~~DOE/R4~~

10214

NC-142

DOE/R4^{4?}/10214--T1

Final Report of

DOE/R4/10214--T1

DE84 000431

Small-Scale Hydroelectric Power in
Watauga County, North Carolina,
U.S. Department of Energy,
Appropriate Energy Technology Small Grants Program,
DE-FG44-80R4102144

Blue Ridge Group, Sierra Club
c/o Harvard G. Ayers
Rt. 3, Box 662
Boone, N.C. 28607

February 22, 1983

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

NOTICE

PORTIONS OF THIS REPORT ARE ILLEGIBLE.

It has been reproduced from the best available copy to permit the broadest possible availability.

MASTER

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

MLP

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency Thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

DISCLAIMER

Portions of this document may be illegible in electronic image products. Images are produced from the best available original document.

Table of Contents

	Page
Introduction	1
Demonstration Project	2
Stream Appraisal	7
Conclusions and Recommendations	9
Summary	10

Diagrams and Enclosures

Results of Watauga County Stream Survey

System Schematic (see WP '81 article)

Electrical Schematic (not included)

Mother Earth News Article - removed

Waterpower '81 Article - copied separately -

INTRODUCTION

In May of 1980, the Blue Ridge Group of the Sierra Club, Blue Ridge Electric Membership Corporation and the Earth Studies program of Appalachian State University applied for a grant to the U. S. Department of Energy (DOE), Appropriate Technology Small Grants Program to evaluate and demonstrate the hydroelectric potential of Watauga County, North Carolina. Notification of DOE's approval of the grant application was received in September, 1980, and the first phases of the project began in December of the same year. The period of the original grant was through March, 1982, but was extended to June, 1982, to allow for completion of the demonstration project. The original grant amount was for \$21,416.00 which was later adjusted by \$5,377.67 for a total of \$26,793.67.

Watauga County is well suited to the generation of hydro electricity by utilizing the natural drop of its abundant streams. The average rainfall for the county (about 60" per year) is high and significant elevation drops occur between its peaks (Grandfather Mountain is 5,964 feet above sea level) and its valleys (as low as about 2,000 feet). Thus the two major factors necessary for hydro production, i.e., water flow volume, and drop or head, are readily available in a number of the county's small streams.

The research project had two major objectives (1) to derive an estimate for the total hydro potential of the county by monitoring the flow of a number of streams monthly over a year's period of time; and, (2) to install a demonstration generating plant on one of the county's streams. It was hoped that these activities would encourage the further development of hydro electric power in the county and surrounding areas.

DEMONSTRATION PROJECT

In February of 1981, Andy Feimster, Bob Powell, Dick Suhre, and the author began designing and building the demonstration project on Laurel Creek in western Watauga County, North Carolina. The major elements of the design include a small dam (maximum height 3 feet), a 1,640 foot length of 8" PVC pipe, a powerhouse which contains the turbine, generator, controls, guages, etc., a tail race, and a weir where system water flow rate is measured. A schematic diagram of the basic layout is included in this report.

The dam is constructed of steel-reinforced concrete faced with stream cobbles. It is about 25' long by 1' thick by about 1-3' in height. The steel-reinforced bars are tied into "eye" bolts which are anchored in the bedrock. Three gates are located along the length of the dam, consisting of boards which slide in verticle runners. The dam is set at a slight angle across the creek with the pipe intake being on the downstream end.

The intake chamber consists of a roofed concrete box with one open side to allow water ingress. An expanded metal screen covers the open side, acting to filter out debris over an inch or so in diameter. The 8" PVC penstock pipe extends through the dam, intruding an inch or so into the intake chamber.

The penstock extends a distance of 1,640' from the dam to the powerhouse. After the first 200 feet, the pipe remains a distance of about 50 feet from the natural creek bed, curving with the creek where necessary. The PVC pipe is in 20' lengths and has about 11° deflection possible to either side at each joint. A 22½° elbow, however, was necessary to make one sharp turn just below the dam.

The pipe runs above ground except for the lowest 100' or so where it is buried. In two separate locations the pipe had to be elevated several feet

above the ground surface due to gullies at right angles to the creek- dips in the pipe cannot be tolerated due to potential freezing in case the system needs to be drained in the winter. Support for the pipe consists of locust posts driven either side of the pipe every 10' or so. Wire cable is lashed around each of the posts and around the pipe.

The powerhouse is a 10x10' wooden frame structure with a concrete floor. Bolts were poured into the floor to anchor the turbine and generator.

Upon entering the powerhouse, the PVC pipe separates in a "Y". One of the sides of the "Y" directs the water to the Pelton turbine and the other side to a safety valve which diverts the water from the turbine in case of a system shutdown. Under normal operating conditions, the water is directed onto the turbine by two separate nozzles which strike the runner at points 70° apart. One of the nozzles is a needle nozzle and is fully adjustable through the full range of its capacity. The other nozzle is simply an orifice and a plug and is either fully open or is carrying no water at all. Each nozzle is designed to carry 1.25 cubic feet/second (CFS). The combination of one adjustable and one non-adjustable nozzle allows us to control the flow over the full 2.5 CFS range.

The runner is a 15" pitch diameter Pelton wheel, manufactured by Dependable Turbines of Vancouver, B.C., and prepared by Cannon Industries of Demming, Washington. It spins at about 720 RPM under loaded conditions under a head of about 145 feet. Its power is transmitted through 2 "V" belt pulleys to a 3 phase, 50 HP induction motor-generator. Since only single phase power lines are present, the 3 phase generator is hooked up to give only 1 phase power. This reduces the power rating of the generator by 40% to 30 HP or about 22 KW. The induction motor is rated at 1770 RPM. In order to run as a generator, 1830 RPM are required.

The electric controls include a starter, voltage and frequency relays and various fuses. In addition a solenoid switch which activates the safety valve system is connected to the voltage and frequency relays. Thus, if either voltage or frequency varies significantly, the solenoid releases the pressure on the safety (globe) valve and the water is diverted from the runner. This has the effect of (1) stopping electrical production; and (2) preventing the overspeed of the turbine-generator combination should the utility load be interrupted.

From the generator the power is transmitted by way of the step-up (from 220V) transformer into the local utility (Blue Ridge Membership Corporation) grid. The 16-17 KW capacity serves an average of 16 residences and a yearly peak of about 5 residences.

Tail water is returned to Laurel Creek by way of a tail race and a weir pool. The "V" notch weir allows accurate determination of stream flow being utilized by the system.

The system first produced power in mid-April, 1982. In June, it was down for about two weeks to make some adjustments to the turbine and to build the weir. It ran smoothly through the summer except that low stream flows required the production of only part capacity. Only the needle nozzle was utilized which produces about 9 KW and uses only about half the design flow.

Fall brought another problem, leaves. The 2'x3' screen on the open side of the intake chamber became clogged in one hour or less when wind, rain, etc., had caused many leaves to drop. When the screen became clogged, the pipe would evacuate the intake chamber, air would be sucked in and the entire system would be shut down by the safety valve solenoid due to voltage fluctuation.

In order to counter the leaf problem, we installed a device called a skimmer. On the advise of Ken Grover of GSA Associates, we placed a log of diameter about 8-12" at an angle to the stream flow just above the intake chamber. The log was attached by a wire to a tree on the reservoir bank and floated with about 2-3" of its diameter above the water level. The lower end of the log was placed such that any leaves floating near the surface (most of the leaves) were deflected over one of the partially open gates in the dam. To the bottom of the log was attached a $\frac{1}{2}$ " mesh wire cover that extended almost to the bottom surface of the reservoir. This screen caught most of the remainder of the leaves not diverted over the dam gate. Any other leaves which managed to get through this barrier were handled nicely by the intake chamber screen. The log system worked fine for several days until the log sank. We recommend against using hemlock. We will perhaps try oak next fall.

Around October 3, the system experienced a major breakdown. Up to that time it had produced about 45,000 KWH. Because of this electrical malfunction, production did not begin again until December 16. The malfunction was due to an element of the electrical system which had not been originally planned on by electrical engineer Dick Suhre. The element was a compressor which served to keep air pressure up in the safety valve. The wiring for the compressor was run through the frequency band monitor. The frequent surges of the compressor coming in eventually burned out the frequency monitor which left the entire electrical system inoperative. Suhre himself came to Laurel Creek and made the necessary repairs in December.

Up through mid January, 1983, the system had produced 56,000 KWH and was producing a steady 17 KW. The coldest of the winter has caused some freeze-up problems of the safety valve system and in the very cold weather we have had

to shut the entire system down to prevent overspeed in the case the utility goes down. We might be forced to insulate the powerhouse to keep the temperature from going too far below freezing.

According to weir readings taken in December, 2.44 CFS were being used by the system. Assuming a head of 145 feet and a given production as indicated by the utility watt hour meter of 17.0 KW, total system efficiency was 57%.

The Laurel Creek project has received widespread publicity. Many local and state newspaper articles on the site have been published. Mother Earth News, (November, December 1982) published an article by David Schoonmaker which featured the Laurel Creek project. SIERRA magazine is expected to publish an article in the March-April issue which shows pictures of and describes the site. In addition, area and national TV coverage (NBC Today show) has occurred.

The site has also stirred a lot of interest in people interested in installing a similar plant of their own. Visitors from North Carolina, other surrounding states and even several foreign visitors (Dominican Republic and Indonesia) have observed the project in various stages of completion. Also, it has served as the major example of a working hydro system for the classes taught at Appalachian State University. It is presently being operated as a demonstration project, on an informal basis, by the Blue Ridge Group, Sierra Club. Plans are to continue this service for as long as the system operates and the Blue Ridge Group has personnel available to offer those tours..

STREAM APPRAISAL

Twenty different stream stations were monitored by the system appraisal project. Those twenty and the raw data results of the year long study are presented herein. Mr. Bob Powell aided by Feimster, Ayers, and others accomplished the study.

Instruments used for the study included a propellor flow meter (General Oceanics; Miami, Florida) and a pygmy-type flow meter obtained from Forestry Supplies Incorporated of Jackson, MS. Flow meters give velocity readings; cross-sectional areas must be multiplied times the velocity to give the desired discharge figure. For shallow streams (less than 1' in depth) we took velocity readings at a point .6 of the way from top to bottom. If the stream was deeper than 1 foot, the readings were taken at .3 and .8 of the depth and averaged. In order to properly weight the 1 foot horizontal intervals, each 1 foot horizontal of the cross section was considered separately. In other words, the cross sectional areas of each 1 linear foot were multiplied by the velocity for that sector, and then these incremental discharges were added together to give the total discharge. The procedures described in this paragraph are standard U. S. Geological Survey (USGS) hydrologic practice.

We had initially hoped to use the figures from this assessment survey to project a KW figure for pipe-the-pressure potential in Watauga County. These figures are presented herein, including average discharge values for each set of readings. Examination of these figures shows a vast variation of discharge for some of the streams. A 10X variation is not unusual. In most cases we do not feel that the spot readings represented an accurate representation of annual usable stream flow. We have consequently employed what we feel to be a more sophisticated technique of discharge prediction based on long term

USGS gauging stations in the vicinity. This method was developed by a recently updated study funded by the N. C. Alternative Energy Corporation and the N. C. Energy Institute. The results of this study for Watauga County are also presented herein. They represent a comprehensive list of the feasible pipe-the-pressure sites in Watauga County.

CONCLUSIONS AND RECOMMENDATIONS

The stream assessment and the demonstration were completed as planned. The demonstration project is functioning well and has served, as we had hoped to promote interest in and knowledge of pipe-the-pressure hydroelectric production. The success of the assessment project was superseded by a subsequent project and is seen as having at least partially provided the impetus and increased sophistication of the latter project.

On the basis of the information we now have at hand, we feel that pipe-the-pressure hydroelectric production has good potential in Watauga County and in the other mountainous counties of the state. We have identified 24 feasible sites in Watauga County and 1593 sites for all the mountainous counties. Total production capacities of these sites is estimated at about 250,000,000 KWH annually. While this figure is not astoundingly high, in the five or so counties where the heaviest concentration of sites exist, the hydro production could amount to about 10% of the present usage.

So, the assessment work has been compiled and the good potential for pipe-the pressure hydro has been demonstrated. What is now needed are several (perhaps 3-4) more demonstration units like ours. Watauga County is a good distance from many of the best sites in the state. In the mountains, decisions to try a new technology are based largely on local success or failure of that technology. Funds need to be found to finance these additional projects.

SUMMARY

We have completed both the installation of the demonstration project and the assessment of the stream flows in Watauga County, North Carolina. The 17 KW, high head (178'), project on Laurel Creek in Watauga County has produced about 60,000 KWH over its first nine months of operation despite some electrical and other problems. It is currently producing 16-17 KW on a steady basis and is functioning as a popular site for visits by people who plan to install their own similar plants in areas throughout the southeast. The stream assessment proved to be less satisfactory than the subsequently developed method for predicting long term stream flows. The latter method has been applied to all western North Carolina and this report presents its general conclusions.

Results of Watauga County Stream Survey

Flows in CFS - 1981

[illegible]

Results of Watauga County Stream Survey (continued)

# of Readings		Jan	Feb	Mar	April	May	June	July	Aug	Sept	Oct	Nov	Dec	Average
8	NY2					2.5	4.9	1.3	1.5	1.0	.2	1.6	.8	1.73
9	PR		1.6	1.9	6.3	3.4	6.6	.6		.6		.9	1.1	2.56
2	PC	3.6		2.5										3.05
5	PC2					6.1	10.0			.8	.2	.8		3.58
3	SM			1.6	3.5	3.9								3.00
10	DR		4.3	3.5	3.4	3.8		2.2	2.6	.7	.2	.8	.8	2.23
2	WR	62.3		89.0										75.65
3	WR2					281.0	168.1	58.1						169.06
3	WR3								22.1	61.4	25.6			36.37