Centralia Steam-Electric Project - A Story of Resource Development

by

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INTRODUCTION

Coal was discovered in southwestern Washington over one hundred years ago but until recently was of only minor local importance. From the peak production year, in which less than one-third of a million tons of coal were mined, until the late 1960's, the coal production of the area degenerated to a point that the coal virtually reverted from a resource to a reserve.

Beginning in late 1970, a coal mine near Centralia, Washington, began producing coal at a yearly rate that will not only greatly exceed the previous peak production year of southwestern Washington, but will greatly exceed the entire state's previous peak production year.

This report examines the historic utilization of the southwestern Washington coal, the factors behind the development of the coal mine near Centralia, the method of mining being employed at this mine, the flow of the material from this mine to and through the consuming facility, and some of the environmental aspects associated with the mine and consuming facility.

COAL FIELD DATA

State of Washington

The original geological content of the coal fields of Washington has been placed at 6,387 million short tons

(2-24). This tonnage was distributed as follows[1]: Anthracite, 2 million short tons; Bituminous, 1,141 million short tons; and Subbituminous, 5,244 million short tons (14-5).

The National Coal Association, and others (7-12), have determined that as of 1967, the Washington coal reserves contained 6,183 million short tons (10-68). This smaller figure takes into account tonnages removed by mining, losses that have occurred, such as fires, and the incorporation of later drilling data. Table 1 gives, in millions of short tons, a breakdown of the coal reserves in Washington, and for comparison purposes, the United States as of January 1, 1967.

Table 1. - Washington and United States Coal Reserves, January 1, 1967

	Anthracite	Bituminous	Subbituminous	Lignite	Total
Wash.	5	1,867	4,194	117	6,183
U.S.	12,969	671,049	428,210	447,647	1,559,875

Source: National Coal Association, Bituminous Coal Facts 1970, p. 68

Centralia-Chehalis Coal District

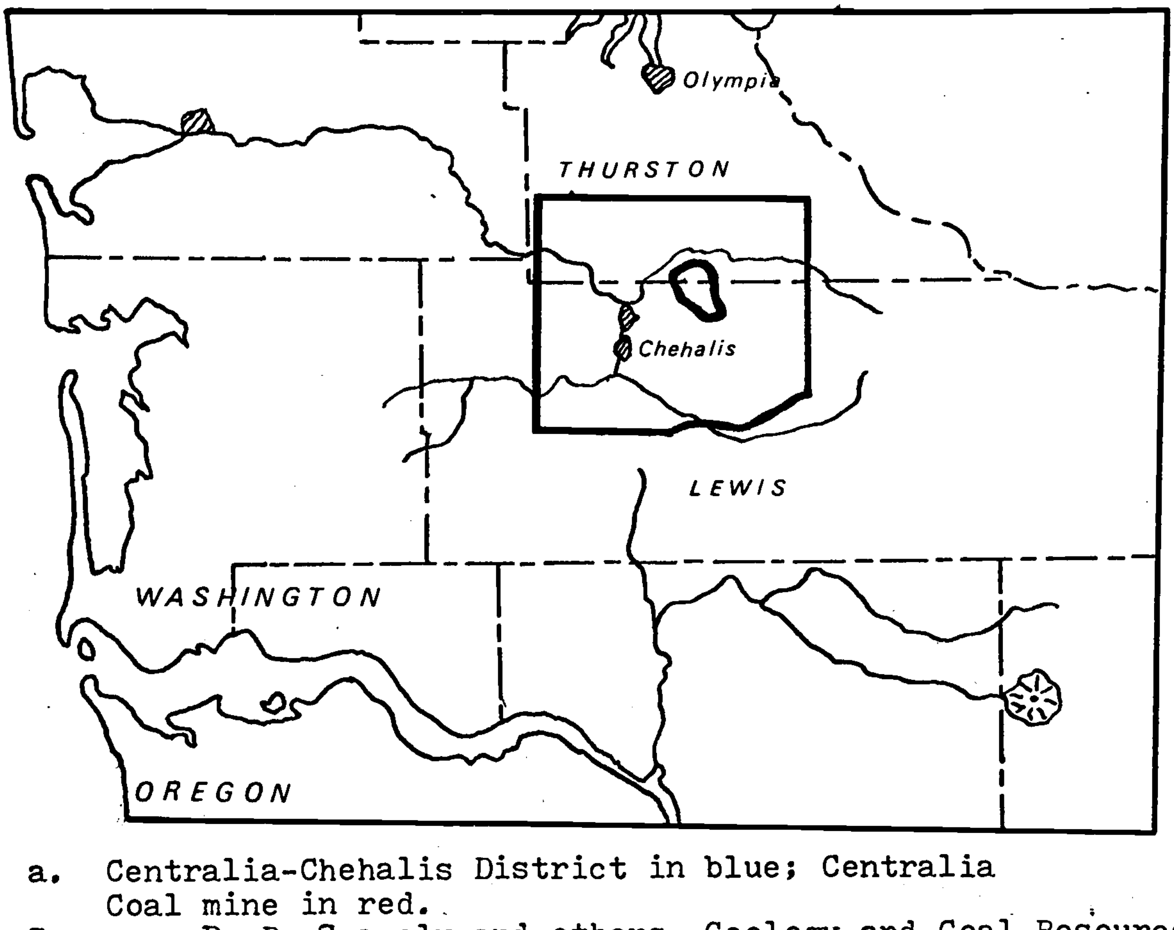
The Centralia-Chehalis coal district (Figure 1) is a rectangular shaped area of about 570 square miles, lying in

1. Values are for depths less than 3,000 feet and, for subbituminous coal, seams more than 2.5 thick containing less than twenty-five percent ash.

the northeastern part of Lewis County and the southern part of Thurston County, in southwestern Washington, midway between Seattle and Portland. The district is named after the two largest cities, Centralia and Chehalis, within the bounded area (4-2).

The fourteen different coal beds evident in the district are in the Skookumchuck Formation which, like all other known commercial deposits of coal in Washington, was deposited during the Tertiary Period, primarily during the

Figure 1. Location of the Centralia-Chehalis District[a] and the Centralia Coal Mine.



a. Centralia-Chehalis District in blue; Centralia Coal mine in red.

Sources: P. D. Snavely and others, Geology and Coal Resources of the Centralia-Chehalis District Washington, 1958, p. 3; data for Centralia Coal Mine calculated by author.

Eocene Epoch (22-276). Individual coal beds in the district range in thickness from a few inches to more than seventy feet; the average thickness of most beds is between six and eight feet (9-87).

The Centralia-Chehalis district is the largest of the subbituminous coal fields in Washington. As of January 1, 1960, the district contained 3,693.78 million short tons of subbituminous coal in seams two and one-half or more feet thick and less than 3,000 feet below the surface. More than one-third of this coal, 690 million short tons, is in beds over ten feet thick (22-280). The subbituminous coal in the district amounts to slightly more than eighty-five percent of the total amount of subbituminous coal in the state and slightly less than sixty percent of all the coal, of all grades, in the state.

Centralia Coal Mine

In the north-central portion of the Centralia-Chehalis coal district is an area which, for purposes of this report, will be referred to as the Centralia coal mine (Figure 1). This area contains approximately 21,000 acres, or about thirty-three square miles, of which approximately 8,670 acres, or about 13.5 square miles, is classified as mining field area (19-6).

The coal mine is located approximately six miles northeast of Centralia on a northwest-southeast axis between the towns of Bucoda and Mendota. Approximately one-third of the coal mine lies in Thurston County with the remainder being in Lewis County. The two major seams of the Centralia Coal Mine are estimated to contain in excess of 500 million short tons of coal. The larger seam, the Big Dirty, varies in thickness from twenty-five to fifty feet. The smaller seam, the Smith, varies in thickness from eight to fifteen feet (19-6).

The Pacific Power and Light Company (PP&L) and the Washington Water Power Company (WWP) either own the land and mineral rights or possess the mineral rights under lease agreements to all of the land referred to as the Centralia coal mine. PP&L and WWP began preliminary field explorations and acquisitions of this property in 1957.

The Centralia coal mine is a consumer-owned (captive) mine of the Centralia Steam-Electric Plant which will generate 1,400,000 kilowatt-hours (kwh) of electricity. The mine's total output, all of which will be mined by surface methods, will be consumed by the steam plant. The plant will consume nearly fourteen tons of coal a minute or approximately seven million tons a year.[2]

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2. Consumption rates have been calculated to be 417 tons per hour per unit. If both units were to operate twenty-four hours a day, every day of the year, consumption would amount to 7,305,840 tons per year.

HISTORIC UTILIZATION

Because specific data have not been published on tonnages mined for the area outlined in this report as the Centralia coal mine, a brief historical examination of the Centralia-Chehalis coal district will be made, for it can be assumed that changes in production and the reasons for these changes will also apply to the Centralia coal mine.

The earliest recorded coal discovery in Washington was made in 1833 by Dr. Tolmie, an Englishman employed by the Hudson's Bay Company. This initial discovery was made south of the Centralia-Chehalis district near the junction of the Cowlitz and Toutle Rivers in Cowlitz County. The state's first coal mine was opened in Whatcom County, on Bellingham Bay, in 1853 (17-8). In contrast, coal was not discovered in the Centralia-Chehalis district until around 1855 and the first recorded mines did not begin operation until the late 1870's (4-4 and -99).

Although during the last fifteen or so years coal has been of minor importance, it was a significant contributor to the economy of the state and district in the past. Coal accounted for nearly twenty-five percent of the cumulative value of all minerals produced in Washington from the time records were first kept until 1863, even though by 1963 it accounted for less than two percent of the state's annual mineral production (22-49).

The Centralia-Chehalis district produced more than nine million short tons of coal between the 1870's and 1960 (Figure 2). By 1966, four mines were still operating in the area but produced only 15,000 short tons (9-101).

Until 1905, annual production in the Centralia-Chehalis district did not exceed 25,000 short tons because wood supplied the majority of the fuel for domestic purposes. From 1905 until the early 1920's, with the exception of a brief period just prior to World War I, coal production expanded greatly due to the increased consumption of coal for domestic purposes and for the operation of the railroads[3]. Proximity of the mines to population concentrations and to transportation routes were the primary factors behind the increased use of coal for domestic purposes (17-5). For a number of years after 1918 more than 300,000 short tons of coal were produced annually.

After 1930 production began to decline. The primary reason, at least initially, for this decline was that oil

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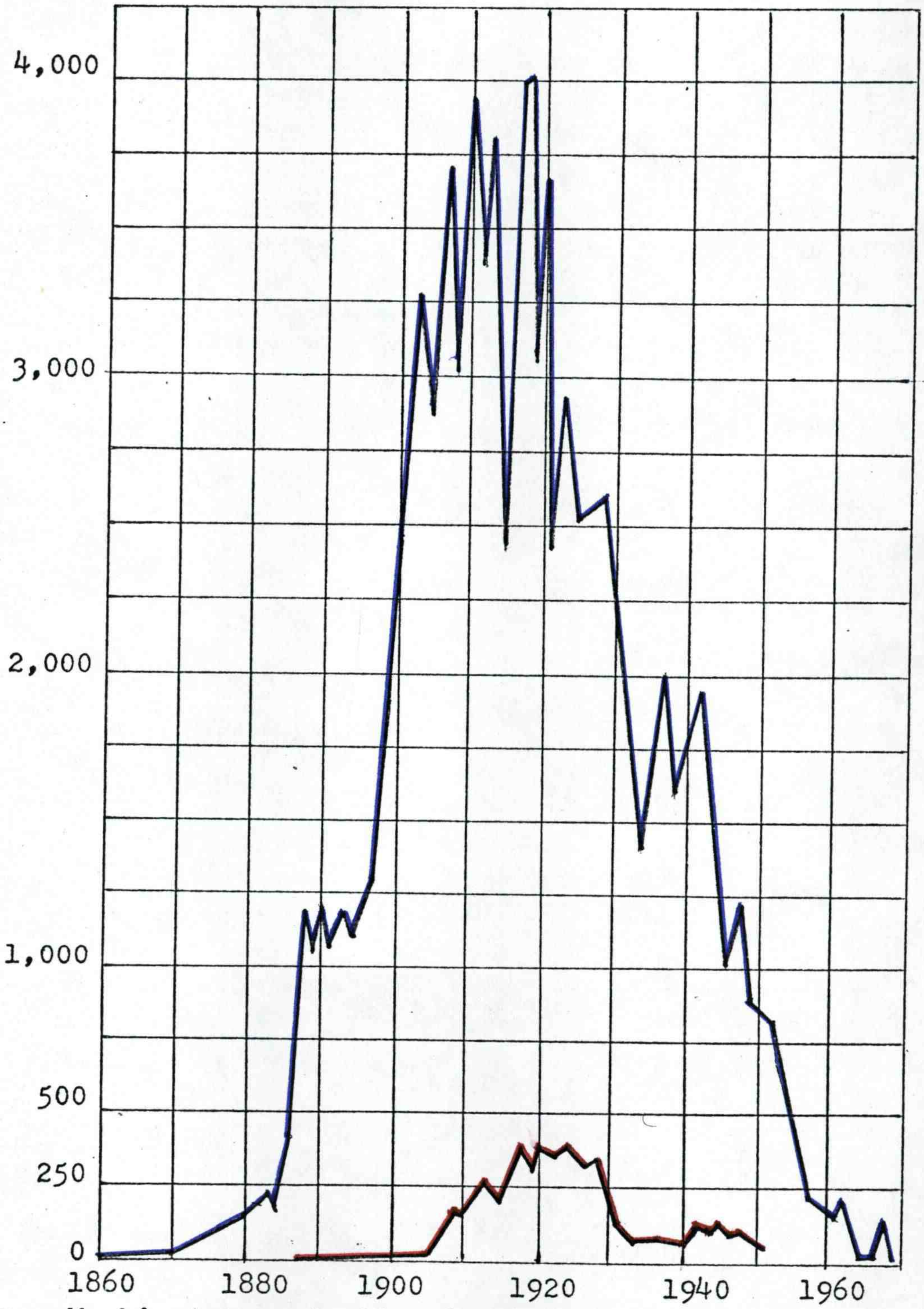
3. A direct relationship existed between the railroads and the production of coal from the days of earliest discovery until the 1930's. Two examples are sufficient to illustrate this point. The building of the first railroad from Seattle to the Columbia River did not take place until the discovery of coal on the Skookumchuck River in the mid-1800's provided the incentive (9-5). In turn, the railroads were the largest single consumers of Washington coal until the 1930's. Of the 2.7 million tons of coal consumed in the state in 1927, the railroads used 1.0 million tons as fuel (2-33).

Figure 2. Coal Production in Washington[a]
and in the Centralia-Chehalis Coal District. (000T)



a. Washington production in blue; district production in red.

Source: Data through 1951 from P. D. Snavely and others, Geology and Coal Resources of the Centralia-Chehalis District Washington, 1958, p. 106.; Data after 1951 from Bureau of Mines, Minerals Yearbook (various years).

began to replace coal as the fuel for steam locomotives as the railroads began a complete conversion to diesel locomotives. After 1930 only about 100,000 short tons of coal were produced annually until the Second World War. A slight upward trend was experienced during World War II when annual tonnages reached 150,000 tons. Since World War II, production has continued to decline, supplying coal only for the constantly declining local domestic market (4-99).

Several other factors are important in the decline of production of the Centralia-Chehalis district. The low quality of the coal from this area made it somewhat less than desirable for domestic consumption. The high percentage of combustible volatile material in the coal produces a great deal of soot when the coal is burned. The high moisture content of the coal causes several problems. When it is exposed to the air it crumbles readily, which leads to storage difficulties. Crumbling also occurs when the coal is placed on a fire. This allowed a high percentage of the coal to fall through the grates of most of the coal burners without being consumed. In addition, a great many sparks are produced when a coal of high moisture content is burned. Finally, the high moisture content of the local coal gave it a lower heating value than the other coals in the state. As a consequence of the above factors the coal was never in as great a demand for domestic consumption as might be expected, except where better coal was scarce and high in price (33-39).

A lack of miners also contributed to the decline. The availability of miners to work the coal fields can be attributed directly to the demand for the local coal and the price received for it, which in turn determined the wages that were offered to the miners. The shortage of miners was particularly important following World War II. Most of the miners that were working in the coal fields left the mines to take jobs with other industries where the wages were more attractive. This lack of manpower led to the depletion of easily accessible deposits and the lack of development work and exploration for new deposits. These factors led to large importations of coal and other energy sources. During 1946, for example, approximately 1.5 million short tons of coal were imported from Utah, Wyoming and Canada. This amount almost equalled the state's total production for that year (17-25). These importations further depressed the local coal industry. Economically, the low-grade, high-cost local coals found it more and more difficult to compete.

Another contributing factor that virtually dealt coal production a fatal blow was the emergence of another competing energy source: hydroelectric power. Beginning in the 1930's, the availability of low-cost hydroelectric power began to have its impact not only on coal but on all energy sources. By 1936 both fuel oil and hydroelectric power were ahead of coal in the production of power with fuel oil generating 33.7 percent of the total power and hydroelectric power generating 31.7 percent. Coal had slipped to 24.0 percent, followed by wood with 6.6 percent and imported coal with 4.6 percent (3-12). By 1950, wood was no longer a factor in power generation. In 1951 coal was no longer a factor and in 1952 oil was no longer a factor (13-23). Hydroelectric power was "king."

Other factors, such as a significant increase in the efficiency of steam generating plants which led to a smaller requirement for fuel to generate a given amount of energy (22-49), and changing economic conditions, particularly the business depression of the 1930's (14-17), had their impact on the production of coal.

Over the years at least fifty-eight mines[4] have produced coal in the Centralia-Chehalis district. Seventeen of these mines have operated at one time or another on the property currently owned by PP&L and WWP. Of this number only two mines, the Black Prince and the Stoker, were still operating as late as 1969 (18-14).

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4. Certain information, such as the name of the mines, locations, name of the coal beds, date of abandonment, etc., are given on pages 106-110 of Geological Survey Bulletin 1053.

The development of the Centralia coal mine will revitalize the coal mining industry of Washington. A single year's production from this mine, once it is in full operation, will be nearly twice as large as the state's peak production year.[5] Based upon the anticipated production figure of 7.3 million short tons of coal per year, this mine, in just over a year, will produce more coal than the Centralia-Chehalis district has produced since its beginning in the 1870's. The Centralia coal mine, during its thirty-five year life expectancy, will produce significantly more coal than has been produced in the entire state in the 110 years coal has been mined.[6] Not only is this mine large by the state's standards, it is large by national standards. The largest bituminous mine in the United States in 1969 produced 6,052,673 short tons of coal (10-78). As can be seen, if the Centralia mine had been in operation in 1969, at anticipated production figures, it would have been the largest coal mine in the United States.

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5. Record production year was 1918 when 4,082,000 short tons of coal were produced (23-627).

6. Total state production up to January 1, 1967 was 149,296,000 short tons (23-627).

FACTORS LEADING TO THE PRESENT DEVELOPMENT OF THE CENTRALIA COAL MINE

Electricity: Supply and Demand

By 1990, the Pacific Northwest will need to triple its electric power capacity to meet the burgeoning demand of its industry and people (40-34). Future increases in the population will result in an ever-increasing demand for electrical energy, simply due to the increase in the number of energy users. Further, the per capita consumption of electrical energy has continued to increase every year and it is anticipated this trend will continue into the near future.

In the recent past, the main source of electric energy in the Pacific Northwest has been from low-cost hydroelectric resources.[7] However, within the next ten to

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7. As of December 31, 1970, thermal capacity amounted to 1,295,000 kwh, or about seven percent of the total installed capacity in the Pacific Northwest. Of this amount, 800,000 kwhs were generated by the nuclear-fired Hanford plant near Richland, Washington. The remaining capacity was generated by fossil-fuel thermal-electric plants owned by public and private utilities and by industrial concerns (30-35). Most of this capacity is old and normally used only as reserves (15-19).

fifteen years virtually all of the economically feasible hydroelectric potential will have been built or will be under construction (5-1 and 15-109). The Bonneville Power Administration (BPA) notes that by the mid-1970's there will be an insufficient number of hydroelectric plants constructed to meet regional needs even if all presently scheduled hydroelectric projects are completed on schedule. The regional growth rate in the consumption of electrical energy, during the time it takes to build a dam, exceeds the the capacity of that dam when it is completed (39-9). To fill the void left by this exhaustion of hydroelectric sites and the slow construction rates, the region is turning to thermal-electric generating plants. The Pacific Northwest is beginning a major transition in its electric power supply program, shifting from a system almost wholly dependent on the hydroelectric potential of its rivers to one in which new thermal sources of generation will provide increasing amounts of the future power supply (16-16).

Economies of Scale

The Bonneville Power Administration markets the power produced by the federal hydroelectric sites to the various private and public utilities and to selected industrial customers. As the demand for electricity increases and the number of hydroelectric sites decrease, investor-owned utilities will have to build more and more generating facilities to replace the power they are now buying from BPA, because BPA must meet the needs of the public utilities before the needs of the private utilities (19-18). By no later than 1986, BPA anticipates that the federal sites will no longer even be able to fully supply the public utilities demands, therefore, the public utilities will also have to begin construction of their own power generating facilities (26-20).

It is only reasonable to assume that the various utilities requiring additional electrical power will try to select that source that will provide the lowest cost per kwh possible at the time the power is required. Officials of PP&L and WWP stated, when construction plans were announced in 1967, that feasibility studies had indicated a conventional-type steam-electric plant, using the Centralia coal for fuel, would produce power at a lower cost per kwh than any other thermal plant, including nuclear-fired, that could be ready for operation in the mid-1970's (25-68).

At present, regional power requirements are growing at the rate of about one million kwh per year. This growth rate coincides well with the fact that thermal plants in excess of one million kwh are the most efficient in light of today's technology (4-7). Private (and public) utilities, therefore, plan to build plants in excess of one million kwh in order to benefit from the economies of scale (39-14). The capital costs per unit of electrical output of a power plant decreases as the capacity increases, i.e., its unit capital cost, in dollars per kwh decreases (28-15). The savings in land and land rights, site preparation, structures and other site-related features of the plant are significant since most of these cost items are normally relatively independent of the size of the unit. Savings can also be realized in other capital items, such as the power generating equipment (39-11). The price of equipment and land increases, but at a lesser rate than the output increases. This same factor is true for the equipment and land involved in the production of the fuel source.

Cooperative Action

Generating plants having capacities in excess of one million kwh will more than meet the immediate needs of the sponsoring builders, even if several utilities are participating in the construction costs and benefits. For economic reasons it is necessary that the temporary surpluses from such plants be efficiently disposed of as long as the surplus exists (39-1). Other difficulties are associated with generating plants of this magnitude. Sponsoring builders are not able to supply the backup generation,[8] the peaking capacity,[9] or the transmission for such large plants, except at an exceedingly high cost.

By cooperative action, BPA and the private and public utilities have worked out an agreement, known as the Hydro-Thermal program, that will solve these problems. Under this agreement the utility companies will build thermal plants, located, sized, and scheduled to best satisfy regional and economic needs. The BPA will acquire and sell to its customers (both locally and on the various intertie networks) all surplus energy from the newly constructed plants. In addition, BPA will provide the required reserves and most of the transmission facilities (15-35). The Federal System[10] can absorb significant quantities of the surplus power for use in serving interruptible industrial loads, for reservoir filling and for sale to other regions (39-14).

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8. Backup generation is required in the event a generating unit is shut down for maintenance work, or because of failure of a unit (1-1).

9. Thermal units are most efficient when operated continuously at full capacity ("base-load plants"). For economic reasons they must be run in conjunction with units that can supply "peaking" demands to meet daily and seasonal peaks in the electrical power demand (1-1).

10. The Federal System consists of the existing and future hydroelectric plants of the Bureau of Reclamation and the Corps of Engineers, integrated by the transmission grid of Bonneville Power Administration (39-14).

The Hydro-Thermal program also included an agreement between BPA and the utilities that provided a 20-year expansion program designed to provide the region with adequate power at a low cost (26-19). The power groups claim that by pooling their resources and building large economic stations they will be able to generate the lowest-cost electricity in the United States (40-34). This program calls for a joint construction program that will add 41.4 million kwh of power to the Pacific Northwest generating system. Of this amount, twenty million kwh of hydroelectric peaking capacity will be built by the Federal System and 21.4 million kwh of thermal-electric capacity will be built by the utilities by 1990. The total investment in the electrical facilities will approximate sixteen billion dollars. Approximately two-thirds of this amount will be by non-federal entities and about one-third by the Federal Government (15-34).

The Centralia Steam-Electric Plant (Figure 3) was the first plant scheduled in this thermal series. Initially the plant (and the coal mine) was to have been constructed by PP&L and WWP, but by June 1970, six other utilities had entered into a joint-financing and joint-use agreement with the original owners. Table 2 indicates the present sponsors of the Centralia

Figure 3. Centralia Steam-Electric Plant

Source: Author.

complex.[11]

Table 2. - Sponsors of the Centralia Complex

Company	Percent
Pacific Power and Light Company	47.5
Washington Water Power Company	15
Snohomish County, Washington PUD	8
Seattle City Light	8
Tacoma City Light	8
Puget Sound Power and Light Company	7
Grays Harbor County, Washington PUD	4
Portland General Electric Company	2.5

Source: P. G. Humphreys, Centralia Steam-Electric Project - A Story of Resource Development, June 1970, p. 20.

11. Sponsorship is 72 percent private utilities and 28 percent public utilities.

Originally the Centralia plant was scheduled to be in service by 1974-1975 (19-18). This was the time period that Pacific Power anticipated they would require an additional one-million kwh of base load generating capacity. Due to delays in the scheduled completion of several federal hydroelectric projects, notably the Lower Granite, and to the greater-than-anticipated load growth of public agency customers, BPA was faced with a power deficiency during the winter months of 1971-1972 and 1972-1973 if the Northwest rivers were to drop to a critical level. To alleviate this eventuality, BPA requested and the owners of the plant agreed to advance the construction schedule to bring the first 700,000 kwh unit on-line, in time to help serve the 1971-1972 winter loads (4-2, 39-10 and 5-60). Construction of the plant began in 1969 and the first 700 megawatt (mw) unit of the plant is scheduled to go on-line September 1, 1971, with the second 700 mw unit scheduled for operation September 1, 1972.

Under the agreement between BPA and the owners of the plant, 426,900 kwh from the first unit will be supplied, for a period of ten years beginning January 1, 1972, to the United States Bureau of Reclamation's Central Valley Project (CVP) in California. The remaining power will be used to replace temporary deficiencies in BPA's power resources (19-19). Table 3 outlines the planned total distribution of power from the Centralia plant.

Table 3. - Distribution of Centralia Power

Date	BPA	CVP	Private Utilities	Public Utilities
9/71-1/72	700 mw	-	--	--
1/72-9/72	273.1mw	426.9mw	--	--
9/72-9/73	973.1mw	426.9mw	--	--
9/73-4/74	273.1mw	426.9mw	700 mw	--
4/74-1/82	--	426.9mw	973.1mw	
After 1/82	--	--	1008 mw	392mw

Source: U.S. Dept. of the Interior, Bonneville Power Administration, A Ten Year Hydro-Thermal Power Program for the Pacific Northwest, January, 1969, p. 10.

Technological Advances

No technological breakthrough suddenly led to the development of the Centralia coal field. Rather, its utilization can be attributed to the appearance of a large guaranteed market and to a series of technological advancements that have made it more economical to produce power by thermal means today.

Power Generating Plants

The trend to larger plants and the trend to larger generating units, i.e., larger capacity per boiler, are two of the notable developments in electric generating technology. These large units require less capital per kwh than the earlier units with lower ratings (24-35). Mouzon noted that this increase in unit size, along with the ever-continuing economic gain, reduced the unit cost of generation from 3.90 mills in 1957 to 3.54 mills per kwh in 1962[12] (24-266). In addition, the economies of scale of these larger units makes it possible to generate power at a lower cost per kwh than combinations of smaller units.

Another trend has been in the increased efficiency of boiler systems. This factor is very important because fuel costs are a very significant portion of generating costs[13]. Any reduction in the amount of fuel required can result in appreciable cost reductions. One advancement that contributed to the efficiency was the advent of furnaces that consumed pulverized rather than chunk forms of coal. Pulverized coal burns much like a gas. This type of furnace was of particular importance for coal such as that found in the Centralia field, since it was unsuitable as a fuel in earlier types of furnaces because of its tendency to crumble.

The efficiency of a steam-electric generating plant may be expressed by the pounds of coal consumed in the

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12. These values included fuel, operation, and maintenance costs but not fixed charges.

13. According to Electrical World's "16th Steam Station Cost Survey," fuel costs in 1968 constituted from slightly less than seventy percent to slightly over ninety percent of total operating costs of all reporting stations with the average being 82.8 percent (32-46).

production of a kwh of electric energy. In 1921 the average efficiency of coal-fired plants was 2.7 pounds of coal per kwh. By 1925 the average dropped to 2.0 pounds; by 1949 to 1.24 pounds, by 1959 to 0.89 pound and by 1968 to 0.86 pound (20-98, 36-105, and 24-41). The pounds per kwh method does not take into consideration the fact that over the years there has also been a decline in the grade of coal consumed as measured in British thermal units (Btu) per ton of coal. This method therefore is not entirely adequate for measuring changes in efficiency. A more satisfactory way to determine the advances made in the efficiency of steam-electric plants is to note the changes that have taken place in the number of Btu required to generate one kwh. The United States average for all plants in 1925 was 25,000 Btu per kwh (15-104). By 1969 the national average was only 10,477 Btu per kwh, or about forty percent of the 1925 value (35-XVIII). In 1925 it required 15,000 Btu for the "most efficient" plant operating to generate one kwh. In 1966 this had been reduced to 8,691 Btu (15-104).

Based on anticipated figures[14], the Centralia plant will require 1.187 pounds of coal to generate one kwh[15]

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14. Consumption is estimated to be 13.9 tons per minute to generate 1,400,000 kwh with 8,100 Btu per pound.

15. 13.9 tons per minute or 834 tons per hour or 1,668,000 pounds per hour to generate 1,400,000 kwh.

and will require 9,650 Btu to generate one kwh[16]. The relatively large pounds per kwh indicates the low heat value of the Centralia coal. In 1968 the national average of all coal consumed was 11,769 Btu per pound (36-105). On the Btu per kwh basis, the plant is well below the national average but above the "most efficient" plant value. This is due at least in part to a loss in efficiency that results from the environmental equipment being used at the plant.[17]

Mining

In addition to the technological advancements that have been made over the years in the power generation plants, several advancements have been made in the mining of coal. Since up to ninety percent of the operating costs of a fossil-fuel steam-electric plant are directly attributable to fuel costs (See Footnote 13), any change that results in a reduction in the production cost of the fuel may be significant.

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16. 1,668,000 pounds per hour X 8,100 Btu per pound = 13,510,800,000 Btu per hour to generate 1,400,000 kwh.

17. Reference the Water Quality Subsection in the Environmental Aspects Section of this report.

Surface mining, or strip mining, in the broadest sense must be considered as a technological advancement in coal mining. Strip mining is not a new development in either the United States or in the Centralia-Chehalis coal district. The birth of bituminous strip mining in the United States is reported to have been near Danville, Illinois in 1866, when horses pulled plows and scrapers to break up the overburden[18], which was hauled away in wheelbarrows and carts. Even prior to this it is assumed that the American Indians, using crude tools, performed a rudimentary form of strip mining (37-113).

In Washington, strip mining has been carried on at various times since the late 1800's (17-25). In the Centralia-Chehalis district at least six mines have conducted strip mining during some portion of their operation[19]. The Tono Mine was the largest strip mining operation in the Centralia-Chehalis district with a maximum production of about 21,000 tons per year (9-101).

The arrival of the power shovel in 1877 marked the

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18. Overburden is the surface material overlaying the coal seams.

19. Columbia Collieries, Penn-Bucoda No. 1, Penn-Bucoda No. 2, K and K, Royal, and Tono.

beginning of mechanized strip mining in the United States. Draglines first appeared in 1890 and the first bucket-wheel excavator appeared in 1944 (37-113).

One of the most significant trends in strip mining has been towards an ever-increasing size of the equipment used in mining, particularly in the last fifteen years (37-113). The world's largest power shovel in 1911 had a bucket size of 3½ cubic yards. In 1959 the largest shovel had a capacity of sixty-five cubic yards. By 1965 power shovels with 180 cubic yard buckets were in operation. The first draglines in 1890 had a one cubic yard bucket. By 1930 the bucket size had increased to twelve cubic yards, and by the mid-1960's the largest bucket size had increased to 220 cubic yards. Similar increases have also been experienced in other equipment, such as coal hauling trucks, the largest of which now have a capacity of 240 tons (31-51).

The objective in increasing the size of strip mining equipment is two-fold: first, to recover seams at depths that were not previously economical to recover and second, to recover the coal at the lowest cost per ton possible. Each generation of stripping machines pushes back the limit to which producers can economically mine (37-123). While the stripping limit has not yet been reached, there is an ultimate limit. Relative gains made possible by larger equipment are becoming less, and thus it appears that the limit is being approached (37-122).

In strip mining, output per man-day is roughly 100 percent higher than in underground mining; average recovery is sixty percent higher and operating costs are twenty-five to thirty percent lower (8-2). Because labor accounts for half or more of the total cost of mining coal (24-35) the higher output per man in strip mining is particularly important. In 1967 the average output per man per day in strip mines was 35.17 tons while the average output from underground mines was only 15.07 tons (10-77). In some individual strip mining operations recoverability approaches 100 percent of the coal being mined, but because certain acreages must be left, such as under towns and water bodies, an eighty percent recoverability figure[20] is usually accepted as average for most strip mining operations (8-7). The importance of recovering all the coal possible cannot be over-emphasized. For example, if a three inch layer of coal is left over an area of one acre, the loss will be about 450 tons. If ten acres of coal are being mined per month the resulting loss will be 54,000 tons per year (38-183).

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20. The average recoverability for underground mines is only about fifty percent of the coal being mined (7-27).

These factors give strip mining a significant economic advantage. Information on the cost of mining coal is proprietary information and is rarely published; however, Mouzon noted that the average price of all coal in the United States in 1958 was estimated to be $5.02 a ton, ranging from $2.00 to over $10.00 a ton. He estimated that coal mined by efficient strip mining methods ranged from $2.40 to $3.50 per ton (24-35). Lyon and Selin estimated that, while the average price per ton of coal in the United States in 1968 was $4.67, coal being produced by highly efficient strip mining methods may have been produced for about $2.50 per ton (21-42).

The increase in the size and efficiency of strip mining machinery has permitted a steady increase in the average and maximum thickness of overburden removed, and as a result the ratio of average overburden thickness to average recovered coal thickness has also been increased[21] as Table 4 illustrates.

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21. The increase in the overburden ratio is also a good indication of the rate low-cover reserves are being depleted.

Table 4. - Changes in the Thickness of Overburden and Overburden Ratios

	1946	1955	1970
Average Overburden Thickness	32	42	55
Maximum Overburden Thickness	--	70+	185
Overburden Ratio	6:1	8.5:1	11:1

Source: P. Averitt, Stripping-Coal Resources of the United States, January 1, 1970, p. 6.

In 1955 the maximum economical ratio of overburden to coal thickness was roughly 20:1 (7-56). It is now thought that a 30:1 ratio is technically feasible as a maximum for present and near future strip mining (8-6).

Other Factors

Several additional factors have aided in the development of the Centralia coal field. The coal mine and the power plant are located close to the consuming markets. This reduces costs in two ways. First, the added expense for the construction of high-voltage transmission lines is reduced. Only about one mile of transmission lines had to be constructed to connect the Centralia complex with one of BPA's high-voltage transmission lines. Secondly, the shorter the distance the electricity must be transported, the less electricity that is lost due to transmission resistance.

Since the mine and the power plant are located adjacent to each other, the cost of transporting the coal is reduced. Waste disposal costs are reduced over both nuclear sites and sites not at mine mouth. The wastes from the power plant and the coal processing plant will be hauled the short distance back to the mine by returning coal trucks.

Because of the generally soft nature of the overburden and of the coal, little blasting will be required to loosen the material. Blasting costs are often a significant expense in strip mining. In many cases it requires one pound of explosives for every three cubic yards of overburden (31-50). With an overburden ratio of about 20:1, it would require seven pounds of explosives per ton of salable coal. Blasting not only requires additional outlays for the explosives, but it also requires additional workers to handle the explosives, additional equipment, and additional time to mine the coal because of delays in operation awaiting the blasting. The Centralia complex is also fortunate in having access to sufficient quantities of surface water for both the processing and power plants.

Even though upwards of 300 feet of overburden will be removed in the Centralia field, a very satisfactory overburden ratio will be obtained because of the thickness of the coal seams. The estimated overburden ratio for the field will be between 5:1 and 6:1; well below the national average.

The final factors associated with the Centralia complex are related to the environment. At this time, public opinion in the Pacific Northwest seems to favor a fossil-fuel electric plant over a nuclear-fired electric plant, as is evident by the resistance encountered by the Eugene and Trojan nuclear projects.

The coal from the Centralia mine is reported to be very low in sulfur, averaging only 0.7 percent. This low sulfur content presently precludes the added expense of removing sulfur to meet air quality standards.

Finally, because the area does not contain any chemical materials that will contaminate adjacent soil, runoff or ground water, savings can be realized in reclamation costs.

OPERATING METHODS AND MATERIAL FLOW[22]

Coal Mine and Processing Plant

Because of local folding, the coal beds in the Centralia coal mine generally outcrop on the western slopes of uplifted ridges. These beds dip toward the east at an

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22. Information for this, and the following section, was supplied by Mr. M. F. Hatch, Vice President, Washington Water Power Company, and Mr. R. W. Beadnell, Centralia Plant Manager.

angle that varies from twenty to thirty degrees. From 200 to 250 feet of overburden cover the first major seam of coal, the Big Dirty. Approximately 100 feet below this seam is another major seam, the Smith. Preliminary investigations indicate that these two seams contain in excess of 500 million tons of coal. Exploration has indicated that at least 150 million tons of this coal is within 300 feet of the surface and can be economically mined.

Vast quantities of overburden must be removed to expose the coal seams. Using the 5:1 overburden ratio, approximately thirty-six million tons of overburden will be removed annually.[23] Two pieces of equipment are being used to remove the overburden. The initial piece of equipment used in the removal of the overburden is a large bucket-wheel excavator (Figure 4). The bucket-wheel excavator was initially used on the Oroville Dam project on the Feather River in California (11-34). The wheel of the excavator contains eight buckets, each having a capacity of 1.3 cubic yards, giving the machine the capacity to remove 6,000 tons of overburden every hour (12d). The material removed by

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23. It is interesting to note that with the vast amounts of overburden being removed, it is necessary for the operators of the mine to purchase their road building materials from outside sources because the area being mined does not contain materials suitable for this purpose.

Figure 4. Bucket-Wheel Excavator

Source: Author.

the bucket-wheel is dropped onto a long mobile conveyor called the "bandwagon," (Figure 5), which in turn initially deposits the material onto one end of a skid-mounted conveyor belt. This conveyor belt, moving at nearly fifteen miles per hour, transports the material to a mobile stacker that is two miles from the bucket-wheel. The mobile stacker, with the aid of a small bulldozer, spreads the overburden received from the conveyor in any configuration desired (11-34).

The bucket-wheel has a 180 degree working radius away from the main conveyor which parallels the face of the ridge. The bucket-wheel excavator begins its cut adjacent to the main conveyor belt and then gradually works its way

Figure 5. Bandwagon

Source: Author.

out, up to 300 feet from the main conveyor belt. When this area has been worked down to a depth of forty feet the bucket-wheel and the bandwagon move "up" the main conveyor belt and begin another cut. Upon reaching the end of the ridge, the bucket-wheel and the bandwagon reverse their direction and move "down" the conveyor belt, cutting off another forty-foot bench. This procedure is repeated until the overburden thickness is sufficiently reduced to be worked by the second major piece of equipment, the dragline.

The dragline (Figure 6) weighs five million pounds and has a 310-foot boom to which a fifty-six cubic yard bucket is attached (11-34). The dragline starts at one end

Figure 6. Dragline

Source: Author.

of the ridge, resting on the bench previously cut by the bucket-wheel excavator. The dragline then cuts a strip about 150 feet wide and up to 100 feet deep the full length of the ridge. The overburden removed is cast over the side into the valley. This operation is analogous to the operation of a common ditching machine.

After the coal seam is exposed, a small, conventional power shovel is brought in to extract the coal. This shovel, which has a capacity of fifteen cubic yards, loads the coal into one of the six large eighty ton coal trucks, which then transports the coal to the processing plant.

After the dragline has completed its first cut the full length of the ridge, and after the coal has been removed, it turns around and heads back toward the other end of the ridge, making a second cut to expose the second coal seam for the smaller shovel.

Because of its reliability and efficiency, the dragline often assists the bucket-wheel and the smaller coal mining shovel in accomplishing their jobs. If the dragline catches up to the bucket-wheel it will make a pass simply to remove overburden. If it has to wait for the coal mining shovel for some reason, it will begin to excavate coal, stacking it in an area that is out of the way of future operations but where it can easily be retrieved by the smaller equipment at a later time.

The coal processing plant is located adjacent to the power generating plant. The distance that the coal is transported from the mine to the processing plant averages a little over two miles. The coal is delivered to the processing plant in its "raw" form, having received no processing at the mine. The coal trucks deposit the coal into a 240 ton hopper, which in turn feeds a crusher that breaks the coal into six inch pieces after which it is stored in a large silo. The coal is removed from the silo, crushed down to one and one-quarter inches, and then washed to remove all foreign material[24]. The refuse from the washing plant is transported to larger hoppers, which in turn are emptied by trucks returning to the mine. Upon leaving the washing area, the coal is rated at 8,100 Btu per pound and contains 16 percent ash, 19.3 percent moisture, 0.7 percent sulfur, 34.4 percent volatile matter and 29.6 percent fixed carbon.

The washed coal is transported by conveyor belt from the processing plant to an automatic coal-stacker-reclaimer, which in turn deposits the coal in one of three places: a "dead" storage area, a "live" storage area, or directly onto a conveyor belt going to the power plant. The "dead" storage area is an eighty acre area that contains the coal that will be used if the mines are not operating for an extended period of time, such as during a strike. The "dead" storage is often called the "strike pile." The coal-stacker-reclaimer deposits the coal for this area in a single stack, which in turn is spread over the eighty acres by earth-moving equipment. The "live" storage area is adjacent to the conveyor belt that runs between the processing plant and the power plant. This storage area is

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24. Because of the method of mining and the natural partings found in the coal, this refuse amounts to between ten and twenty percent of the delivered tonnage.

used in the event there is a malfunction in the processing plant. The coal can be retrieved, as needed, from either of the storage areas by the stacker-reclaimer.

The Washington Irrigation and Development Company, a wholly owned subsidiary of the Washington Water Power Company, operates the mine and supplies the power plant with coal on a contract basis. Coal is not delivered at a fixed price per ton but rather a fixed price per million Btu. The original contract specified a delivery price of sixteen cents per million Btu; however, increases in cost due to inflation, labor adjustments and increased development costs have raised this figure to an estimated twenty cents per million Btu.[25] (15-11). No breakdown is available as to the f.o.b. mine price, transportation costs, processing costs, etc., because this is proprietary information.

Presently, because the power plant is not yet in operation, all coal being produced is being stockpiled in the "dead" storage area. When the first unit of the power plant goes into service on September 1 of this year, coal will be supplied to the "dead" storage area, the "live" storage area, and to the power plant. When the second unit

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25. The sixteen and twenty cents per million Btu price is the "as burned" price which includes all of the costs incurred up to the delivery of the coal to the furnace.

goes into service on September 1, 1972, the storage areas will most likely contain the amounts of coal required; therefore, the mine and the processing plant will be supplying only the power generating units. At this time it is anticipated that about 150 employees will be needed to operate the mine and coal processing plants. Since the mine and the processing plant have a larger production capacity than the power units can utilize, it is probable that mine and processing plants will operate on a three-shift, five-day-week basis. The mine will probably operate with a full shift during the day and with fewer men during the night; operating only the overburden removal equipment. The processing plant will therefore likely have a full shift during the day to handle the incoming coal and water treatment with smaller crews on the later shifts to meet the maintenance, clean-up, and water treatment requirements.

Power Plant

The electric generating capability of the plant will be 1,400mw when the second generating unit goes into service in 1972, making it the second largest electric power generating site in the Pacific Northwest[26]. This plant will

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26. Grand Coulee has an existing capacity of 2,042mw. Centralia will be the fourth largest generating plant when the present construction on the following dams is completed: Grand Coulee, 5,977mw; John Day, 2,160mw; and The Dalles, 1,807mw (15-21).

have nearly three times the generating capacity of Bonneville Dam[27].

The coal received from the processing plant (via conveyor belts) will be routed to sixteen silos (eight for each generating unit) where it will be regulated by automatic feeders to sixteen pulverizing units. Each pulverizer will grind the coal to a powder and then distribute it, by means of a hot air injection system, to four furnace burners.

The coal "as burned" contains sixteen percent ash of which eighty percent will be exhausted as fly ash and twenty percent will be discharged as bottom ash (slag). The fly ash will be captured by electrostatic precipitators and then stored temporarily in forty large hoppers. The hoppers will be periodically emptied into trucks returning to the coal field. The bottom ash will be removed from the bottom of the boilers hydraulically and deposited in de-watering bins. After the water settles out of the ash in the bins it will also be trucked back to the coal field. The water that settles out of these bins will be routed to the coal washing plant for treatment.

No local market is presently known for the ash, however, the company is receptive to the idea of selling the

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27. Bonneville Dam has a capacity of 518 mw.

ash if and when a market develops. An active industry-wide research program has developed several uses for ash, including fly ash bricks. These bricks meet or exceed the quality of clay bricks, but at the same time are lighter and cheaper to produce. The fly ash can also be used as a cement additive, a soil conditioner, or in water clarification (29-98). It would seem likely that at some time in the future, a market will develop locally for the ash because of the large quantities of ash available[28] and because of the easy access to transportation facilities[29] and population concentrations.

Approximately 100 workers will be employed in the power generating plant. These employees will be fairly well distributed over three shifts because this is a base-load generating plant and will be generating essentially the same power output each hour of the day. The 100 employees required to generate the 1,400 mw is equal to 0.14 employee per megawatt of capacity, which compares favorably with the national average of 0.18 employee per megawatt of capacity (35-XV).

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28. Assuming 20,016 tons of coal will be consumed per day (834 per hour), at sixteen percent ash, 3,202 tons of ash will be produced per day or 1,168,730 tons per year.

29. A railroad spur line adjoins the power plant.

Company officials have estimated that the total cost[30] of generating power at the Centralia plant will be between five and six mills per kwh. Since the power plant is not yet in operation, a breakdown as to production costs per kwh is not available; however, it can be assumed that these costs will approximate the costs of other existing generating plants. Table 5 presents the 1969 average production expenses for conventional fossil-fueled steam-electric plants and the average expenses for the five coal-fired plants[31] operating in 1969 that had essentially the same generating capacity as the Centralia plant will have.

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30. Including operating costs and annual fixed charges.

31. Included are the Paradise Plant at Drakesboro, Ky., generating 1,408 mw; the Homer City plant at Homer City, Pa., generating 1,319 mw; the Muskingum River Plant at McConnelsville, Ohio, generating 1,467 mw; the Marshall Plant at Terrell, No. Carolina, generating 1,350 mw; and the Clifty Creek Plant at Madison, Ind., generating 1,303 mw (35-pg. 122, 112, 104, 97, and 37).

Table 5. - 1969 Production Expenses for Fossil-Fueled Steam-Electric Plants [21]

Cost	National Average[a]	Fire-Plant Average[a]
Operation	.37	.26
Maintenance	.39	.43
Sub-Total	.76	.69
Fuel	2.77	2.01 (1.94)[b]
Total	3.53	2.70
Fuel Cost/Million Btu[c]	26.6	21.3 (20.0)[b]

a. Mills/kwh.
b. Estimated values for the Centralia plant.
c. In cents.

Source: Federal Power Commission, Steam-Electric Plant Construction Costs and Annual Production Expenses, January 1971, p. XXX.

It is estimated that the fuel cost at the Centralia plant will be 1.94 mills per kwh[32]. This value, while

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32. The coal is rated at 8,100 Btu per pound or 16,200,000 Btu per ton. At a delivery price of twenty cents per million Btu this would make the delivery price of the coal $3.24 per ton. The plant is expected to consume 834 tons of coal per hour, which at $3.24 per ton is equal to $2,712.16 per hour. Therefore, it will cost $2,712.16 to produce 1,400,000 kwh, or 1.937 mills per kwh. A value of 1.930 mills per kwh is obtained if calculated using the estimate that the Centralia plant will require 9,650 Btu to generate one kwh (see footnote 16).

being low by national standards, closely approximates the five-plant average, which would indicate that the estimate of twenty cents per million Btu currently being used as the "as burned" price of fuel for the Centralia plant is a reasonable estimate.

The whole Centralia project was designed with expansion in mind. The land required for additional generating units, water cooling towers, etc., was taken into consideration and purchased when the land required for the present units was purchased. This was also the case for the water supply (25-69). The coal processing plant and conveyor belt systems have a design capacity of 1,400 tons per hour of which only about 840 tons per hour will be used to supply the two generating units.

Of the 21,000 acres originally purchased, nearly 8,700 acres are classified as mining field area. Only 5,600 acres are expected to be mined over the 35-year life of the plant as presently configured. The coal mine can already produce more coal than the present power plant will be able to utilize. This capacity can easily be increased by purchasing additional coal mining shovels, adding larger coal hauling trucks, and by increasing the size of the bucket on the dragline which is designed to handle any bucket size up to 100 cubic yards. Even the coal hauling roads have been designed and constructed to handle larger trucks, and if required, a railroad.

ENVIRONMENTAL ASPECTS

The development, or the proposed development, of new electric power projects brings about increased environmental concern. This concern is being expressed both locally and nationally as is evident by the ever increasing enactment of State and Federal legislation. The following four sections outline some of the key environmental aspects related to the Centralia complex.

Hydro-Thermal Program

The Bonneville Power Administration, as a Federal agency, is required to carry out all Congressional mandates as expressed through such legislation as the Federal Water Pollution Act, the Air Quality Act, the Environmental Quality Improvement Act, etc. All contracts executed between BPA and utilities constructing thermal power plants contain sections requiring the utilities to obtain, from all federal, state and local agencies, all licenses, permits and other rights and regulatory approvals necessary for the ownership, construction, and operation of the projects (30-62).

Water Quality

No water, from either the steam plant or the coal processing plant, is returned to State waterways because every water system is a closed circuit system (12). The water required for the complex is obtained from the Skookumchuck River. A dam[33] on the river impounds the excess winter runoff which is then released during the summer low flow period, providing a constant year-round supply of water. The water is brought from the river by a three mile pipeline and a pumping system having a capacity of 24,000 gallons per minute. This water is stored in a holding tank that contains about fifty-two million gallons of water.[34]

The Centralia complex uses an evaporative cooling system rather than the once-through cooling system often used in thermal-electric plants. Water used in the generating plant for cooling is pumped to evaporation cooling towers.[35] Each tower contains six eighteen-foot high fans

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33. The dam is 165 feet high and 1,340 feet in length, containing 2.2 million cubic yards of fill material. The reservoir formed is 4.5 miles long and has a surface area of 550 acres and a volume of 34,800 acre-feet.

34. The pond is 1,100 feet x 900 feet and averages 7 feet in depth.

35. There are two cooling towers for each of the power generating units. Each tower is sixty-five feet tall, 240 feet long and seventy-five feet wide and cools approximately 110,000 gallons of water per minute (12d).

that draw in air through the sides of the tower. The air reduces the heat content of the water trickling down the tower with the heat being forced out the top of the fan housing. Approximately 7,000 gallons of water per minute are lost in this cooling cycle due to evaporation. The cool water is then returned to the plant to continue the cycle.

Evaporation of the circulating water causes a build-up of the solids in the water, both natural salts and chemicals. This build-up is controlled by removing water from the system. The water removed is replaced by water from the holding pond. The removed water is pumped to the coal processing plant where it is used in the washing of coal.

An evaporative cooling system is more costly than a once-through cooling system because construction, operation, and maintenance costs are higher and because of the added costs for water treatment. The capital costs of this type of system may be roughly estimated as an additional $5 per kwh of capacity as compared with a once-through cooling system (15-108).

More important, however, is that evaporative cooling results in higher condenser temperatures than once-through cooling. This higher temperature decreases the efficiency of the turbine which results in a reduced plant capacity (15-153). The reduction of capacity and the increased fuel costs due to the reduced efficiency effectively doubles or triples the $5 per kwh of capacity figure (15-108).

The water used in washing the coal is continually processed to remove the material washed from the coal and to remove the salts and chemicals from the evaporation towers. The resulting waste material is then collected and returned to the mine where it is covered with overburden. The processed water is recycled within the processing plant.

Natural occurring surface waters and runoff within the mining areas are diverted by means of constructing ditches, where necessary, and by natural channels into six settling ponds that have been constructed at the base of the various small watersheds. This water is retained in the settling ponds for as long as possible to allow for natural settling of any silt carried into them by incoming water. Chemical treatment of this water will be accomplished as necessary and the ponds will be dredged as required with the dredged material being returned to the mine for burial. When it is necessary for water to be decanted from the ponds, the quality of the decanted water is in compliance with the Waste Discharge Permit (No. 3530) that was issued by the Washington State Department of Ecology, dated December 10, 1970 (6-16).

Air Quality

A comprehensive program to determine the prevailing air quality and weather characteristics in the vicinity of the complex has been initiated. Under the supervision of the Engineering Research Division at Washington State University and through the Engineering Research Division and Agriculture Research Center a group of scientists and engineers have launched a comprehensive six-year atmospheric study that will run for a period of four years prior to plant operation and for a minimum of two years after the plant begins operating (16-17). A similar study has also been assigned to an independent industrial consultant, Dr. W. L. Faith of San Marino, California.

This surveillance required the installation of a 200-foot meteorological tower with automatic recording instruments in a weather station on a ridge overlooking the plant site. Data being recorded, at fifteen minute intervals, includes the amount of air pollutants, wind direction and speed, temperature, precipitation and other related conditions (12a).

Associated with each of the power generating units is a 470-foot chimney (or stack) having a base diameter of eighty feet. Gases will be exhausted from these stacks at ninety feet per second. High stacks and discharge rates are used to attain greater upper level dispersion and to reduce ground level concentrations of stack emissions (35-IX).

Between each of these stacks and the main plant structure is an electrostatic precipitator. These precipitators at the time of installation the largest ever built in the West, were installed for controlling fly ash emissions, since eighty percent of the ash in the coal is emitted as fly ash. Each of these precipitators contain 189 vertical plates which are spaced nine inches apart (12b). Negatively charged fly ash particles are attracted to the plates, which receive a positive charge. The fly ash clings to the charged plates until removed by a vibrator system. The ash collected following the cleaning will be stored in hoppers awaiting removal. The electrostatic precipitators cost approximately five million dollars and are designed to remove 99.4 percent of the fly ash emissions. The precipitators will virtually eliminate fly ash emissions with only approximately fifteen tons per day being discharged into the atmosphere.[36]

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36. Based upon the following calculations: 834 tons of coal/hour x 24 hours = 20,015 tons of coal/day, of which sixteen percent, or 3,202 tons, is ash. Eighty percent of the ash is emitted as fly ash which is equal to 2,561 tons/day. Six-tenths of one percent of this is not captured by the precipitators, therefore, .006 x 2,561 = 15.36 tons/day.

The sulfur content of the Centralia coal[37] is lower than the one percent level recommended by the United States Department of Health, Education and Welfare, in March, 1967, as the acceptable maximum sulfur content for fossil fuel to be burned in the future in plants serving Federal installations in areas containing 15,000 or more people per square mile. Since the Centralia complex is located in an area composed primarily of farms and timber, this facility was well within acceptable limits at the time of construction (19-11). Large quantities of sulfur, as sulfur dioxide, will be emitted into the atmosphere when compared to fly ash emissions. It is estimated that approximately 140 tons of sulfur will be discharged daily.[38]

Significant capital expenditures are required for air quality just as they are for water quality. The capital expenditures for air cleaning equipment and high stacks, excluding any sulfur expenditures, can be estimated at about $10 per kwh of capacity for coal fired plants (15-108).

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37. The sulfur content of the Centralia coal field averages about seven-tenths of one percent.

38. Based upon the following calculations: 20,016 tons of coal/day, of which seven-tenths of one percent is sulfur. Therefore, .007 x 20,016 = 140 tons of sulfur/day.

Reclamation

The sponsors recognize that reclamation is an integral part of doing business and coordinate reclamation with mining operations. By combining these operations it is possible not only to minimize reclamation costs but to also restore the land to usefulness and insure continuing profits after the coal is depleted. To assist in the accomplishment of this task, a long range plan, including both the mining and reclamation phases, has been developed. It is anticipated that the plan will have to be modified because it is impossible to predict all the circumstances that may dictate changes over such a long time period.

The historic use of the land has been for the growth of forest and the grazing of livestock. This land has also provided habitat for wildlife. The reclamation plan being followed is directed to the continuation of these uses (6-9). The topography favorable for this reclamation is similar to the topography that existed prior to mining, namely, a moderately rolling topography with rounded ridges and flat valleys containing minor drainage systems (6-11).

Reclamation of the land disturbed by the dragline can be begun immediately after a cut has been made, whereas, reclamation of the spoils deposited by the bucket-wheel, because they are deposited layer upon layer, cannot be begun until the uppermost layer has been deposited.

Grass species and legumes that have the potential of enriching the soil and increasing its humus content, as well as providing grazing and forage for wildlife, will be planted as soon as possible following mining. After a year and a half, this vegetation will be plowed under and then nursery grown trees will be transplanted to re-establish forest growth. The toal is to nurture and manage this plantation to obtain a future commercial timber crop while at the same time receiving the benefits of soil stability, runoff protection and wildlife habitat (6-13).

Experiments dating back to 1963 have been conducted in local mine spoilage areas to determine the vegetation that can best be grown in the environment. In the fall of 1968, thirty acres were divided into twenty-two test plots to conduct grass seeding experiments. This was followed in the spring of 1969 by the planting of 14,000 seedling trees, mostly Douglas Fir, which complemented a test planting of pine trees by the Scott Paper Company in 1963. In addition to these tests, the Agricultural Research Department of Washington State University has been engaged to conduct pre- and post- operational vegetation studies (19-13).

Restoration costs are normally more than the value of the reclaimed land for agricultural or most other purposes. The minimum cost of reclamation has been estimated to be $100 per acre, with the national average being estimated at about $230 per acre. This cost provides for a minimum level of reclamation (8-26). Cost of complete restoration to a natural-appearing contour and vegetation can range up to $3,000 per acre in difficult cases according to John A. Corgan, head of the Environment Division of the U.S. Bureau of Mines (27-72).

According to Washington State law, a mining company must complete the reclamation of the land not more than two years after completion or abandonment of each mining segment (6-18). Before a surface mining permit will be issued by the State, the operators of the mine must post a bond in the amount of $400 for each acre to be disturbed. In the event the operating company fails to reclaim the bond, and the money will be used to reclaim the land[39].

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39. Based upon correspondence received by the Washington Irrigation and Development Company from the State of Washington Department of Natural Resources, dated April 13, 1971, entitled "Operating Permit--Surface Mining Application/Permit No. 10145."

SUMMARY

Coal mining in the Centralia-Chehalis coal district, as in all coal mining areas, has historically been related to the demand for coal and the competitiveness of the coal supplying this demand. After discovery, the coal began to supply various markets such as domestic heating, railroads, and power generation; however, primarily because of the low quality of the coal and the fact that it did not remain competitive with other fuel sources, these markets began to dwindle and eventually died.

A combination of factors has recently brought about a large-scale demand for this coal. The demand for electricity has continued to increase while the number of available hydroelectric sites have been decreasing. The utilities, therefore, have been forced to find alternate means of producing electricity. A cooperative effort between the various utilities and the Bonneville Power Administration, for the pooling and sale of the generated power, has allowed the construction of plants that can take advantage of the economies of scale.

Advancements that had been made in the design and efficiency of coal-fired generating plants and in the development of new strip mining equipment and techniques contributed greatly to the economics of generating electricity, using coal as a fuel. Several additional

factors, including the proximity of the captive mine, mine-mouth generating complex to the consuming market, the nature of the overburden, and the low sulfur content of the coal added to the economics of generating electricity using the Centralia coal.

Because of the favorable overburden ratio, the equipment being used in the mining operation, although large, is not large by present day standards. The bucket-wheel excavator utilized is unique to the strip mining industry because of its mobile conveyor belt system. This belt transports the overburden from the point of removal up to two miles away and then deposits it in any manner desired, which reduces the cost of handling the overburden and the cost of reclamation.

The factors that have made the Centralia complex economically feasible were to a certain degree offset by the costs that have been added for environmental reasons. Such things as closed circuit water systems and electrostatic precipitators that are necessary for pollution control add not only to the capital cost of generating the power, but also to the operating cost because of an associated reduction in plant efficiency.

The owners of the Centralia complex made provisions for the expansion of the complex in their initial design. Coal reserves in excess of present requirements were purchased, as were mining and coal processing equipment. In addition, the land required and the additional water supply required for an expanded capacity were also purchased initially.

Any future expansion in the production of this coal will depend on the same factors that have historically affected the utilization of the coal: a market (through an increased demand for electricity), and the ability of coal to compete with the alternate fuel sources available at the time the market develops.

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