be obtained from these individuals.

Ben Rinehart
Idaho National Engineering Laboratory
P.O. Box 1635, M.S. 3830
Idaho Falls, ID 83415-3830
phone: (208) 526-1002
fax: (208) 526-0969

Jim Francfort
Idaho National Engineering Laboratory
P.O. Box 1635, M.S. 3875
Idaho Falls, ID 83415-3875
phone: (208) 526-6787
fax: (208) 526-8883

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