Chapter 3

Port and Shipping Technologies for Exporting Coal

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BACKGROUND

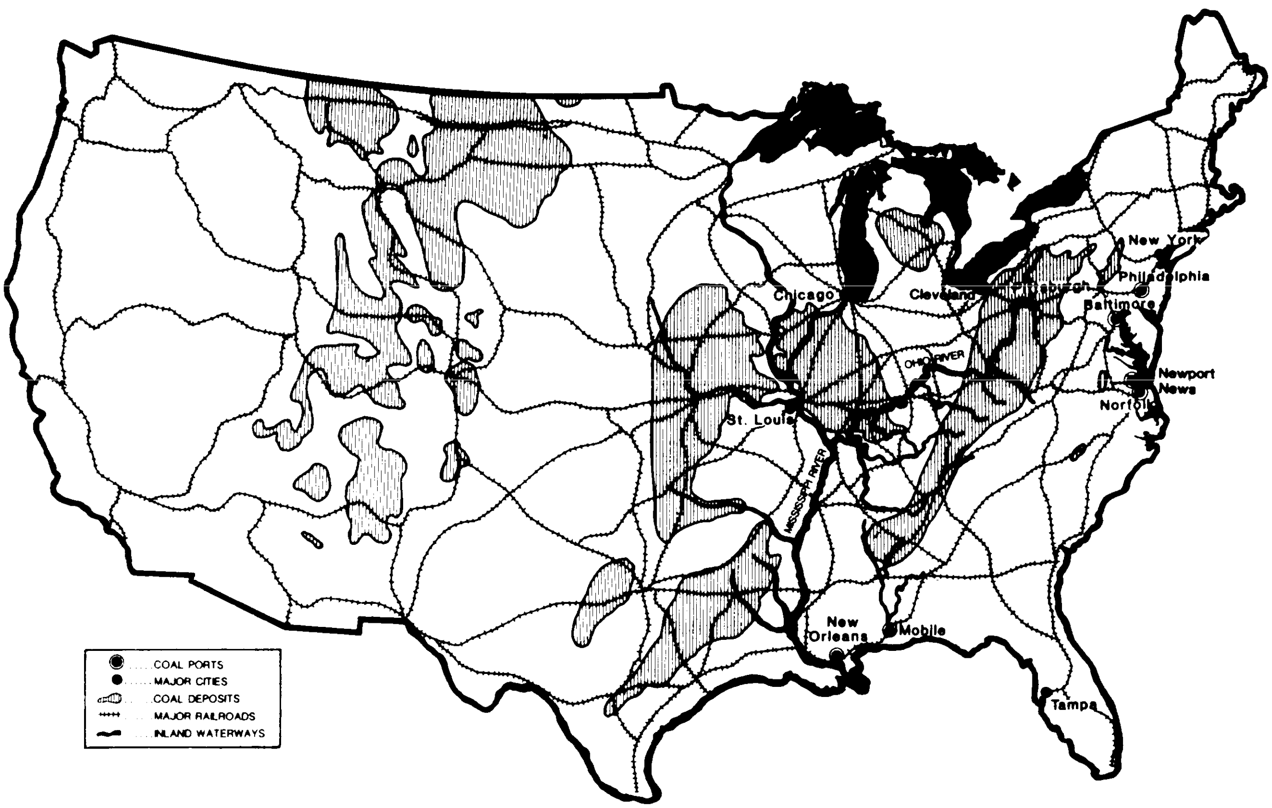
Most U.S. coal is exported through just a few large terminals at major east coast, gulf coast, and Great Lakes ports.

U.S. coal deposits are found in 31 of the 50 States (see fig. 2). Appalachian coal deposits are predominantly deep and have thin seams. Presently mined Western coal is extracted in strip and surface mines. The Powder River region in northwest Wyoming and southeast Montana contains about 40 percent of the U.S. surface coal reserves. Low-sulfur coal is found in the West and in central Appalachian mines. High-sulfur coal is predominantly located in the Midwest and in northern Appalachian mines. At present almost all export coal is high-Btu bituminous coal from Appalachian mines. Exports of Western coal to the Far East may become important in the future if Pacific Coast transportation and terminals are developed.

Brief History of U.S. Coal Exports

The history of U.S. coal exports begins in the late 1800's when small quantities were shipped

Figure 2.— Major U.S. Coal Deposits, Transportation Systems, and Coal Ports



SOURCE Dravo Corp

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to Canada and the east coast of South America. European demand for U.S. coal began by the turn of the century and increased steadily up to World War I. In 1917, approximately *24* million tonnes (mmt) were exported to foreign buyers. By 1920, 38 mmt left U.S. ports, with 22 mmt bound for non-Canadian points.

Exports dropped to a low of 9 mmt in 1932, and remained below the 20-mmt level through most of the 1940's. Immediately following World War II, the United States emerged as a major coal supplier with levels reaching 69 mmt in 1947—used primarily by European nations seeking to rebuild industrial activity. The level achieved in 1947 was not reached again until 1957 when total exports exceeded *76.4* mmt. Following that year, coal leaving U.S. ports was always less than the 1957 totals, until 1980, when almost 90 mmt were exported. (See table 2.)

Metallurgical grade coal dominated U.S. exports in the past. This coal is converted into coke in large heating ovens and eventually used for processing iron ore into steel.

All existing major east coast coal export terminals were developed by railroad companies. Their primary purpose is to handle metallurgical coal which requires complicated blending, and hence, massive rail-classification yard setups. Up to recently, steam coal was exported only through Great Lakes ports to Canada.

The Situation in Existing Coal Ports

The increasing foreign demand for U.S. steam coal has exerted a number of physical, operational, and administrative burdens on existing port-handling capacity.

The facilities designed for metallurgical coal, which requires extensive sorting and blending of coal types, are not as suitable for steam coal. The terminals at Baltimore and Hampton Roads have been operating at near 100-percent capacity, allowing no margin for errors or mechanical failure.

Historically, the ports of Hampton Roads, Baltimore, Philadelphia, Mobile, and New Orleans have handled almost all of U.S. coal exports desined for overseas markets. In addition, a number of ports on the Great Lakes have shipped sizable quantities of coal to Canada. Most notable are the facilities at Ashtabula, Conneaut, Sandusky, and Toledo, Ohio. During 1980, two major terminals in Hampton Roads handled 51.8 mmt of export coal, one major terminal in Baltimore handled 12.1 mmt, one in New Orleans 3.8 mmt, and one in Mobile *2.4* mmt. Excluding shipments to Canada, these four ports handled 98 percent of all export coal. (See table 3.) They each operated at full capacity and continued to search for various ways to

Table 2.—History of U.S. Coai Exports (thousands of short tons)

Year	Production	Exports	Export as a percent of product ion
1945	577,617	27,956	4.8
1946	533,922	41,197	7.7
1947	630,624	68,667	10.9
1948	599,518	45,930	7.7
1949	437,868	27,842	6.4
1950	516,311	25,468	4.9
1951	533,665	56,722	10.6
1952	466,841	47,643	10.2
1953	457,290	33,760	7.4
1954	391,706	31,041	7.9
1955	464,633	51,277	11.0
1956	500,874	68,553	13.7
1957	492,704	76,446	15.5
1958	410,446	50,293	12.3
1959	412,028	37,253	9.0
1960	415,512	36,541	8.8
1961	402,977	34,970	8.7
1962	422,149	38,413	9.1
19(13	458,928	47,078	10.3
1964	486,998	47,969	9.9
1965	512,088	50,181	9.8
1966	533,881	49,302	9.2
1967	552,626	49,528	9.0
1968	545,245	50,637	9.3
1969	560,505	56,234	10.0
1970	602,932	70,944	11.8
1971	552,192	56,633	10.3
1972	595,386	55,997	9.4
1973	591,738	52,870	8.9
1974	603,406	59,926	9.9
1975	648,438	65,669	10.1
1976	678,685	59,406	8.8
1977	691,344	53,687	7.8
1978	665,127	39,825	6.0
1979	776,299	64,783	8.3
1980	830,000	89,882	10.8

SOURCE: National Coal Association, *International Coa/: 1979* (Washington, D. C., 1980).

Table 3.—U.S. Exports of Bituminous Coal (thousands of short tons)

Seaport	1974	1975	1976	1977	1978	1979	1980
Hampton Roads. .	35,745	36,952	32,000	24,244	15,396	33,753	51,773
Baltimore	5,949	6,769	6,327	7,055	5,887	9,141	12,124
Philadelphia	1,431	802	447	187	90	55	1,522
New Orleans.	992	1,292	1,297	1,432	1,388	1,410	3,826
Mobile.	1,746	2,745	2,755	3,611	1,848	1,284	2,447
Great Lakes	14,063	17,108	16,580	17,158	15,214	19,140	18,189
Total	59,926	65,669	59,406	53,687	39,825	64,783	89,882

SOURCE U.S. Department of Commerce, as reported in National Coal Association, *International Coal: 1979.*

squeeze out more capacity. The massive 1980 demand for U.S. coal was caused by some unusual factors in other supplier countries—most notably the labor disputes in Poland, which took that country out of the present export business, and strikes in Australia, which disrupted their production.

Long lines of ships, some waiting for more than *2* months, are now outside of Baltimore and Hampton Roads harbors. These ships incur demurrage costs of $15,000 to $20,00()/day. This situation will probably not continue but major new terminal capacity—even on an emergency basis—is still many months away.

The five major U.S. (east and gulf) ports are each in the process of expanding existing terminals, and constructing new piers, open storage areas, and handling equipment. The proximity to the Appalachian mines, along with the existing rail and equipment infrastructure, has supported the investment at these terminals. The substantial activity at the Chesapeake Bay terminals will probably ensure that they retain an important future role in the coal export trade. Gulf coast exporting facilities will also be important in the coal export trade, particularly since both barge and rail networks can be used to deliver coal to the ports and can assure inland transport-price competition.

Recent private investments within the coal mining and coal transportation industries have followed from the surge in foreign buying demand. Substantial levels of investment are needed to construct coal-handling terminals, stacker/reclaimer systems, rail-yard trackage, and support equipment. Few private firms had sought to construct new export facilities during previous decades. Following World War II, demand for U.S. mined coal was fairly stable and the major railroad carriers had met the need for export capacities. Those railroads were the Chessie System (Baltimore and Ohio, Chesapeake and Ohio, and Western Maryland; now part of the CSX System following merger with Seaboard Coast Lines), Norfolk and Western (merger negotiations in final stages with Southern Railroad), and Conrail (formerly Pennsylvania Railroad and New York Central Railroad).

Proposals for New Coal Ports

Ports on the Great Lakes, Atlantic, gulf, and west coasts are in the process of planning new facilities. In general, proposals for facilities along the Atlantic and gulf coasts appear to be advancing more rapidly than those on the Great Lakes or west coast.

Three new terminals are planned for Baltimore, one of which is under construction, which should increase the export capacity by about *40* mmt. Two or three new terminals planned for the Hampton Roads area, one starting construction soon, would also add about 40-mmt capacity there. Mobile is now adding 5-mmt capacity to its terminal. Plans for Philadelphia and New Orleans will add to the above, thus providing strong evidence that the total capacity of these five traditional ports could double within the next 5 years. (See table 4.) Despite the limited shipping season and 27-ft maximum depth on the Great Lakes, proposals are receiving considerable attention and several projects are moving ahead, most notably Erie, Pa., Buffalo, N. Y., and Conneaut, Ohio, Indeed, a major Canadian steamship line will begin to export coal from U.S. ports on the Great Lakes in self-

Table 4.—Summary of Existing and Proposed Facilities at Five Major Coal-Handling Ports (short tons)

Port owner	Location	Current capacity estimates (millions of tons~	Proposed capacity expansion (millions of tons)a	Cost (millions of dollars)	Completion date
Hampton Roads					
Norfolk & Western Railroadb	Norfolk: Pier 5	4.0	1.0	—	—
	Norfolk: Pier 6	29.0	7.3	—	—
Chessie Railroadb (Chesapeake & Ohio)	Newport News: Pier 14	16.5	—	—	—
	Newport News: Pier 15	5.3	5.0	—	—
A. T. Massey Coal Co.	Newport News: Pier 9 and adjacent areas		5.0	$60	1983
Cox Enterprises	Craney Island		20.0	100	—
Baltimore					
Chessie Railroadb (Baltimore & Ohio)	Curtis Bay	16.6	11.0	20	1981
Chessie Railroadb (Western Maryland)	Port Covington	3.0	—	—	—
Consolidation Coal	Canton		15.0	110	1984
Soros Association	Marley Neck		15.0	270	1985
Phiiadelphia					
Conrailb	Greenwich: Pier 124	2.5	10.0	—	1984
Mobiie					
Alabama State Docksb Department	McDuffie Island	5.5	5.0	55	1986
New Orleans					
international Marineb Terminals	Davant, LA	7.0	3.0	—	—
Electro-Coal	Burnside	—	—	200	—

aTaken from U.S. Department of Energy, *Interim Report of the Interagency Coa/ Export Task Force* (January 1981, P. 1-13).
‘Existing facility.

SOURCE: Office of Technology Assessment,

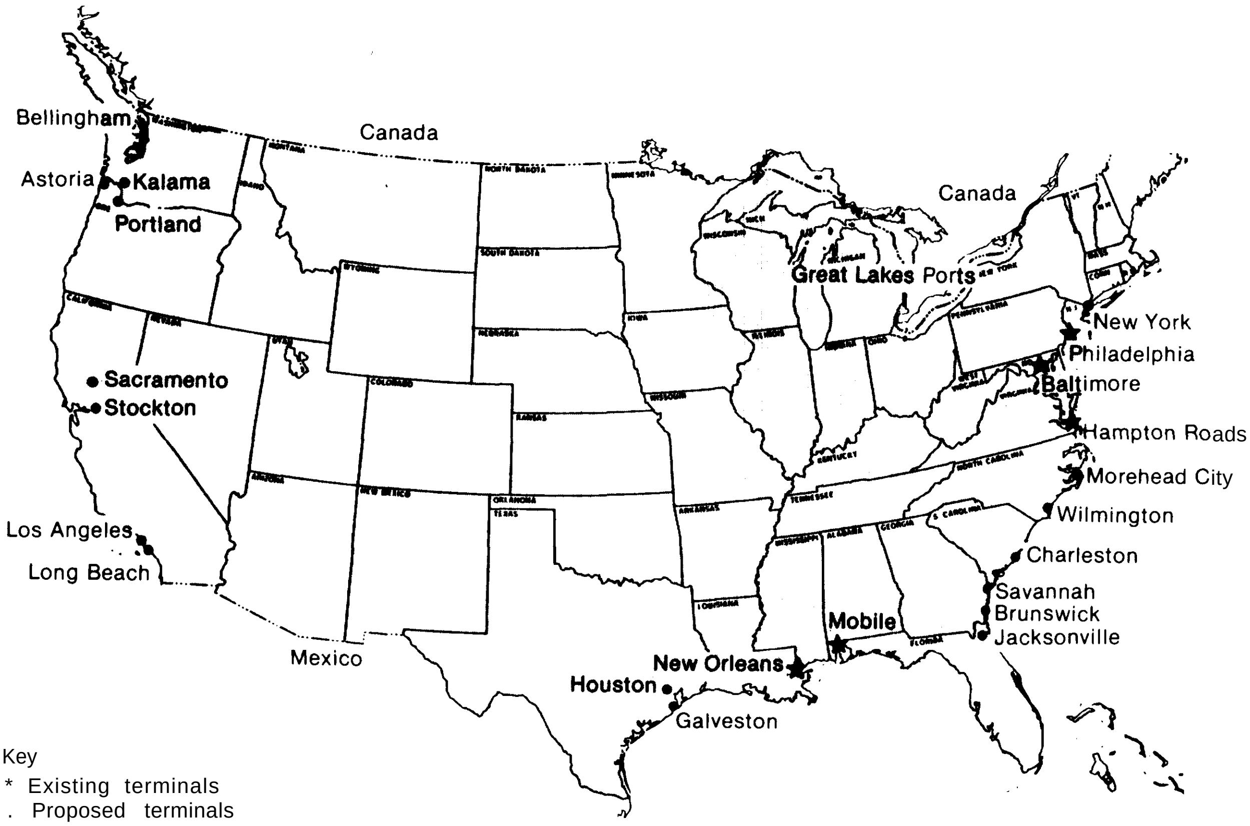
unloaders for transshipment at deeper draft ports on the St. Lawrence River. At Pacific Northwest and California ports, a series of proposals are also advancing rapidly. Figure 3 illustrates the location of various proposals for coal port development around the country.

Transportation Networks

The coal export industry has traditionally relied on rail-to-port or barge-to-port transportation. The existing networks of rail trackage and inland waterways have required regular upgrading and improvement, and several significant modifications have occurred or are in the process of being developed. Perhaps most notable in the rail industry are the spate of mergers which will allow for easy switching of coal flow from mine to export point. The mergers also have disadvantages because they may reduce price competition in this sector of coal transportation.

In addition to the existing networks, new technologies are evolving for moving coal for export. Coal slurry systems have received considerable attention and have demonstrated their feasibility on specific inland routes, although some problems remain in developing systems for overseas exports. Large steam-coal handling terminals, such as at McDuffie Island in Mobile, combine high-capacity handling and open storage for efficient coal export. Other new techniques are evolving for ship-to-ship transfer of coal. This would allow shallow-draft ships loading coal at Great Lakes ports to traverse the narrow locks of the Welland Canal, and St. Lawrence River, and then load onto large deep-draft vessels close to the mouth of the St. Lawrence Seaway.

Figure 3.—Existing and Proposed Coal Piers, Continental United States



SOURCE Office of Technology Assessment

INLAND NETWORKS AND SYSTEMS

The movement of coal over existing networks can be classified into long- and short-distance transport (gathering and distribution systems).[1] Long-distance transport primarily involves unit trains and barge.

Railroads to Ports

The primary form of coal movement in the United States is by rail, and more specifically, by unit trains. A unit train is a single-purpose dedicated train used for hauling a single commodity. It is composed of special-purpose cars which haul continuously between a mine and the consumer. The trains may move over 800-miles/day instead of the 60-miles/day associated with general freight schedules. For the railroad companies, unit trains provide better equipment and plant utilization than do other rail modes.

In some instances, the cars employed in unit train service are owned or leased by either the shipper (coal mining company) or consignee (domestic utility company), although, railroad-owned equipment is used more often on a lease-out basis,

Historically, the unit train evolved in competitive response to the many coal slurry pipe-

[1]This categorical breakdown is discussed in Bureau of Mines, Department of Interior, *Comparative Coal Transportation Costs: An Economic and Engineering Analysis of Truck, Belt, Rail, Barge, Coal Slurry, and Pneumatic Pipelines* (prepared by Center for Advanced Computation, University of Illinois at Urbana, Champaign, 1977).

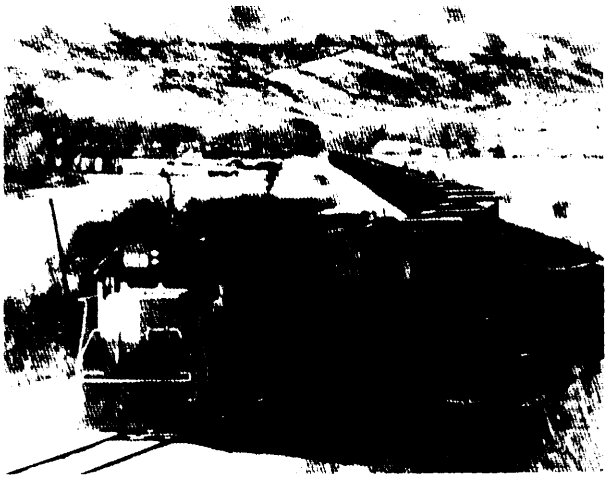


Photo credit: Ortner Freight Car Co.

Typical 100-car unit coal train

lines which were being proposed in the 1950's. The first operational slurry line connected a southern Ohio coal field with a major Cleveland, Ohio utility.[2] The railroads argued that unit trains were the only means available to compete effectively. The resulting reduced rates eliminated most slurry proposals. From the mid-1960's to the present, unit train use has been growing.

Given the forecast levels of future domestic and foreign coal demand, and the possible future shift from Appalachian mined coal to Rocky Mountain supplies, extensive railroad equipment expansion is anticipated. The emphasis will be on more powerful locomotives and larger hopper cars. However, increasing rail capacity involves a wide variety of problems. Railroad track beds must be upgraded to a level at which they can endure the anticipated heavier usage.

The adequacy of rolling stock and existing lines have a significant and directly measurable impact on unit train costing, system capacity, and hence, rates charged to foreign buyers. Inadequate equipment limits the number of trains available, leading to increased prices and limited throughput. Inadequate tracks and roadbeds reduce train speed and also contribute to escalated costs.

To remain competitive, the major coal-carrying railroads are upgrading their systems. One of the major constraints is the need for additional steel for trackage. While U.S. steel production capacity is more than adequate, shortages are known to occur. Some researchers have proposed that the U.S. Corps of Engineers could be a central organization for the rebuilding and extension of rail systems.[3] The Corps has already been involved in the relocation of rail lines in connection with dams and waterway projects.

The United States has 41 class 1 railroads.' Of these, 10 account for 88 percent of total coal traffic, and 4 are currently handling the predominant share of coal for export. The four are: CSX (Baltimore & Ohio for the Port of Baltimore and Chesapeake and Ohio for the Port of Hampton Roads), Conrail (Port of Philadelphia), and Norfolk & Western (Port of Hampton Roads) (see table 5).

The rail lines to be used to haul the projected increases in coal export traffic through 1990 are shown in figure 3.[5]

Barges to Ports

Commodity transportation by barge is possible on about 25,000 miles of navigable inland waterways in the contiguous 48 States. Even though the railroads have carried the major portion of the coal produced in this country, the inland waterways handled 14 percent of the total in *1975*.

The location of the major river systems make waterways an attractive means by which to move the projected volumes of coal from central Appalachia and the northern Great Plains to the gulf. Until the recent steam coal export boom, very little attention had been paid to shipping

'This line has since been closed. It and the Black Mesa line were the only two used to transfer coal in the United States.

[3]B. Hannor and R. Findley, "Railroading the Army Engineers: A Proposal for a National Transportation Engineering Agency," National *Resources Journal*, spring, 1977.

[4]A class 1 railroad is one with annual operating revenue of over $50 million in 1978.

'Taken from Corps of Engineers, *Moving U.S. Coal to Export Markets*, June 1980.

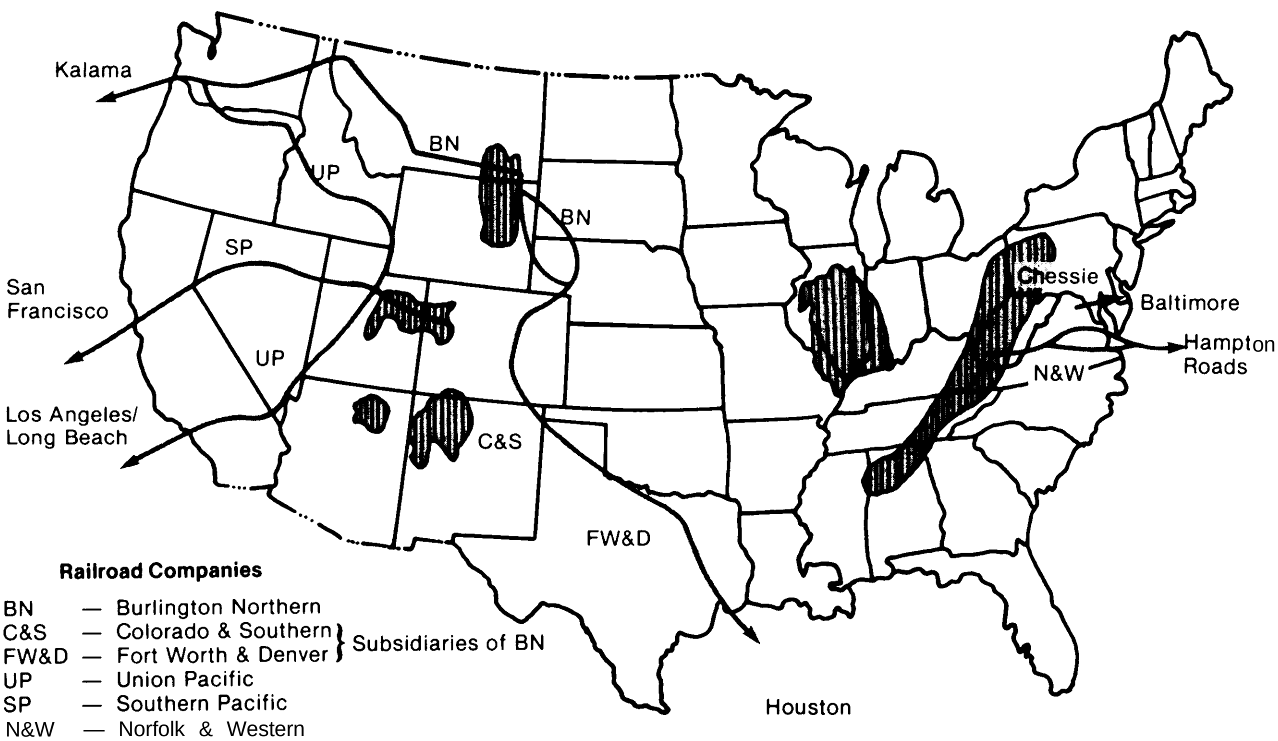
Table 5.—Rail-Carried Coal Tonnage for 1978 (short tons)

Railroad	Tonnage[a] (millions of tons)	Percent	Port used for export tonnage in 1980
Baltimore & Ohio[b] (CSX System)	21.5	5.8	Baltimore
Burlington Northern.	63.0	17.0	—
Chesapeake & Ohio[b] (CSX System). .	43.6	11.8	Hampton Roads
Conrail[b].	31.6	8.5	Philadelphia
Denver & Rio Grande Western	13.2	3.6	—
Illinois Central Gulf	15.0	4.0	—
Louisville & Nashville (CSX System) .	53.7	14.5	—
Norfolk & Western[b].	47.3	12.8	Hampton Roads
Southern	28.3	7.6	—
Union Pacific	17.3	4.7	—
Others	36.3	9.8	—
Total.	370.8	100.070	

[a]These tonnage figures are for all coal movements, of which exports constitute only a portion.
[b]Exlstlng major coal export railroad

SOURCE National Coal Association, Coal *Traffic Annual, 1979* edition (Washington, D.C. , 1980), p II-8.

Figure 4.— Principal U.S. Coal Basins and Rail Transportation Routes to the Export Market



SOURCE Interagency Coal Export Task Force

coal by river for export transshipment at gulf coast ports. The ports of Mobile and New Orleans have a number of terminal facilities to accommodate future export levels, and several additional projects are either in the design or development stage.

The inland waterway systems in mid-America are improved by *265* locks, channel alinements, bank stabilizations, modifications, and cutoffs. They are maintained by the Corps of Engineers by periodic dredging, cleaning, and snagging of the channels. The Corps operates most of the

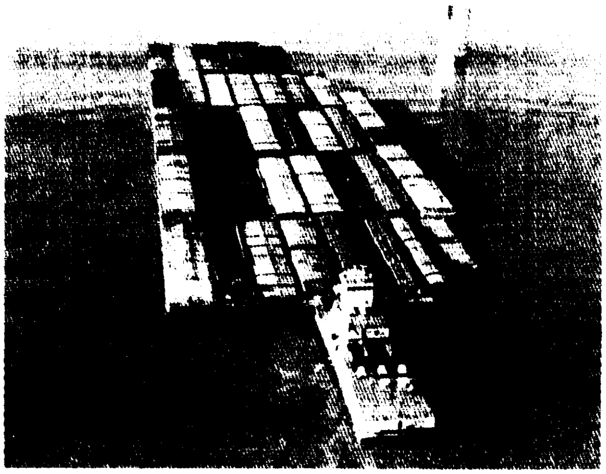


Photo Credit: **Dravo** Corp.

Typical unit tow operating on the Lower Mississippi River, showing in excess of 30 barges being moved by a single towboat

locks and maintains most of the improved waterways and harbors.

Several constraints hinder the movement of coal for export through the mid-America inland waterway system. The current drought plaguing many portions of the United States has reduced the navigable channel areas dramatically. The low-water levels along the inland river systems are a source of major concern and have led to safety and navigation difficulties, and reduced traffic flows.

A second constraint is the passage of coal-barge tows through locks particularly above St. Louis, Mo. Frequently, more than one tow will arrive at a lock at the same time. The result is congestion and waiting lines of up to several hours or even days to pass through locks. Scheduling of traffic to stagger arrivals could reduce some delays and the resulting costs of waiting.

MAJOR COAL PORTS AND TERMINALS

Historically, the Port of Hampton Roads has handled approximately 75 percent of U.S. overseas coal exports. The Port of Baltimore has been secondmost in the 20-percent range, and the ports of Mobile, New Orleans, and Philadelphia have followed. Each of these facilities will be discussed in turn, with emphasis in the discussion given to new proposals for development.

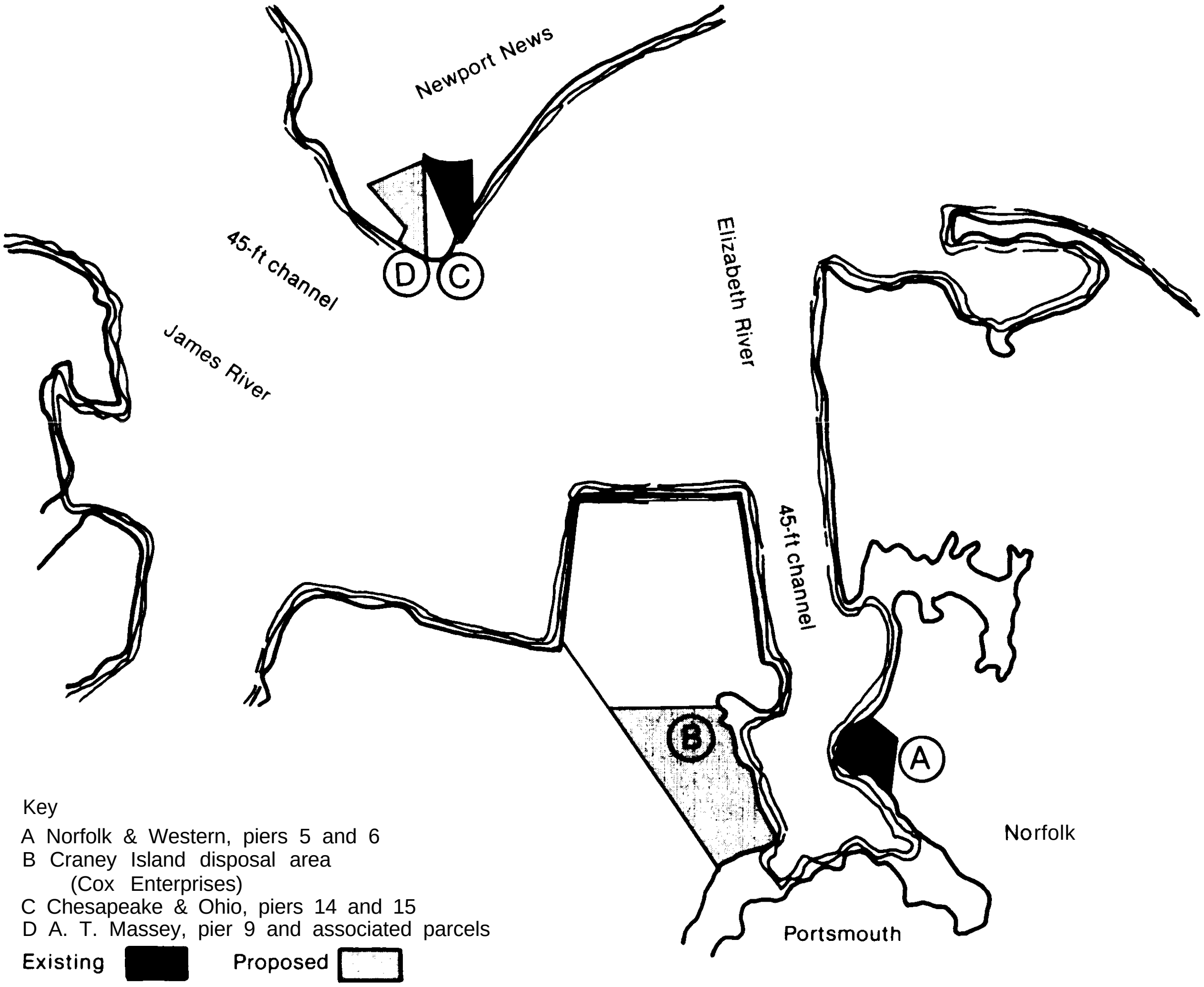
Several major firm proposals have been made for upgrading existing terminals, constructing terminals at ports currently exporting coal, and for developing entirely new projects at ports which have not historically handled coal. Whether schemes for dramatic expansion or the provision of entirely new facilities elsewhere, such as those proposed for the New York/New Jersey area, will be adopted is more questionable. But short leadtimes are required for some midstream transfer operations on the Great Lakes and the Mississippi River Delta at New Orleans, which are now being pursued.

Port of Hampton Roads

In 1979 the Port of Hampton Roads exported *33.8* mmt of coal and during 1980, this total increased to 51.8 mmt. According to the Virginia Ports Authority (VPA), the Port of Hampton Roads will export 75 mmt/yr by 1985—more than the entire United States for 1979. Besides the easy waterway access for vessels to reach Hampton Roads, the major factor leading to the predominance of Hampton Roads as a coal export site is its proximity to Appalachian coalfields.

The Port of Hampton Roads is currently serviced by two major coal-loading terminals, each owned by railroad companies (figure 5). The Norfolk & Western (N&W) Railroad own and operate piers 5 and 6 at Lambert Point on the Norfolk side of the Hampton Roads area. Pier *6* is the larger of the two facilities and acts as the terminus of coal originating from more than 200 producers on the N&W rail system. Channel

Figure 5.— Existing and Proposed Coal Piers, Port of Hampton Roads



SOURCE Office of Technology Assessment

depths are *46.5* ft, and the two tandem dumpers are capable of dumping four hopper cars, feeding loaders at a rate of 8,000 tonnes/hr.

Pier 5 is the smaller facility, consisting of one fixed electric car dumper with a capacity to handle fifty 70-tonne cars per hour. Pier 5 is used less regularly than pier 6 due in part to the limiting 35-ft alongside depths.

The Chesapeake & Ohio Railroad (C&O) facilities are located in Newport News at piers 14 and 15. Pier 14 supports two electric-traveling loading towers with stated capacity of *6,000* tonnes/hr. Pier *15* reopened on August 1, 1980, after 4 years of dormancy due to the surge in export steam coal demand. Channel depths are 45 ft for pier 14 and 38 ft for pier 15. Demonstrating the unprecedented demand in steam coal exports, the C&O's export level increased dramatically from *400,000* tonnes in 1979 to 4.5-mmt in the first 6 months of 1980 alone.

A number of new projects have been proposed for increasing the capacity of Hampton Roads to handle export requirements. One proposal calls for a 300-acre" coal facility operated jointly by several coal companies led by Cox Enterprises and including A. T. Massey, Pittston Coal Export Co., Island Creek Coal Sales Consolidation Coal Co., Westmoreland Coal Co., and United Coal Co.

The facility would be designed to have a 20-mmt/yr capacity and cost between $60 million to $100 million. This project has run into legal trouble with N&W, claiming it is still the rightful owner of the land. The land had been sold by N&W to Trailsend Land Co., and Hampton Roads Energy Co., a subsidiary of Cox Enterprises with a proviso that an oil refinery would be built on the site. Six years have elapsed since the 1974 sale, and according to N&W attorneys, the property should revert back to them. This issue has not been resolved. The Commonwealth of Virginia has also proposed to purchase this land and construct a State owned and operated coal terminal. However, the City of Portsmouth is opposed to such State ownership because it would reduce their tax base.

A second proposal involves pier *9* at Newport News which was sold by Chessie Railroad to A. T. Massey Coal Co. Massey plans to build a $60 million coal storage and shipment terminal. Pier 9 is adjacent to the pier 14 and 15 facilities owned and operated by C&O. The sale included an adjacent 60-acre parcel of land where **a** rail and conveyor system, plus ground storage area capable of holding 1.5 mmt of coal will be located.

The final development at the Port of Hampton Roads was the sale of *72* acres of land to four coal-producing firms. The land is located between C&O's pier 14 and Massey's pier *9* at Newport News. Though no confirmation has been received, Sprague Coal International, a division of Westmoreland Coal, is believed to be involved. No details of project scale, cost, or scheduling have been released.

Port of Baltimore

At the Port of Baltimore, two of three former coal piers are currently in operation loading vessels for export, and several major development projects are underway. The port's largest coal export facility is located in the Curtis Bay area of the harbor, and is owned and operated by the Baltimore & Ohio (B&O) Railroad (figure *6).* Since Baltimore is equipped with only one major facility, many vessels are known to remain anchored for up to 1 month and more. And though the vessel waiting lines for the port's coal piers are not as long as that of Hampton Roads, the waiting time can be longer. It is believed that the shortage of close-in anchorage areas, and constricted approach to Curtis Bay has additionally led to increased delays.

The B&O railroad has begun to reduce the 40-to-45-day wait by barging coal to waiting vessels at its Port Covington ore pier from Curtis Bay.

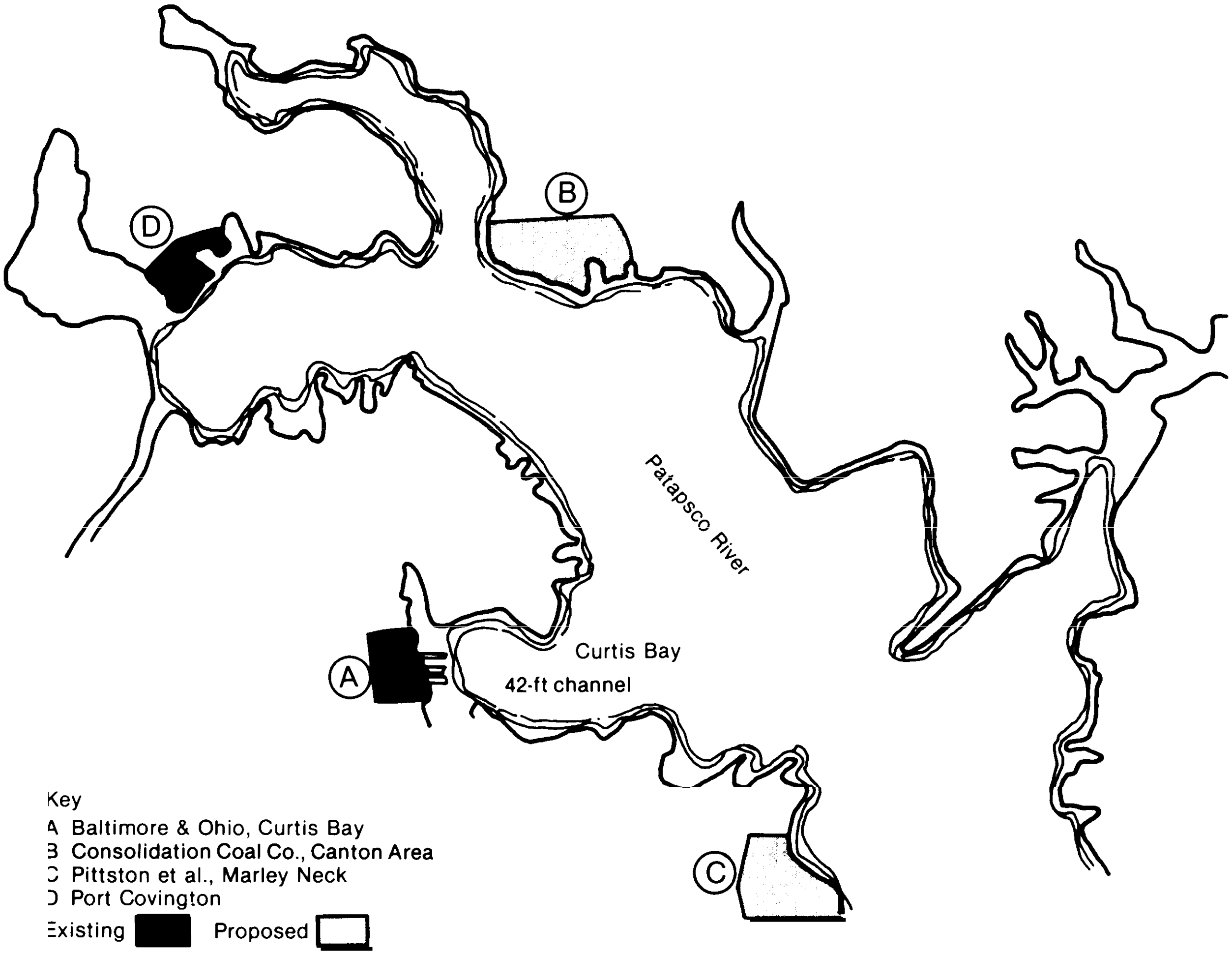
The procedure involves a grab-bucket operation that is capable of loading an average 50,000-tonne coal ship in about 3 days. Coal is initially loaded onto barges at the underutilized barge side of the Curtis Bay terminal. The barges are then towed north to Port Covington.

From a physical facility standpoint, several specific proposals have been made for the Port of Baltimore. First, the Island Creek Coal Co., a subsidiary of Occidental Petroleum Corp., and the leading coal exporter from the Curtis Bay pier, has committed *$40* million to develop a 25-acre coal-stocking yard adjacent to the existing coal pier. The development of the yard, and the installation of coal-dumping machinery is scheduled to be completed by September 1981.

The yard will have a storage capacity of between *300,000* to *500,000* tonnes, depending on the mixing requirements for different grades of coal. New equipment will include rail tracks, scales, reclaimers, conveyor equipment, and dumping machinery. All construction will control dust movement through several spray systems. The Baltimore City Council has been presented with a proposal to help finance the Island Creek project by issuing industrial development bonds.

A second major terminal improvement has been advanced by Consolidation Coal Co.(Con-Sol), a subsidiary of Continental Oil Co., to buy the old Canton Marine Terminal for *$30* million, including the local switching railroad owned by the Canton Co. A low-interest rate

Figure 6.— Existing and Proposed Coal Piers, Port of Baltimore



SOURCE Office of Technology Assessment

Baltimore City bond has been approved to assist the Consolidation effort.

The facility will have an on-the-ground storage capacity of 750,000 tonnes and will be able to accommodate 100,000 car arrivals annually. It has an open conveyor system, thawing sheds, a dual-car rotary dumper, and an extensive antidust spraying system.

Initially, the ConSol pier will load 10 mmt and service 175 to *200* ships annually. An existing pier now used to discharge ore will be extensively redeveloped and transformed into a coal-loading facility. Plans call for the pier to load ships on one side and barges on the other. Total investment for the first phase is $110 million, including the land purchase.

ConSol is leaving the option open of expanding the pier's loading capacity to 20 mmt/yr. Whether or not this second phase of development takes place will largely depend on the future coal market and the dredging of the channel.

ConSol has set a target date of the first quarter of 1983 for completion of the storage and pier facility. Advanced engineering drawings have been completed and ConSol is moving in the permit process.

A third and largest project involves a 500-acre tract sold by CSX Resources, Inc., to Soros Associates. The site is located in the Marley Neck area of northern Anne Arundel County, not far from the Curtis Bay facility. A consortium of five major coal producers have pooled financial resources to develop the 15 mmt/yr capacity for *$270* million. The coal producers are Pittston Co.; Mapco Co.; Elk River Resources, a subsidiary of Sunoco; Old Ben Coal Co., a subsidiary of Sohio; and Utah International, Inc., a subsidiary of General Electric.

The design of this facility is unique in the sense that a 6,000-ft trestle will be constructed over the shallow areas of the Patapsco River. Cost considerations and potential problems with dredge-spoil disposal areas prompted Soros to select the offshore loading procedures rather than pier-side operation. Operational startup is scheduled for early 1985.

Port of Philadelphia

The Port of Philadelphia is currently served by one active coal terminal. Pier 124 is located on Greenwich Point on the Delaware River near the Philadelphia naval yards. The pier is owned and operated by Conrail, and can accommodate vessels on the south side of the pier. It is equipped with two rotary car dumpers and mechanical conveyors, telescopic chutes, and trimmers. Barges can be loaded on the north side of the pier. It is serviced by a 40-ft channel.

Development plans are underway to upgrade the pier so that two vessels can be loaded simultaneously. Capacity has been stated as reaching 3 mmt/yr after phase I development, and potentially 10 mmt/yr if all development plans are completed. This project will help to increase the pier's handling capacity of vessels from 40,000 to 80,000 deadweight tonnes.

In addition to the Greenwich Pier, Conrail has recently completed the rehabilitation of 230 miles of rail trackage between Philadelphia and the Clearfield, Pa. coalyards. A total of *$60* million is being spent for *1,550* open-hopper cars, and the refurbishment of *17,000* older vehicles.

An unused facility is located at Port Richmond's pier 18. Should interest be sufficient to reactivate it, complete renovation including a new pier, dredging, and all required equipment would be needed.

The Delaware & Hudson Railroad serves the Port Richmond area and has reportedly been pursuing trackage rights for access to the terminal from the Southeastern Pennsylvania Transportation Authority.

A third development site under consideration is located at the site of the Northern Shipping Co. marine terminal north of downtown. The 162-acre tract is presently used for general- purpose stevedoring activity, but could be reconfigured for coal export. Preliminary data indicates that the new terminal could handle up to *6,000* tonne/hr., employing unit trains. If the new terminal is developed at Northern Shipping, the existing stevedoring activity would be relocated to an adjacent site.

Port of Mobile

The Port of Mobile is located in the southwestern part of Alabama, at the junction of the Mobile River and the head of Mobile Bay. The port is about *28* nautical miles north of the bay entrance from the Gulf of Mexico, and *170* nautical miles west of New Orleans. The port's principal waterfront facilities are located along the lower 5 miles of the Mobile River.

The outer harbor of Mobile consists of the deepwater channel extending from the mouth of the Mobile River. From the upper reach of the Mobile Bay channel, the Arlington channel leads northwestward to a turning basin at the southwest end of Garrows Bend. Garrows Bend channel leads northeastward from the turning basin, and terminates south of the causeway connecting McDuffie Island with the the mainland. McDuffie Island is just west of the Mobile Bay channel at the mouth of the Mobile River, and is the location of all coal exporting activities.

McDuffie Terminal is recognized as one of the most modern coal-handling facility in the world. At the present time, most of the coal is being mined in the north Alabama fields and shipped by barge to McDuffie for export. A small amount is being transported by rail for export. It is owned and operated by the Alabama State Docks Department, the only domestic coal-handling facility involving direct public interest. It was placed into operation in January 1975, incorporating the newest and most innovative approaches to material handling and automatic barge unloading in the United States.

McDuffie Island is accessible from the mainland by a causeway and is served by the Terminal Railway of the Alabama State Docks Department. The island is adjoined on three sides by dedicated channels. The Mobile River channel on the east side is presently authorized and maintained to a depth of *40* ft. The Arlington channel on the south side is authorized and maintained to a depth of *27* ft, and the Garrows Bend channel is authorized to a depth of **27** ft, but has not been maintained since the construction of the causeway at the north end of the island.

The fact that McDuffie Island is south of the 44-ft-deep channel crossings of Interstate Highway 10 and Bankhead Tunnels, places the facility in the advantageous position for the future handling of much larger bulk carriers if a plan for deepening the Mobile ship channel to the gulf is approved to increase the present authorized depth of **40** ft to a depth of 55 ft.

The initial facilities constructed on McDuffie Island included an automatic barge unloader, railcar dump, truck dump, two storage pads, a stacker/reclaimer and material handling conveyor system, ship dock, ship loader, offices and control tower as well as backup maintenance buildings, and receiving tracks for railcars. Expansion facilities will include an additional barge unloader, additional stacker/-reclaimer, two additional storage pads, the construction of a loop track for handling of unit trains of coal, and an integrated conveyor system.

The barges are brought into the fleeting area and moored by various towing companies that also remove the empty barges from the fleeting area (fig. 7). Movement of the barges within the fleeting area is accomplished by a workboat under contract to the various shipppers. The barges are presently unloaded by a high-capacity ladder-type bucket-elevator unloader. The bucket elevator remains stationary while the barge is moved back and forth beneath it to allow the unloader to remove the coal and place it on the conveyor system. The new barge unloader will be of similar design.

The open-storage area has a capacity of *430,000* tonnes. The electric-traveling stacker-reclaimer has a 180-ft boom equipped with a reversible 72-inch belt conveyor and a continuous bucket wheel. It has a stacking rate of 4,000 tonne/hr, and a reclaiming rate of 5,000 tonne/ hr.

By May 1981, the second phase of development should be complete, adding a second stacker/reclaimer, two additional storage pads, one more barge unloader, and a rail facility which will accommodate unit trains in a loop-track setup. Total price of $20 million is estimated to complete this work.

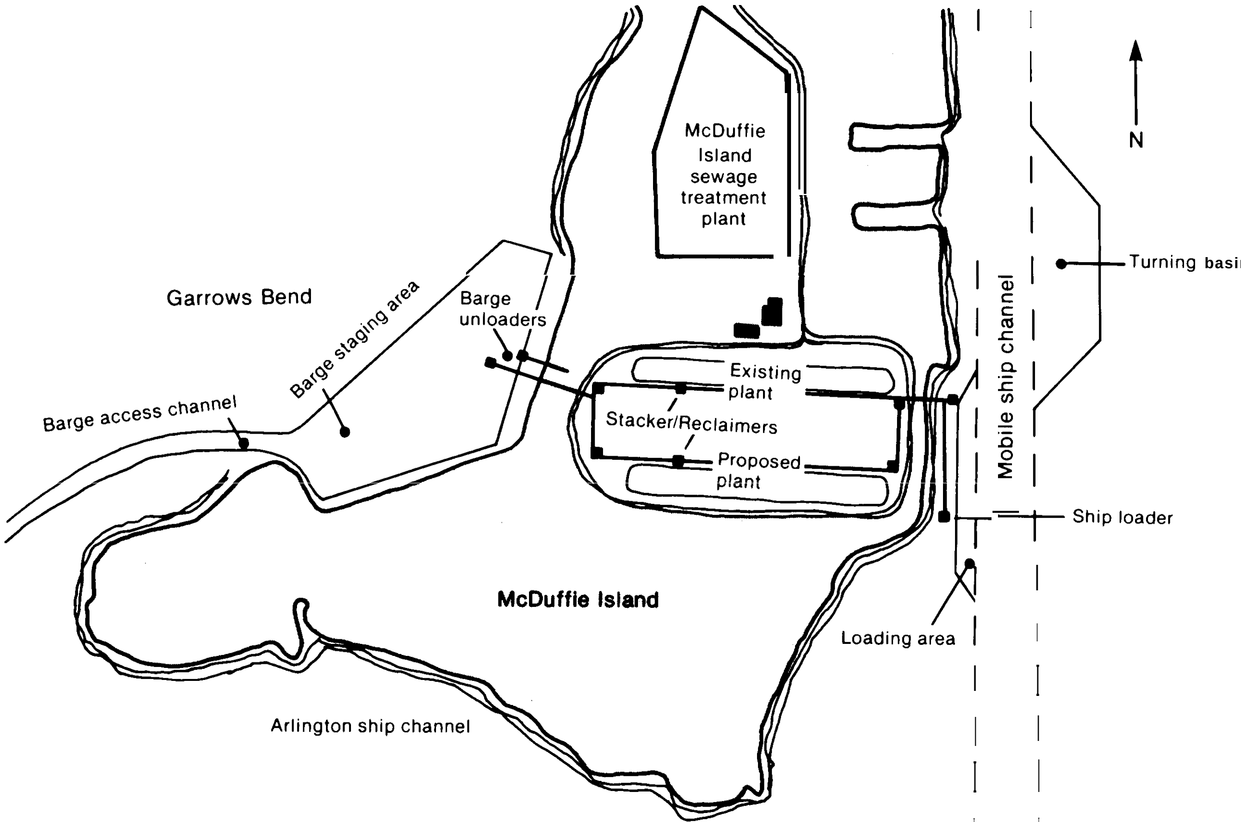
Phase III development will include a new dock, shiploaders, and a third stacker/reclaimer for approximately $30 million to $35 million. To allow for the second and third phases of development, a 143-acre site was recently acquired by the State, immediately adjacent to the existing complex. The new area includes 2,800 ft of riverfront berthing space.

Port of New Orleans

The Port of New Orleans currently handles coal for export at two terminals located in Plaquemines Parish' (fig. 8), Coal exports were first handled in 1978 at the International Marine Terminals, Inc. (IMT) facility, located 50-miles

[b]Based **in** part on comments provided by Colonel Herbert R. Harr, Jr., Associate Port Director, Board of Commissioners of the Port of New Orleans, before the Energy Bureau, **Inc. 's, "Coal Export Conference, " Washington, D. C.,** Dec. 15 and 16, 1980.

Figure 7.—Physical Layout, McDuffie Island



SOURCE: Off Ice of Technology Assessment

below New Orleans. Expansion to 12 mmt/yr by 1985, and up to 25 mmt/yr by 1990 has been proposed. The terminal currently accommodates shallow draft, open-hopper river barges unloaded by a continuous unloader with a capacity of *5,500* tonne/ hr. A 270,0()()-tonne ground storage area is available. Reclaiming of coal occurs via dozer at an average rate of 1,000 tonne/ hr.

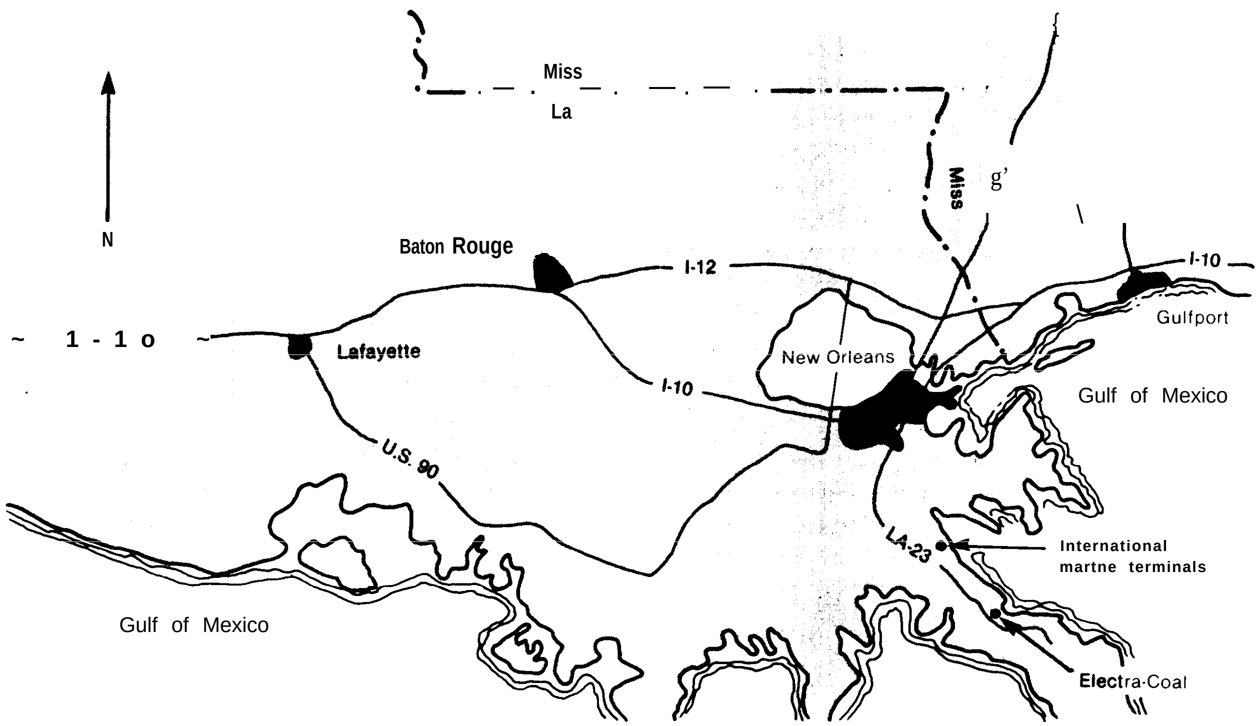
Phase II calls for the addition of a new dock and installation of a traveling ship unloader having an ultimate capacity of *7,000* tonne/hr. In phase III a stacker/reclaimer is scheduled to be used at full development and nearly 1 mmt of active storage area will be available. The IMT officials have indicated that it is their hope that *5* or *6* large-volume customers will require the greatest share of coal.

The second export facility in operation in the New Orleans area is the Electro-Coal Transfer Terminal. Electro-Coal is expanding its capacity with a *$200* million, two-phase program. The expansion will allow them to handle *25* mmt/yr by 1990.

In addition to the existing facilities, several other proposals have been made for new export terminals. Near Baton Rouge, the River & Gulf Transportation Co. has acquired almost *600* acres of land for an export terminal capable of handling 11 mmt/yr of coal and 5 mmt/yr of iron ore by 1985. A subsequent phase calls for a 15-mmt/yr-coal exporting capacity by 1990.

The ability of the Mississippi River to transport large volumes of coal has been the direct stimulus of the interest in gulf coast ports.

Figure 8.— Existing Coal Terminals, Port of New Orleans



SOURCE Off Ice of Technology Assessment

Several major inland waterway barge carriers have recognized this by investing $55 million in modern rail-to-water transfer facilities capable of handling *30* mmt/yr. The American Commercial Barge Line and Federal Barge are currently transporting large volumes of coal along the Mississippi River coming from States bordering on the upper Mississippi and its tributaries.

The influence of the French Government is strongly felt in the New Orleans area for coal export. The Association Technique de L'Importation Charbonnierc (ATIC) is sole agency in France responsible for importing the large quantities of foreign coal needed to replace oil. ATIC is currently acting as agent for the Spanish and Netherlands Governments, as well as coordinating efforts for West Germany. The aim of ATIC is to negotiate long-term contracts with coal suppliers in nations with stable governments. Their interest does not stop at the purchase of coal but extends to the transportation and shipment. To be assured of a smooth flow, ATIC will obtain a participating interest in barge companies and in coal export terminals.

Terminals on the lower Mississippi River are capable of being served by both barge and rail. The Illinois Central Gulf Railroad is investing heavily in improvement of their trackage to New Orleans in anticipation of unit train movements of coal to and from the Illinois coalfields. This competition with the barge lines should limit increases in transportation costs such as have occurred in Western areas where only one mode of transportation is available.

COAL PROJECTS AT OTHER PORTS

A number of significant proposals have been made for constructing, or at least investigating the feasibility of constructing new terminals at ports which have not historically exported coal. Virtually all possible locations have been considered, ranging geographically from ports on the Great Lakes, to New York, Jacksonville, Long Beach, and Puget Sound. The following text is based on accounts provided in reports, newspaper articles, magazines, etc. Due to the confidential nature of new projects, many details never are presented publicly and analysis must remain somewhat superficial. Nonetheless, by assembling information from a number of sources, a reasonable description can often be made of likely coal export terminal development patterns.

The likelihood is remote that all of the proposed projects will be developed. Many industry observers have voiced the concern of overdevelopment of capacity and unwarranted expenditure. As the export situation continues to evolve, the feasibility of new proposals will become more evident and coal companies and railroad executives will be better able to evaluate the risk and return on investments. Many experts seem to agree that free marketplace demands will dictate the suitability of one proposal v. another, and that the Federal Government should not try to outguess business decisions.

Great Lakes Ports

The U.S. Great Lakes coal-loading port facilities are generally railroad-owned and have historically served the U.S. domestic and American-Canadian coal trade[1]. In 1979, total annual tonnage amounted to about $41.5 mmt, of which *23.5* mmt were domestic movements (e.g., Duluth-Superior to Detroit), and *18.0* mmt were exported to Canada. The domestic trade is served by U.S.-flag bulk vessels. Canadian bulk vessels generally handle the export tonnage.

[1]Department of Commerce, Maritime Administration, Great Lakes Region, ***Great Lakes Ports Coal Handling Capacity and Export* Coal *Potential,*** December 1980.

A recent U.S. Maritime Administration study analyzed a four-ship feeder service from Conneaut, Ohio to Quebec. This system would deliver coal to Quebec at a price of approximately $56.65/tonne. This price was believed reasonably competitive with *$51.00* to $55.00/ton price at Hampton Roads, Baltimore, or Philadelphia, which are served by rail.

There are currently seven U.S. ports on the Great Lakes that have the capability to handle shipments of coal for either export or domestic use. They are:

- Ashtabula, Ohio,
- Conneaut, Ohio,
- Erie, Pa.,
- Sandusky, Ohio,
- South Chicago, Ill.,
- Superior, Wis., and
- Toledo, Ohio.

The ports of Erie and Conneaut both began shipping domestic steam coal for overseas exports in 1980 and their activity is expected to continue.

Ashtabula, Ohio.—Currently handles both steam and metallurgical coal for export to Canada and domestic use. Approximately 75 to 80 percent is steam coal for Canadian markets. The facility is being modernized and utilizes a 7,000-tonne/hr conveyor system for loading vessels. Ground storage is 1.5 mmt and approximately 500 railcars can be stored onsite. There is no blending capability and there are no plans for expansion at the present time. A new stacker/reclaimer is planned for 1981.

Conneaut, Ohio.—This is a modern facility that also was the first to ship coal for export to Europe through a Canadian transshipment facility (Quebec City). An estimated 150,000 tonnes of steam coal has moved from Conneaut during 1980. The facility does provide a blending service. A conveyor system capable of 7,700 tonne/hr loads coal into vessels from a 6-mmt ground storage area. The facility has the capability to increase shipment tonnage without any improvements. There are no plans for expansion in the near future.

Erie, Pa.—Presently a temporary facility is being used at the port to ship steam coal for domestic use. These coal shipments were initiated in 1980 on a trial basis and 1981 plans indicate an increase in tonnage shipped. The temporary facility is receiving coal by truck from western Pennsylvania mines and has a ground storage capacity of 20,000 tonnes. Vessels are loaded by conveyor and there is no blending capability. The Erie-Western Pennsylvania Port Authority has received $95,000 from the Commonwealth of Pennsylvania to perform a marketing feasibility and land-use study for a permanent coal-loading facility. This study will be completed in 1981. Additionally, Pennsylvania has passed legislation to secure bonding power for up to $10 million for development of a permanent facility. The results of the study will determine when this development will commence and to what degree.

Sandusky, Ohio.—Coal shipments consist of s55 percent for export to Canada and 45 percent for U.S. domestic users, Approximately 65 to 70 percent is metallurgical coal with the balance being steam coal. The facility uses a *3,500*-tonne/hr car dumper for vessel loading and can stage approximately 2,800 railcars. Blending can be accomplished through mixing of railcars. A ground storage capacity of $950,000 tonnes is also available. This facility is presently dedicated to contract customers. Future expansion is not planned at the present time.

South Chicago, Ill.—This facility has only handled shipments of coke to both Canadian and U.S. domestic customers, although the capability and capacity to ship coal is present. A 5,00@ tonne/hr-loading rate by two traveling towers provides rapid offloading of railcars. A 1,500-car capacity is available on the site. Barges can also be loaded. Through the mixing of railcars, blending could be accomplished. Expansion for coal handling can be accomplished on the present 40-acre site with little capital cost.

Superior, Wis.—Currently, Western steam coal for the U.S. domestic market is handled at this facility, which is less than 5 years old. Railcars are immediately dumped and material is placed into either ground storage or loaded directly onto vessels via an extensive conveyor system. Ground storage capacity is currently 7 mmt and initial design plans allowed for 12 mmt. However, expansion to this capacity will require additional capital investment and is not planned in the near future. The loading rate of *8,500* tonne/hr by conveyor is the fastest on the Great Lakes. Blending can be accomplished by controlling the underground reclaimer plow feeders if required. Vessel size is limited to seaway-size vessels.

Toledo, **Ohio.**—There are four separate loading berths at the facility. Coal shipments are 60-percent-steam and 40-percent-metallurgical coal and are primarily destined for the U.S. domestic market with only some shipments to Canada. One berth (east pier No. 4), uses a 4,500-tonne/hr" conveyor for vessel loading. The other three berths use an 1,800-tonne/hr car dumper. Berth east side No. 1 has not been used for the past 8 years although it can be operated if needed. These three berths are limited to seaway-size vessels. The facility does not have any ground storage capacity but can accommodate approximately 5,000 railcars. Blending can be accomplished through mixing of railcars. Currently, there are no plans for future expansion. If demand requires, the inactive berth can be operational with little, if any, capital investment. In 1965 and 1966, Toledo moved 34.8 mmt and 34.3 mmt.

Port of New York

Several proposals have been presented for developing coal-export handling facilities at the Port of New York. The two major proposals center on Arthur Kill and the Ambrose Channel of the lower Hudson River. The Arthur Kill project is a short-term solution designed to divert some of the coal activity to New York from Hampton Roads and Baltimore. The plan calls for transporting coal to Conrail's Port Reading coal pier and loading it on barges. The barges would then be moved to a deepwater pier where the **coal** would be transshipped to ocean vessels.

Port Reading is located on Arthur Kill, the narrow body of water between New Jersey and Staten Island. The channel depths at that point are too limiting to allow large-draft vessels to enter, and therefore the barges must be used.

To accommodate demand by the mid-1980's the Port Authority of New York and New Jersey has been considering a number of sites including a point near Stapleton, which is south of St. George on Staten Island, Greenville in Jersey City, or along the Ambrose Channel.

Ports of North Carolina and South Carolina

The North Carolina State Ports Authority has advanced discussions and plans for one export terminal at one of several locations including Morehead City or Wilmington. Discussions have been held with several coal companies investigating the feasibility of a 3-mmt to 8-mmt tonne/yr terminal. The Seaboard Coast Line Railroad (now part of the CSX system) serves the Port of Wilmington, and has expressed its willingness to haul coal. Southern Railroad (soon to merge with Norfolk& Western), which serves Morehead City, has not actively pursued coal terminal development, although they would be willing to haul it.

The South Carolina State Ports Authority has pursued the development of a coal-exporting facility, with the most probable location being Charleston. Southern Railway serves Charleston and is considering the merits of possible investment. A. T. Massey has expressed firm plans to begin construction on a $75 million terminal at Charleston, capable of handling 12 mmt/yr. Massey has arranged for the purchase of a 55-acre site from Burris Chemical Co., located between North Charleston and Columbus Street Terminals of the South Carolina State Ports Authority. To assist in the finance, the Charleston County Council has expressed a willingness to release a $75-million industrial revenue bond issue.

Rail service to the Charleston site would be provided by a combination of Southern, Seaboard Coast Lines, and Louisville and Nashville railroads. Approval has already been obtained for channel-deepening from 35 to 40 ft. Yet, since the Corps of Engineers is completing a study to redivert silt buildup in a feeder river, dredging must wait. When the rediversion project is completed, dredging could follow with completion expected in the 1985-86 time frame.

Ports in Georgia

The earliest commitment for a new export facility at U.S. South Atlantic ports came from the Port of Savannah. A 12-mmt to 15-mmt/yr terminal was announced on September 22, 1980, with an attached price of $50 to $60 million on the 250-acre Hutchinson Island site. Coal is scheduled to be transported over Louisville and Nashville, and Clinchfield Railroads from mines in Kentucky and southwest Virginia. The coal will also move over Seaboard Coast Line trackage beginning at Spartanburg, S.C. Savannah has channel depths of 38 ft, plus a 7-ft tide, considered adequate for coal vessels. In addition, the Corps of Engineers is now evaluating the deepening of the channel to 42 ft.

In addition to Savannah, preliminary plans have been developed calling for a 15-mmt/yr capacity (2.3 mmt/yr initially) terminal in Brunswick, Ga. to be constructed as soon as the channel leading to the site can be dredged beyond its current 30-ft depth to 36 ft. In light of the Savannah commitment, the potential development for this terminal seems less likely. The 1985 time frame has been identified as a target date for full operations. The terminal would be located on 100 acres of Colonel's Island and be equipped with a full stacker/reclaimer system. The island is connected to branch lines of Seaboard Coast Line Railroad and Southern Railroad by a 21.7-mile hookup.

Port of Jacksonville

Consideration is being given to utilizing the regional coal transshipment facilities being studied for Blount Island as a coal-export terminal. The Jacksonville Electric Authority (JEA) and other Florida-based utility companies are evaluating the feasibility of a coal-unloading terminal for regional electricity production. Individuals familiar with the project indicate that the utility companies do not want to eliminate the possibilities of using the new receiving terminal as an export point as well.

Ports in Texas

In the State of Texas, primary attention is focused at Galveston and Houston for coal-export facilities. The Pelican Island Terminal at Galveston is being coordinated by Orba Corp., which leased needed land from the port approximately 5 years ago. Ninety-six acres are proposed for near-term development with 76 acres as backup expansion area. A 15-mmt/yr terminal is planned under full development schemes, to be equipped with 2,600 ft of berthing space, and a 56-ft channel. The final approval for channel-deepening is expected this summer. The 56-ft channel depth is believed to support the sailing fees of up to an additional 2 days as compared to the use of east coast ports. Excellent rail service is provided by the Burlington Northern, Missouri Pacific, Southern Pacific, and Santa Fe railroads.

The neighboring Port of Houston has advanced development plans for an export terminal on the Houston ship channel, adjacent to the port's Green Bayou bulk-material handling plant. Thirty-two acres have been leased to Soros Associates for development of the facility.

California Coast Ports

Port officials at California cities are optimistic over the prospects for exporting Western States mined coal through their facilities. Most notably, the Ports of Los Angeles, Long Beach, Sacramento, and Stockton have presented the strongest arguments for using their facilities. Currently, only limited coal is being shipped to California ports for export on experimental runs. In general, the costs of using rail transportation to move coal across the Rocky Mountains from the mines requires considerably higher rates than the use of Eastern coal terminals, despite the waiting lines and demurrage fees. Also, environmental opposition to increased unit train movement is expected to delay rapid project implementation.

The Port of Sacramento is being given consideration as a result of it being the closest port in railroad mileage from major Western coalfields. Sacramento additionally offers large areas for open storage and its rail-yard system is known to be considerably less congested than other California ports. Sacramento suffers from having only limited 30-ft-deep approach channels, but port officials maintain that the shorter rail distance counterbalances the need to use small draft vessels.

The Port of Stockton has handled coal in the past and is evaluating interest in constructing a major export terminal. Located 75 miles east of San Francisco, possessing channel depths of 35 ft, rail access, and required land area. Port officials in Stockton believe they have a very likely site. Plans call for developing a storage area capable of holding 100,000 tonnes. This area would be combined with an existing 40-car-per-8-hour shift dump facility, conveyor belt system, and potential for a circular unit train track.

At the Ports of Long Beach and Los Angeles, some limited rail deliveries have been made for final delivery to Japan, Taiwan, and South Korea. Mines located in Utah and Colorado have provided the coal.

The Port of Los Angeles has capacity for up to 1.5 mmt/yr as currently configured. The 51-ft channel depth, and storage area capable of holding 100,000 tonnes, stand ready for increased service. Long Beach also has a deep channel at 40 to 48 ft, and could handle up to 2.0 mmt/yr. Both Long Beach and Los Angeles have announced plans to expand coal-export capabilities there. Long Beach plans to modernize its existing terminal and build a new one which would have a 30-mmt/yr capacity by 1985. Los Angeles has announced approval of planning for a 20-mmt terminal.

Pacific Northwest Ports

Ports in the Pacific Northwest States appear to be advancing more rapidly than California ports in developing coal-export facilities. Interest is highest at Portland, Oreg., and Kalama, Wash. Officials at Portland are in the process of seeking bids to begin work on a multiphased export terminal with proposed final design capacity of 10 mmt to 12 mmt/yr. A $30-million first stage is contemplated with startup by late 1982 or early 1983 expected. The 100-

acre site is to be located on the Willamette River, approximately 100 miles upstream from the Pacific Ocean on a 40-ft deep channel. Rail service provided by three carriers will allow for dramatic expansion beyond the 200,000 tonnes handled in 1980.

The Port of Kalama, Wash. has unveiled plans to build a $50 million to $60 million coal port on a 200-acre site of the Columbia River. The Honolulu-based firm of Pacific Resources, Inc. (PRI) is to lease the land from the port following completion of the sale from Burlington Northern. Coal will be brought to Kalama on Burlington Northern and Union Pacific main rail lines from Rocky Mountain States.

Pacific Resource is expected to design the terminal to handle 15 mmt/yr, but initial development will be on a smaller scale. The facility will be able to accommodate mile-long unit trains in two circular rail tracks to be emptied into a hopper below the tracks.

Port officials at Bellingham, Wash., announced plans in November of *1980* to develop a $50-million bulk terminal designed to handle coal and other commodities. The proposed site is located on land previously dedicated to an oil terminal. However, there is community opposition to this proposal, and final designs have not been made.

A *$50* million, 215-acre site is being evaluated on the Skipanun River at the Port of Astoria, Oreg. Preliminary design plans call for a 5-mmt/yr capacity but upgrading of Burlington Northern rail trackage to the site is a must.

A final major prospect comes from the Port of Bellingham, Wash., approximately 100 miles north of Seattle. Port officials are quick to point out that only Bellingham can accommodate 250,000-tonne tankers due to its deep-draft harbor.

SUMMARY OF COAL PORT PROJECTS

Figure *9* summarizes the approximate scheduling of new projects as discussed above. As indicated, and as experience would dictate, the proposed projects possessing the shortest start-up times are located at ports already handling coal. Definite commitments have been obtained by six seaboard port areas, as well as from Great Lake ports. The longest buildout periods are projected for ports which do not currently export coal, and which do not have firm commitments from coal companies, railroads, and investment houses.

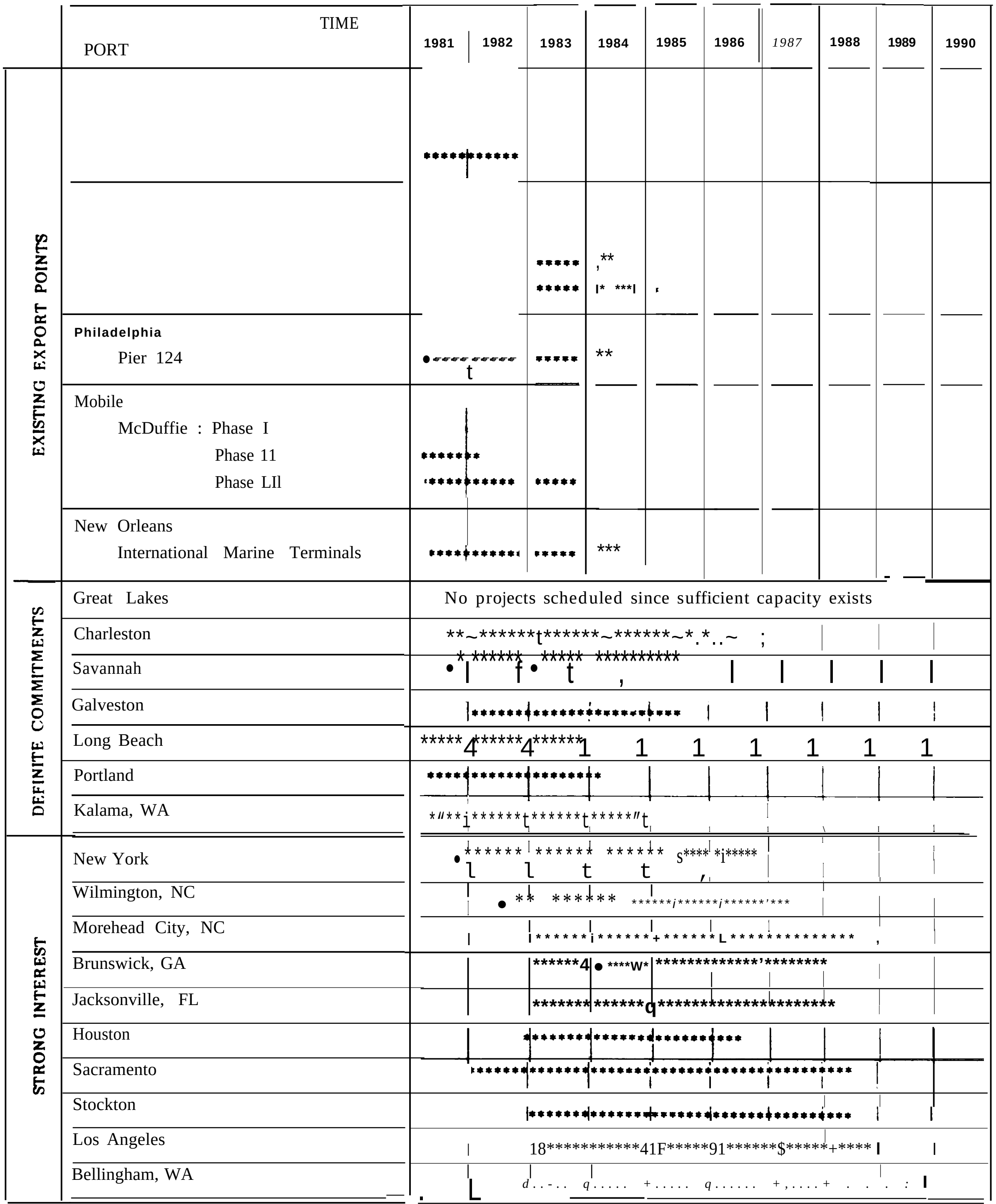
SHIPS IN THE COAL EXPORT TRADE

Coal is transported from U.S. ports and terminals to Europe, Japan, and other countries aboard large bulk ships ranging in carrying capacity from 10,000 to over 100,000 tonnes.

There is considerable changing character to the ships in the coal export trade. Prior to *1965,* the conventional ship with a deadweight tonnage (dwt) of 15,000 tonnes tended to dominate the trade, This domination disappeared with the advent of the large bulk carriers and the combination, oil-bulk-ore, carriers. The bulk carriers are suitable for carrrying a number of dry bulk cargoes such as grain, coal, phosphate, bauxite, and other ores. Thus, there are many ships that can move into and out of the coal trade. This versatility with respect to all commodities is necessary where there are surges and changes in the trade. In the past two decades the dry-bulk fleet has increased from 10-million-dwt to over 150-million-dwt capacity. In recent years the greater use of larger ships in the World and North American coal trades is summarized in table *6.*

The ships available to trade between specific ports, are dependent on three factors: the exporting port's channel depths, the importing

Figure 9.—Approximate Implementation Schedule of New Coal-Export Terminals



Note: Time periods are estimated for the "Definite Commitments." and 'Strong Interest" sections.

SOURCE Office of Technology Assessment

Table 6.—Size Distribution of World Coal Fleet (deadweight tons)

	Less than 40,000	40,000-59,999	60,000-79,999	80,000-99,999	100,000 & over
World Coal trade by vessel size					
1974	**45%**	**28%**	**19%**	**2%**	**6%**
1979	**35%**	**15%**	**20%**	**4%**	**260/o**
North American coal exports by vessel size					
1974	**26%**	**30%**	**30%**	**5%**	**9%**
1979	**19%**	**16%**	**27%.**	**6%**	**32%**

SOURCE: OSG Bulk Ships Inc., New York, February 1981.

port's channel depths, and the depths of canals traversed between the ports. The present U.S. major coal-loading ports and their present controlling channel depths are:

Hampton Roads ....45 ft
Baltimore ....42 ft
Philadelphia ....40 ft
Mobile ....40 ft
New Orleans. ....40 ft

The relationship between a ship's deadweight tonnage and draft, which relate to the channel depth restrictions, is approximate because of differences in hull form and length-to-beam ratios. However, a useful approximate relationship is given in table 7 along with limiting ship dimensions for traversing the Panama Canal.

Present worldwide coal exporting and importing facilities as related to deadweight tonnage is presented in tables *8* and *9.* The present world coal trade is transported in a fairly wide range of ship tonnages as a result of the various restraints and economic factors. Table 10 summarizes the range for 1979. The utilization of bulk and combined carriers by coal as compared to other cargoes is shown in table 11, indicating that coal accounts for approximately 18 percent of the tonnage carried. The makeup of the existing world fleet carrying these cargoes is shown in table 12 along with the present orders for new ships. New orders for bulk carriers indicates a continuing shift to larger ships.

Economics of Coal Ships

The selection of ships and routes is largely dependent on the economics of the transport and the availability of ships. Economies-of-scale are an important determinant of unit costs of coal transportation, these costs increase with distance and decrease with ship size. Three general sizes of coal carriers are noted below.

- *60,000* dwt.—This is roughly the median size for present coal shipments; it is also the maximum size which can pass fully loaded through both the Panama and Suez Canals at present. U.S. Flag cost per ton per day = $0.53. '
- 100,000 dwt.—This is roughly the average size of the largest long-distance coal shipments at present; it is also the maximum size for a number of coal ports now and in the future. U.S. Flag cost per ton per day = $0.40. *
- 150,000 dwt.—There are very few coal shipments of this size at present but it is estimated that it will be a common size on some journeys by 2000, many iron ore shipments are already of this size. U.S. Flag cost per ton per day = $0.32. *

Coal ships operate worldwide with complete mobility between trades. They can shift easily and rapidly from one dry-bulk commodity to another. Entry into and exit from the bulk- shipping business is completely unrestricted. The industry is unregulated, and the market where bulk-shipping services are bought and sold is large and well-developed. There is no significant differentiation in the provision of shipping services, and considerable price competition exists in bulk shipping. Therefore, the above costs are often quite different from actual prices of freight rates charged.

The overall trend in oceanborne coal transportation cost, as a function of ship size, is shown in figure 10. The unconstrained (op-

*Source: Maritime Administration, December 1980.

Table 7.—Dimensions of Selected Ships by Coal-Carrying Capacity

Coal-carrying capacity (dwt)	Overall length (ft)	Beam (ft)	Draft (ft)
40,000	630	105	35
60,000	760	105	40
100,000	910	116	48
150,000	980	133	56
200,000	1,020	150	62
Panama Canal limiting dimensions for transiting commercial ships	900	107	35'6"

SOURCE. Maritime Administration and Panama Canal Co.

Table 8.—Coal-Loading Facilities for Large Bulk Carriers Analyzed by Area and Capacity (number of facilities)

	Vessel classes by dwt							
Area	35,000-39,999	40,000-49,999	50,000-59,999	60,000-69,999	70,000-79,999	80,000-99,999	over 100,000	Total
United States	2	3	1	2	2	1	—	11
Canada	—	—	1	—	—	1	1	3
Australia	1	1	—	2	1	1	1	7
Poland	1	—	—	—	—	—	1	2
U.S.S.R.	1	—	—	—	—	—	—	1
South Africa	2	—	—	—	—	—	1	3
Other	—	—	1	1	—	—	—	2
Total world	7	4	3	5	3	3	4	29

SOURCE: H P Drewry (Shipping Consultants Ltd), *Ports and Terminals for Large Bulk Careers.*

Table 9.—Coal-Discharging Facilities for Large Bulk Carriers Analyzed by Area and Capacity (number of facilities)

	Vessel classes by dwt							
Area	35,000-39,999	40,000-49,999	50,000-59,999	60,000 - 69,999	70,000-79,999	80,000-99,999	over 100,000	Total
Scandinavia	—	2	–	—	—	—	—	2
EEC	2	5	7	2	7	3	3	29
Other Europe	1	1	—	—	1	1	1	5
Japan	2	6	2	2	2	2	10	26
South America	1	1	1	—	—	—	—	3
Other	2	3	1	—	—	—	—	6
Total world	8	18	11	4	10	6	14	71

SOURCE" H P Drewry (Shipping Consultants Ltd.), *Ports and Terminals for Large Bulk Carriers.*

timistic) case assumes no constraint on ship draft, i.e., that ships can be as deep as is required to minimize transportation costs. The constrained (realistic) case recognizes the realities of draft limitations in harbors.

As coal is a low-value commodity, savings in transportation costs are significant in the course of choosing between alternative sources of supply. Even though the ocean transportation cost of coal is very low when compared with that of other modes, it still adds between 20 and 35 percent to the cost of U.S. coal based on its value at the export port. Accordingly, both coal importers and exporters strive to control ocean transport costs.

Although prevailing spot-voyage freight rates are highly variable and receive considerable market attention, long-term vessel charter rates are established on the basis of full recovery of ship costs to the vessel owner. These costs include capital outlays, financing costs, etc. When operating costs (crew wages, insurance), fuel, and other costs (canal costs, port charges) are added to vessel capital costs; one obtains the

Table 10.—The World Coal Trade by Vessel Size, 1979

	Less than 40,000	40,000-59,999	60,000-79,999	80,000-99,999	100,000 & over
Exporting areas					
Eastern Europe	700/0	160/0	7 %	30/o	4%
Other Europe	62	8	15	11	4
North America	19	16	27	6	32
Australia	16	23	31	2	28
South Africa	26	7	9	5	53
Others	100	0	0	0	0
Importing areas					
United Kingdom					
Continental	30	9	20	5	36
Mediterranean	43	16	16	10	15
Other Europe	58	16	13	4	9
South America	27	33	24	1	15
Japan	24	16	23	3	34
Other	49	16	19	1	15
Totals	350/0	15%	20%	4 %	2 6 %

SOURCE: OSG Bulk Ships Inc , New York, February 1981

Table 11 .—Shipments of Dry Bulk Commodities by Bulk and Combined Carriers[a]

	1974		1976		1978		1980 est.		1981 est.	
	Volume	Percent	Volume	Percent	Volume	Percent	Volume	Percent	Volume	Percent
Millions of tons										
Iron ore	301	44.3%	276	37.8%	256	31.5%	290	31.7%	275	29.30/o
Grain	88	12.9	125	17.1	151	18.6	165	18.0	170	18.1
Other	200	29.4	227	31.1	300	36.9	305	33.3	320	34.0
Subtotal	589	86.6	628	86.0	707	87.0	760	83.0	765	81.4
Coal	91	13.4	102	14.0	105	13.0	155	17.0	175	18.6
Total	680		730		812		915		940	
Billions of ton-miles										
Iron ore	1,483	42.8	1,389	37.6	1,284	31.4	1,460	30.7	1,400	28.3
Grain	529	15.2	696	18.8	865	21.1	1,010	21.2	1,070	21.7
Other	956	27.6	1,076	29.1	1,446	35.4	1,475	31.1	1.550	31.4
Subtotal	2,968	85.6	3,161	85.5	3,595	87.9	3,945	83.0	4,020	81.4
Coal	501	14.4	538	14.5	494	12.1	810	17.0	920	18.6
Total	3,469		3,699		4,089		4,755		4,940	

[a]Only includes shipments on vessels greater than 18,000 dwt. Capacity of the fleet between 10,000 and 18,000 totaled about 115 *million dwt In 1980.*

SOURCE OSG Bulk Ships, Inc , New York, February 1981.

total cost of ocean shipping. These long-term "equilibrium" costs, for various voyages and two ship sizes, are shown on table 13.

The economies of scale that are achievable with larger ships have become more important in affecting the future size distribution of the world shipping fleet because of the growth in trade between distant ports. The ocean transportation cost component is a significant portion of the total delivered cost of the coal in the trade between Europe and the United States and even greater when the exports are from Australia. The increasing cost of petroleum bunker fuel also makes shipping economies more important.

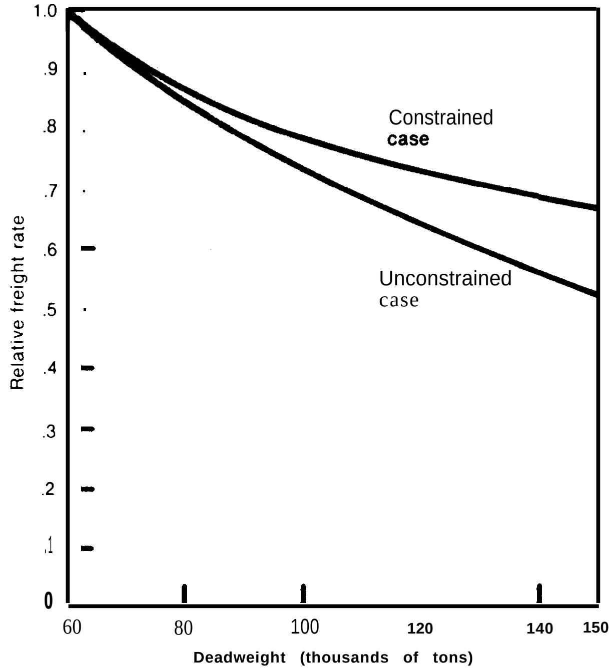
The increases in ship size would not have been practical without parallel development of port facilities capable of handling large vessels. The limits on ship size at U.S. ports, are about *80,000* dwt at Hampton Roads; smaller limits prevail elsewhere. Coal-loading facilities for ships of 100,000 dwt and over are located in Western Canada, Australia, and South Africa. Discharging terminals accessible to carriers in

Table 12.—The Existing Fleet and Tonnage on Order by Size Class (millions of dwt)

Size classes in dwt	Existing 1/81	On order 1/81	On order as percent of existing
Bulk carriers:			
10,000-39,999	**76.0**	**6.3**	**8.30/0**
40,000-59,999	**24.7**	**3.4**	**13.8**
60,000-79,999	**19.5**	**6.5**	**33.3**
80,000-99,999	**3.0**	**0.5**	**16.7**
100,000 & over	18.2	9.2	50.5
Total	141.4	26.0	18.40/0
Combination *carriers:*			
10,000 -59,999	1.8	0.2	11.1 0/0
60,000-79,999	5.2	1.1	21.2
80,000-99,999	4.8	0.3	6.3
100,000 & over	35.8	1.4	3.9
Total	47.6	3.1	6.5%

SOURCE OSG Bulk Ships, Inc , New York, February 1981

Figure 10.— Economies of Scale in Seaborne Coal Trade



SOURCES: lRan Hettena, In *Critical Issues in Coal Transportation Sysftems, 1979*

H Mellanby Lee, The Long Run Economics of the Ocean Transport of Coal, December 1978

Table 13.—Coal Shipping Costs for Round Trips From Selected U.S. Ports (assumes no demurrage charges)[a]

Coal loading port	Coal discharge port	Cost per tonne 60,000 dwt	Cost per tonne 110,000 dwt
Hampton Roads, Va.	Rotterdam, Netherlands	13.49	10.15
	Taranto, Italy	16.15	11.96
	Yokohama, Japan	31 .95[b]	34.57[c]
Mobile, Ala..	Rotterdam, Netherlands	16.70	12.32
	Taranto, Italy	19.36	14.13
	Yokohama, Japan	30.79[b]	35.35[c]
Portland, Oreg..	Yokahama, Japan	15.39	11.43

aThe above table of equilibrium coal shipping costs does not include the effect of demurrage (delay) charges As of this writing (February 1981), large numbers of ships are waiting to load coal at the U.S. east coast ports of Hampton Roads and Baltimore The delays associated with this average $600 per ton which is added to the cost of shipping U.S. coal overseas

[b]vla Panama Canal.

[c]via Strait of Magellan (South America)

SOURCE. ICF, Inc., October 1980

excess of 100,000 dwt exist in Western Europe and Japan, and more are planned.

Important constraints on ship size are imposed by the Panama Canal and, to a far lesser extent, by the Suez Canal. The draft and beam restrictions of the Panama Canal limit passage to ships of up to about 50,000- to 80,000 dwt; for this reason, ships in this dwt-range are commonly referred to as “Panamax” vessels. There are no plans at present for enlarging the Panama Canal.

Ships that are too large to pass through the canals must use the longer routes around the southern capes of South America and South Africa. Because of the greater voyage costs thereby incurred, it may be cheaper on particular routes to use a smaller vessel that can pass through the canal, in spite of the higher daily cost per tonne transported (including “canal dues” of about $2/tonne).

The expected growth in coal movements and achievable economies of scale will make large ships more common. It is expected that the number of ships exceeding 100,000 dwt will increase substantially, leaving a smaller portion of the coal fleet at 50,000 to 80,000 dwt for primary transit through the Panama Canal.

PROPOSED NEW TERMINAL AND SHIPPING SYSTEMS

Several types of new systems have been proposed for moving coal. Foremost are high-capacity terminals, slurry pipelines, and midstream transfer. Other proposals such as pneumatic-tubes, conveyor belts, barge-carrying ships, and shallow draft ships have received some attention as well.

In the long run, economics and large volume exports may force the introduction of new technologies to transport coal for export. Expansion of existing facilities and transportation networks will not always be the most effective approach. If new mines for export are developed in the West, it may make sense to develop a total system for mine to-terminal-to-ship transportation. If large volume, long-term export contracts are negotiated in the East, and harbors are not dredged, it may make sense to develop an offshore, deep-water, coal-loading terminal. The technologies to transport coal for export with dedicated systems outside of existing networks can be available without excessive development. While most of the efforts to develop new systems are in the private sector, certain Federal actions could help or hinder development—e.g., if some harbors are not dredged, alternative systems for offshore loading could be more attractive. However, one should consider these alternatives with caution because most are not short-term options, the technologies are not yet in place and foreign buyers, shippers, and terminals will need to agree and adapt to any major changes.

High-Capacity Terminals

To a large extent, high-capacity export terminals are being developed because of the increased demand for steam coal. The new terminals typically occupy 100 acres or more, and ideally up to *600* acres. This allows for the arrangement of a series of open-storage stacking areas, and the use of stacker/reclaimer mechanical equipment.

Almost all new proposals for developing high-capacity export terminals involve the use of stacker/reclaimers. Historically, coal export terminals were designed to service up to 200 different blends of high-grade metallurgical coal. Consequently, the coal is stored in railcars until blended and loaded. Steam coal does not require as much care in loading and ideally is ground-stored, allowing for the use of high-speed equipment.

Beyond these recognitions, the most concrete way of defining a high-capacity terminal is by way of the example offered by McDuffie Terminal in Mobile, Ala. Designed in the early *1970's*, McDuffie became operational in 1975, and incorporated the newest and most innovative approaches available to material handling, automatic barge unloading, and unit train movement. A three-phase design concept was developed. Phase I is entirely developed. Phase II is more than 75-percent complete. Phase III will be finalized by 1983-84.

Coal arrives by both barge and railroad at the terminal. Barges are unloaded by a high-capacity ladder-type bucket elevator unloader capable of moving 1,500 tonne/ hr. The bucket elevator remains stationary while the barge is moved back and forth beneath it to allow the unloader to remove coal and place it on the conveyor system. From here the coal can be stored in large piles, known as open storage, or go directly to a waiting vessel.

The same conveyor system serves the rotary car dumper for unloading rail cars rapidly. Standard coupled cars are unloaded at a rate of 25 cars/hr. It is projected that swivel coupled cars in unit train lots can be unloaded at 30 cars/ hr.

Once the coal is unloaded from barges or railcars, it can be loaded directly onto a ship or put into stacking yards for later loading. The mechanism used to take the coal from the conveyor system, or return it to the conveyor system from the storage piles is known as a “stacker/reclaimer ,“ The stacker/reclaimer is an enormous piece of mechanical equipment capable of moving up to 4,000 tonne/hr of coal. It is equipped with one long outreach boom, usually measuring more than 150 ft, numerous internal conveyor systems, operator cabin, etc. The stacker-reclaimer is the heart of the new high-capacity coal-handling terminals. Two stacker/ reclaimers are currently located at McDuffie, and a third is scheduled for delivery once the third phase of development is underway.

Coal Slurry Systems

Thus far, no coal slurry system is in operation designed to move coal for export. The only operational line in the United States, the Black Mesa line serving Las Vegas, has been used successfully since *1970*. It carries more than 5.5 mmt/yr through some *270* miles of 18-inch pipe serving the Southern California Edison Co. Proponents of the slurry systems cite the Black Mesa line as proof that larger and more lengthy systems can be replicated. Opponents of the systems maintain that until a more substantial effort is constructed, the successful implementation of slurry pipelines must remain in question.

A number of companies specializing in pipeline technology have developed complete engineering design plans for exporting coal. Recently, a project manager with Wheelabrator-Frye described the mechanics and economies of an offshore export buoy. [a]

The coal slurry export terminal would operate something like the deepwater crude oil import systems, only in reverse. Proponents suggest slurry export terminals as a rapid means for short-circuiting the port bottleneck, claiming them to require no piers or deep-draft harbors, and to be environmentally acceptable.

The basic concept requires either a slurry pipeline from the mine or a slurry terminal several miles inland with adequate rail and/or barge connection. The terminal would be similar to any other open-storage coal stacking yard such as at Mobile, or Superior, Wis.

The coal would be ground into the slurry mixture and piped to an offshore, single point, mooring buoy, for loading vessels up to 200,000 dwt.

Two types of system movements are contemplated:

- slurry load—slurry unload, and
- slurry load—dry (conventional) unload.

The need to consider the dry unload capability is obvious. Without a slurry unload system on the receiving end, the coal would have to be unloaded using conventional techniques. One major obstacle in implementing the slurry export process is, in the event of a dry unload requirement, the coal must not be more than 12 percent liquid content. Thus, once the coal is delivered to the vessel in slurry form it must be

‘American Association of Port Authorities, “Coal and Ports Symposium, ” Feb. 16-19, 1981, Mobile, Ala.

dried to 12 percent to avoid damage to the dry unload equipment and procedures.

This problem has not been solved completely according to the official of Wheelabrator-Frye. However, if a slurry unload system were developed somewhere in Northern Europe, only 27 to 36 months would be needed for construction of the terminal in the United States. Favorable sites have been identified in Alabama and North Carolina.

Several major domestic coal slurry pipelines are under consideration. They are being designed primarily to serve domestic utility and manufacturing consumption. In addition, the slurry design engineers are quick to point out that little extra effort is required to extend the pipelines to offshore buoys.

Studies have been conducted of the use of coal slurry pipelines both to transport coal from the mines to the port and from the port to a collier anchored at an offshore terminal. While experience is being gained in the West for transporting coal by means of a slurry pipeline from a mine to a powerplant, it is not clear whether wide-scale use is practical over longer distances for long periods of time. Water requirements are a major factor. Saltwater cannot be used in coal slurry operations because of absorption of the salts into the coal. Consequently, nonsalty water must be used and recycled through the system, including shore-to-ship and ship-to-shore. In some locations, competing use for the available freshwater will hinder the development of slurry pipelines for coal export.

The issue of eminent domain continues to plague the slurry advocates. In order to transfer coal by slurry from interior points, the slurry lines must cross or run parallel to property owned by railroad companies, the slurry lines' major competitors. Thus far, the railroad lobby groups have been able to block attempts to grant permission to slurry interests to cross railroad property. Unless the right of eminent domain is granted, it is unlikely that interior slurry lines will be constructed. This is why the proposals for exporting coal by slurry rely on rail and/or barge for delivery to the slurry plant.

Midstream Transfer

Though not commonly utilized, several existing instances of direct barge-to-ship, or "midstream" transfer can be identified. At the Port of New Orleans, coal-handling stevedoring firms are providing midstream transfer by placing a grab-bucket crane-barge between an ocean-going vessel and a coal barge, and simply moving coal from barge to vessel.

An improved version of this concept is scheduled to be implemented in the Great Lakes this spring. Canadian steamship owners and operators have indicated that they intend to use self-unloading dry-bulk colliers to ship coal from the Great Lakes, through the St. Lawrence Seaway lock system, to the deep-draft port of Quebec City on the St. Lawrence River. The self-unloaders would then transfer coal to larger, ocean-going vessels for the international journey. The midstream transfer is less costly than double handling at a transshipping port site.

Port officials at New Orleans cite that very large tonnages could be loaded by midstream transfer techniques and several companies have stated they intend to pursue this approach.

There are very few technical and/or equipment limitations to this approach, and appears more and more to be a highly acceptable formula which can be immediately implemented. The one major obstacle to this approach is guaranteeing that a sufficient number of coal-carrying barges are in place to meet foreign steamship vessels when they arrive. But this should not present extreme difficulties. Of course, it would be necessary to provide a deep-draft sheltered area to load very large colliers.

Pneumatic Pipelines

Pneumatic transport is no a new concept. It has been used commercially for the movement of ores and other materials Basically, it is a pressurized pipeline into which coal is fed and conveyed in a suspended state by compressed air. There are a number of advantages to this mode. Among them are ease of automation, no need for water, and flexibility.

Air is used as the carrier and is thoroughly cleaned before vending. Unlike coal slurry lines, it is easily started after stopping, avoids the expense and disposal problems of dewatering, avoids the cost expenditure of crushing coal to a fine powder, and does not present the same problems as slurry lines in the event of line breaks.

The most immediate application appears to be as an adjunct to rail or barge transport. In this role a pneumatic pipeline may operate as a loader/unloader and gathering/feeder systems. It could possibly compete with short-haul unit trains, conveyor belts, and truck transport.

Pneumatic pipelines have not been used for coal transport and the most recent uses have been for much different products over short distances. This system will require testing before a determination of economic or technical feasibility.

Conveyor Belts

Conveyor belts are an old, established method for the movement of bulk materials. Most applications are short-distance oriented such as may be seen at coal mines or handling terminals. Yet, long-haul movements of coal in enclosed conveyor belt systems are entirely feasible.

Conveyor systems, like slurry lines and pneumatic lines, are capital-intensive, requiring little staffing with respect to distance. Costs decrease with both distance and throughput. However, previous research has indicated that system economics are best where throughput is neither variable nor intermittent.

As an operation, belts are relatively noisy and can create spillage and dusting problems. Belt width can minimize spillage, and a covered system reduces both noise and dust.

For practical purposes, the system should be above ground. But this creates land-use and right-of-way problems. Also, ambient temperatures affect the operation and may limit usefulness in areas of extreme cold or heat.

Once in place, the conveyor belt is not very flexible. Like pipeline operations, failure at any point can jeopardize the entire system.

Extra Wide-Beam Ships

A design for ships of wider beam hull forms has been considered for coal carriers for restricted draft service. For draft restrictions characteristic of U.S. ports, about 30 to 50 percent increase in deadweight tonnage can be obtained by accepting reasonable departures from conventional ship proportions. Transport costs are significantly reduced by using ships of greater capacity. However, the construction costs for wider, shallow-draft ships would be higher than for conventional ships for a given tonnage. A modification to loading facilities may also be required to accommodate the increased beam of the shallow-draft collier,

Navigation in shallow water will be different for the wide-beam ship, manueverability characteristics in restricted waters will probably be significantly different and may require more channel width than normal ships. However, if found suitable for bulk cargo transport from restricted channel depths of U.S. ports, these ships may provide important side benefits. They, as a class, could be useful for noncoal bulk cargo shipments from many ports. They have not thus far been mass produced in foreign shipyards; and *if* constructed using advanced technology, U.S. shipyards could possibly build them competitively for the international trade.

Barge Carrying Ships

Barge carrying ships also present an alternative to deepening shipping channels and may be particularly pertinent to coal users who are located on the inland water routes of Europe. The concept is an extention of present barge carrying ships used in the general cargo trade. Coal barges would be towed a deep part of the harbor for loading aboard oversized ships,

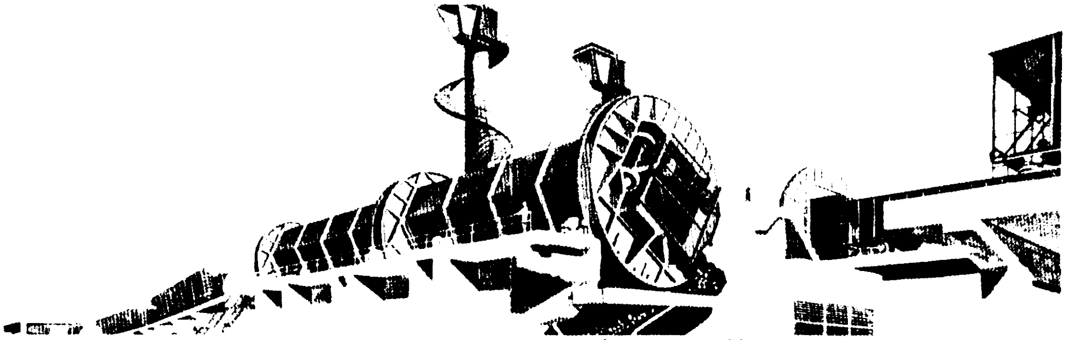
In one design, the barge size visualized for these systems is the standard 1,500-tonne Mississippi barge—195 ft long, 35 ft wide, and 12 ft deep with a draft of 9 ft. Up to 80 of these would be loaded onto five decks of the carrier ship which is estimated to be approximately 1,257 ft in length, 213 ft in beam, and *38.7* ft in draft.

The barges would be offloaded at the ship's destination and then towed to a location nearest the coal user plant. While an outer part of the United States and destination ports would have to be dredged deep enough to accommodate the barge loading and unloading operations, dredging might be minimized.

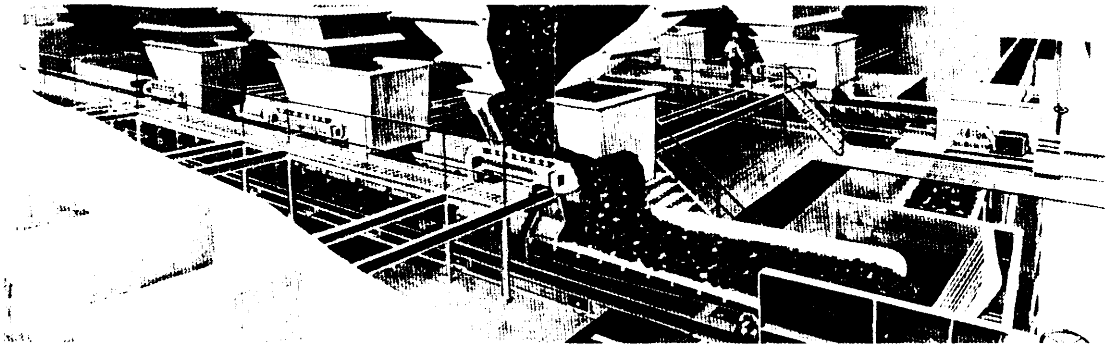
There are inefficiencies associated with this concept that must be considered in practice. There are nonpayload void spaces between barges and between decks. In addition, the added weight of the barge structure must be transported, and demurrage costs of at least one extra set of barges per ship would be involved.

However, the system could be used for other bulk cargoes and U.S. shipyards might participate in both ship and barge construction.

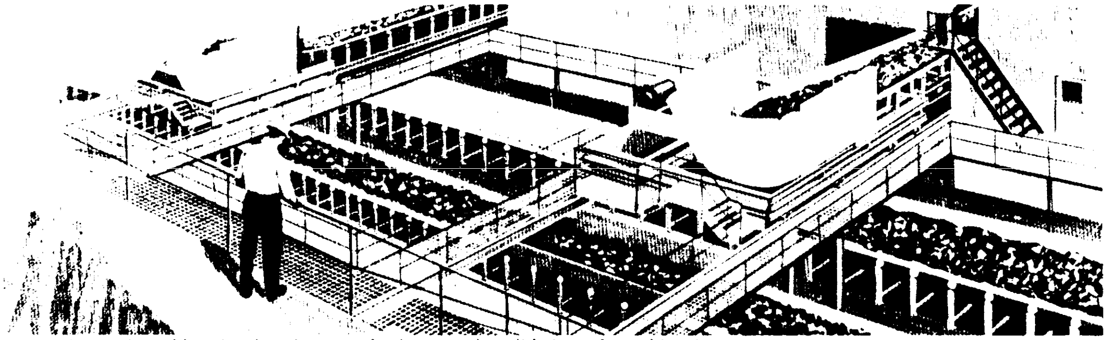
Schematic of the Norfolk& Western System, Norfolk, Va.



Rotary dumpers at Custom Blending Station empty four coal cars into transfer bins.



Coal, regulated by feeder mechanism, is placed on variable-speed shuttle conveyors.

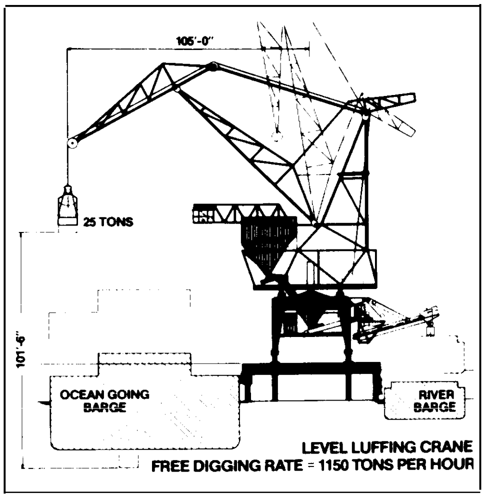


Blended coal is mixed at the transfer house when it is transferred to pier conveyors.

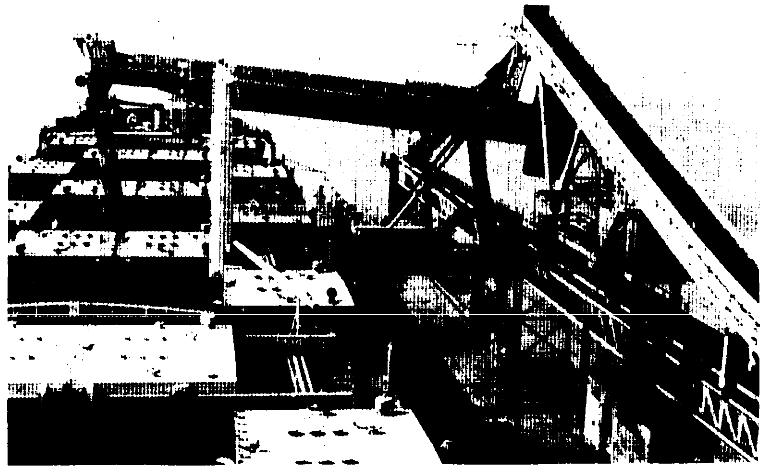
Coal is mixed for a third time at the loading towers, and is deposited aboard ship.

SOURCE Norfolk & Western Railway

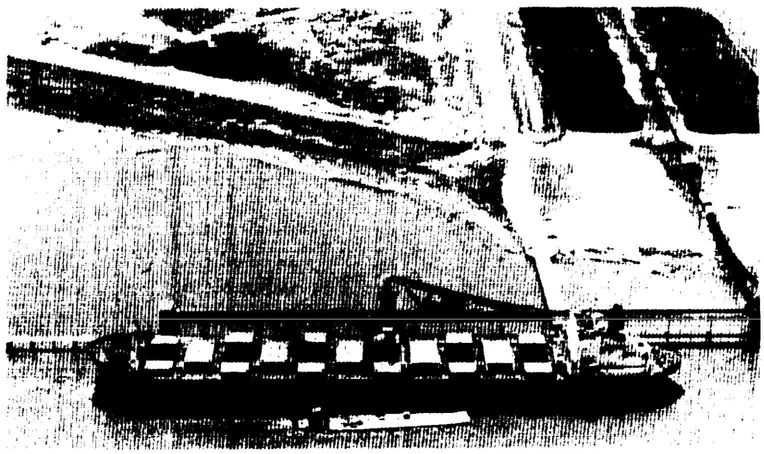
Mobile, Ala.



Schematic of level luffing crane



7,000 tonne/hr t raveling ship loader



75,000 dwt bulk carrier

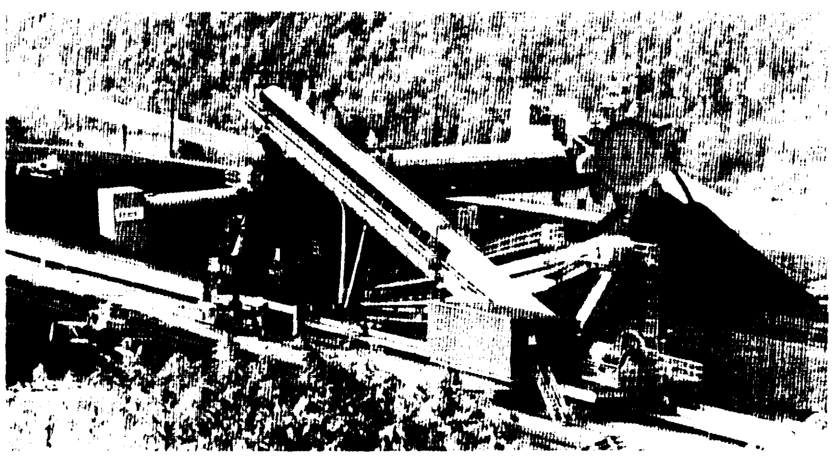
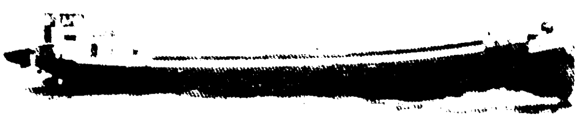


Photo Credits" Dravo Corp.

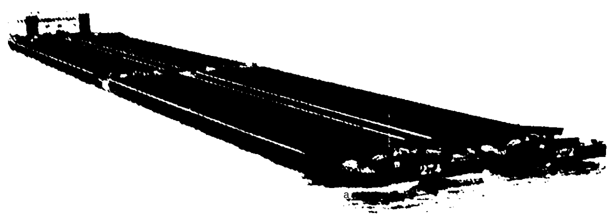
High capacity stacker/eclaimer system

Rotterdam, Netherlands

Aerial view of Ekom Terminal, Rotterdam, Netherlands



Typical Rhine River self-propelled barge



Four-barge unit push tow

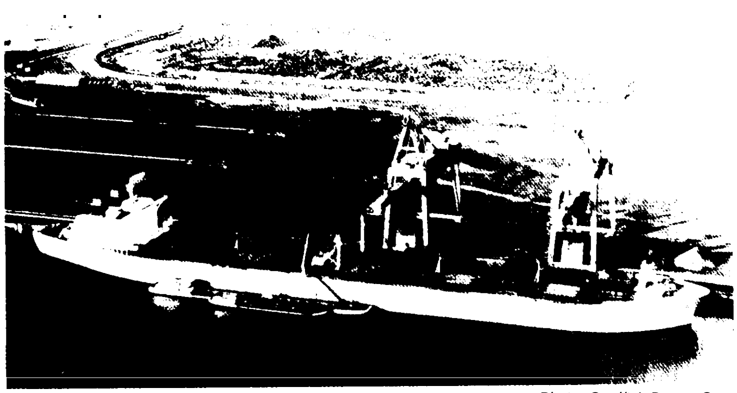
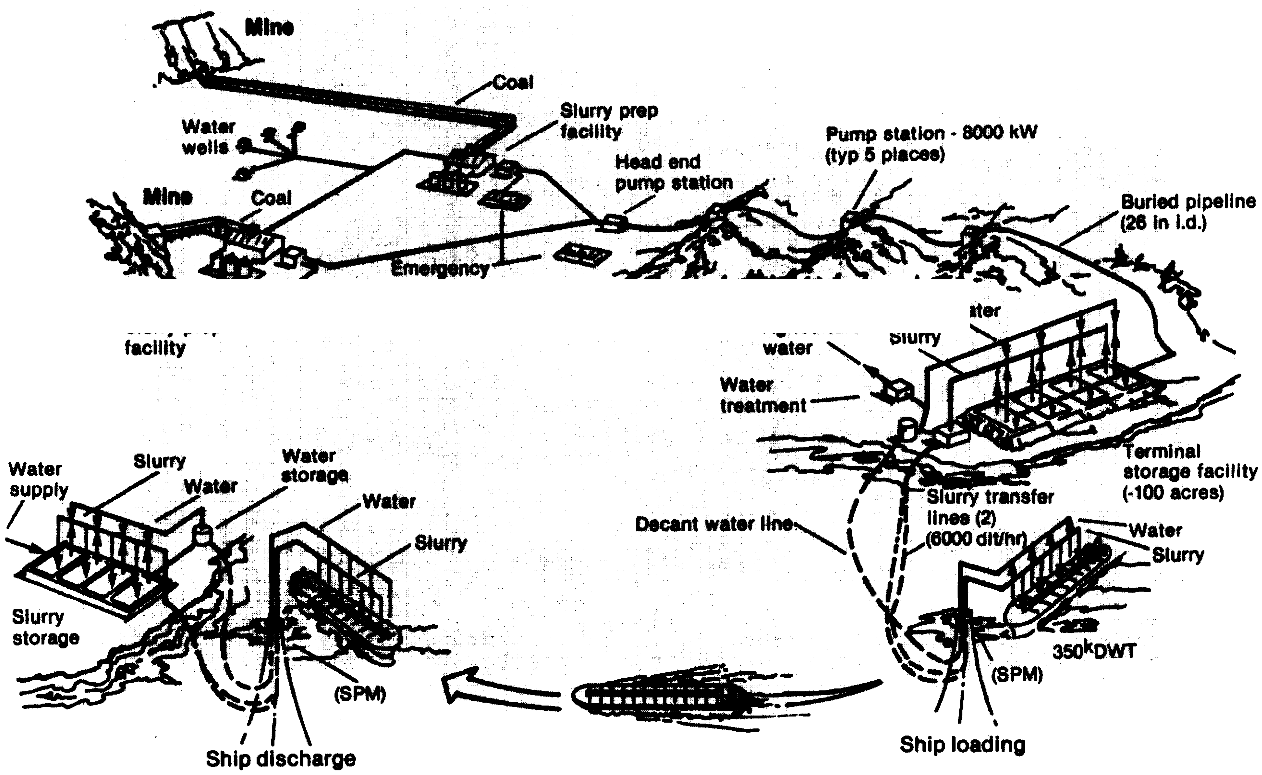


Photo Cred/ts' Dravo Corp

Unloading terminal for super-colliers at Rotterdam

Proposed Coal Slurry System From Utah to Oxnard, Calif.



SOURCE Boeing Co