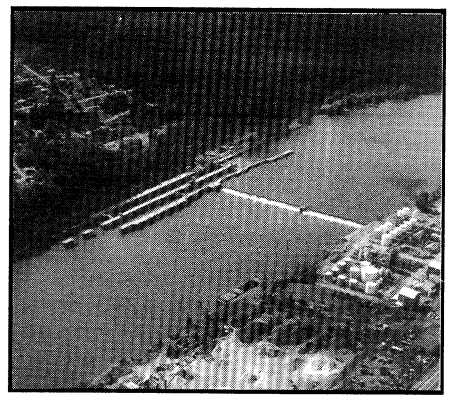
US Army Corps of Engineers
Pittsburgh District

Lower Monongahela River Navigation System Feasibility Study

Interim Report



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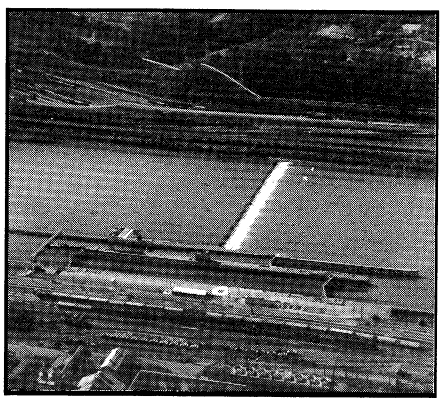

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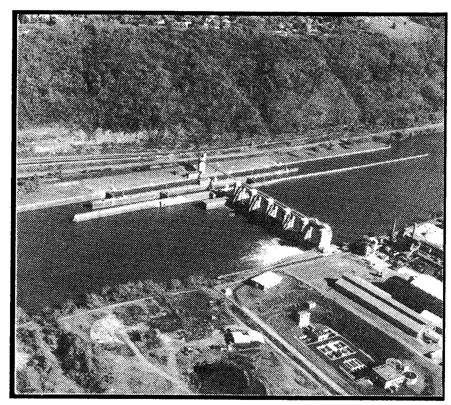

Locks and Dam 4

Volume 3 of 6

Study Area Resources and Economy,
Plan Formulation, and Structural Condition Appendices

FINAL
December 1991

LOWER MONONGAHELA RIVER
NAVIGATION SYSTEM STUDY

FEASIBILITY REPORT

VOLUME 3

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STUDY AREA RESOURCES AND ECONOMY

U.S. Army Engineering District, Pittsburgh
Corps of Engineers
Pittsburgh, Pennsylvania

LOWER MONONGAHELA RIVER NAVIGATION STUDY
STUDY AREA RESOURCES AND ECONOMY

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SECTION 1. INTRODUCTION

1. PURPOSE AND SCOPE

This appendix was prepared by the Special Studies Branch, Planning Division, Pittsburgh District of the U.S. Army Corps of Engineers. Its purpose is to define and describe the geographic area that is affected by the navigation projects on the Lower Monongahela River in terms of general economic and social characteristics, with special emphasis on the economic sectors affected by the navigation system. The description includes a discussion on the the development of the area, its present condition, and projections for the future. It is intended to provide the setting for understanding the importance of the navigation system to the development of the region and the county.

2. REPORT ORGANIZATION

The remainder of the appendix is organized into six topical section. Section 2 describes the study area in terms of geography, topography, and climate. Section 3 provides data on the natural resources of the area, with particular emphasis on coal. Section 4 describes the human resources of the study area. Section 5 describes the economy of the study area in terms of sectoral employment and income, including recent and projected changes. Section 6 differentiates the study area between the urban and industrial portion near Pittsburgh and the rural and mining portion along the headwaters of the Monongahela River. Section 7 summarizes the outlook for the area in light of recent and future events.

SECTION 2. PRIMARY STUDY AREA

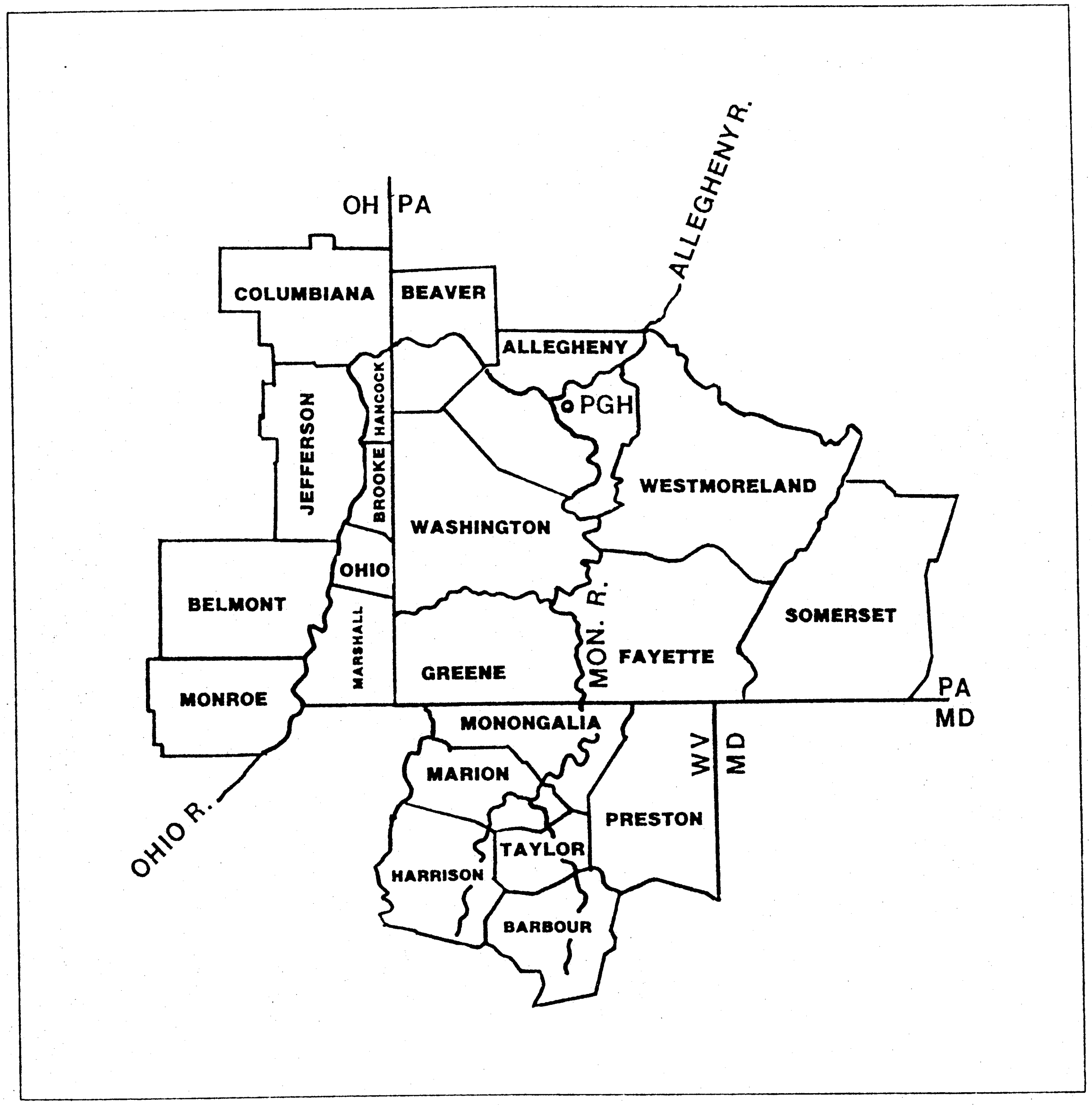
1. GENERAL

The navigation projects under study are all located on the lower 42 miles of the Monongahela River, just upstream of the city of Pittsburgh. However, the area affected by the projects extends beyond this area. In order to define the affected economic area, an evaluation was made of the origins and destinations of the traffic that pass through the projects. The result was a study area defined as the area adjacent to the Monongahela River from its source in West Virginia to its terminus at Pittsburgh and along the Ohio River from Pittsburgh to Wheeling, WV. Over 75 percent of Lower Monongahela River traffic moves entirely within this area. The area encompasses portions of three states: southwestern Pennsylvania, northern West Virginia, and eastern Ohio. The focal point is the city of Pittsburgh, but the study area includes numerous industrial and mining communities south of the city on both the Monongahela and Ohio Rivers. Table 1 lists the counties included in the study area and Figure 1 is a map of the area.

TABLE 1
COUNTIES IN STUDY AREA

Pennsylvania	Sq.Mi.	Ohio	Sq.Mi.	West Va.	Sq.Mi.
Allegheny	727	Belmont	537	*Barbour	343
Beaver	436	Columbiana	534	Brooke	90
*Fayette	749	Jefferson	410	Hancock	84
*Greene	577	Monroe	457	*Harrison	417
*Somerset	1073			*Marion	312
Washington	858			Marshall	305
Westmoreland	1033			*Monongalia	363
				Ohio	106
				*Preston	651
				*Taylor	174
Subtotal	5498		1938		2845
% of U.S.	0.16		0.05		0.08

* Denotes the counties that are in the Upper Monongahela portion of the study area. All others are in the Lower Monongahela portion.



LOWER MONONGAHELA RIVER NAVIGATION STUDY
STUDY AREA MAP

2. PHYSICAL DESCRIPTION

The study area includes lands adjacent to both the Monongahela and Ohio Rivers. The Monongahela River extends from Fairmont, West Virginia to Pittsburgh, Pennsylvania where it joins with the Allegheny River to form the Ohio River. It drains an area of 7,386 square miles and falls a total of 147 feet in its 128.7 mile length, or about one foot per mile. The Ohio River flows southwesterly from Pittsburgh to Paducah, Kentucky where it joins with the Mississippi River. It drains an area of 204,000 square miles and falls a total of 420 feet in its 981 mile length, or about one-half foot per mile. Only the upper 125 miles of the Ohio River are within the study area.

The topography of the study area is rough, and many areas are sloped at varying degrees of steepness. It is located in the Kanawha section of the Appalachian Plateau, an area characterized by a gently rolling upland, deep and narrow valleys, and steeply rising slopes. The local relief is 200 to 300 feet along minor tributary streams and 400 to 500 feet along the major streams. The maximum relief within the drainage basin is 4,000 feet.

The climate of the area is continental, with marked contrasts in temperature and moisture. Average annual temperature is about 54 degrees, with warm and humid summers and relatively cold winters. Mean minimum temperatures of 23.7 degrees occur in January and mean maximum temperatures of 84.0 degrees occur in July. Precipitation is well distributed throughout the year ranging from 2.29 inches in February to 3.78 inches in July. Total precipitation for the year averages 36.2 inches. Snow lies on the ground in the suburbs of Pittsburgh for an average of about 33 days during the year.

SECTION 3. NATURAL RESOURCES

1. GENERAL

The study area's major natural resources include limestone, sand and gravel, and timber. While these and other resources are all vital to the economy of the area, coal and water dwarf all others in importance. Water is important not only to satisfy the needs of residential and industrial consumers, but also as a means of low cost transportation. In conjunction with the area's abundant supplies of coal, large and dependable water supplies are among the most important reasons for the economic development of the area. Water is an especially critical input into the electric generating and steel making processes.

Coal is both produced and consumed in large quantities in the area. The extensive steel complex in the area developed partially because of the availability of metallurgical coking coal nearby. At the time these mills were established, coal was the single most important raw material in the manufacture of steel. Most of the large electric generating stations in the area are also designed to burn coal, again because of its local availability. Because of the importance of coal to the area in general and the navigation system in particular, the coal resources of the area are described in greater detail in the following paragraphs.

2. COAL RESERVES

Despite the fact that coal has been mined in the area for over 150 years, the area still contains significant reserves of coal. The demonstrated reserve base is 22.8 billion tons or 5 percent of the U.S. total (Table 2). Probable reserves are 49 billion tons, or over twice the demonstrated reserves. This is sufficient to continue producing coal at the current rate for the next 1000 years. The study area is not in imminent danger of depleting its coal reserves.

TABLE 2
COAL RESOURCES
(Millions of Tons)

County	Identified Coal Resources	Demonstrated Reserve Base
Allegheny	1,300	902
Fayette	5,200	1,077
Green	8,600	6,599
Somerset	5,400	1,297
Washington	8,600	3,649
Westmoreland	4,500	765
PA Subtotal	33,600	14,289
Garrett	730	634
MD Subtotal	730	634
Barbour	2,966	1,076
Harrison	1,661	444
Marion	3,414	2,713
Monongalia	3,701	3,148
Preston	2,234	148
Taylor	875	412
WV Subtotal	14,851	7,941
Total:	49,181	22,864
U.S.	------	436,685

3. COAL PRODUCTION

Coal production in the study area has averaged about 60 million tons per year over the past dozen years (Table 3). This represents 6 percent of total U.S. production, a percentage consistent with the study area's share of national reserves.

TABLE 3
COAL PRODUCTION
(Million Tons)

County	1975	1980	1985	1987
Allegheny	3,937	3,208	1,416	1,028
Washington	13,361	10,221	7,214	6,159
Greene	8,055	9,539	10,440	13,451
Westmoreland	2,846	1,304	671	516
Fatette	2,816	2,544	492	208
Somerset	6,024	7,061	4,003	4,803
PA Subtotal:	37,039	33,877	24,236	26,165
Monongalia	11,070	12,766	15,383	17,664
Preston	2,558	2,807	3,209	4,181
Marion	5,514	5,408	5,821	5,907
Harrison	4,451	3,453	3,586	3,669
Taylor	171	62	20	45
Barbour	3,672	3,517	1,955	1,253
WV Subtotal:	27,436	28,013	29,974	32,719
Study Area Total:	64,475	61,890	54,210	58,884
U.S. Total	648,438	825,673	883,638	918,762

Because of the topography of the region, most of the area's coal is mined using underground techniques. Generally speaking, underground mining is more difficult and less productive than surface mining, particularly when compared to the large surface mines found out West. Despite this, production from area mines is significant, as indicated by the fact that 13 of the ninety largest mines in the country are in the study area (Table 4). Moreover, the largest mine east of the Mississippi and the largest underground mine in the country is the Baily mine, located in Greene County, Pennsylvania of the study area.

Table 4
LARGE MINES IN STUDY AREA
(Millions of Tons; 1989)

Rank	Mine	Company	County	State	Production
21	Baily	Consol	Greene	Pa	6.0
40	Federal No 2	Eastern	Monongalia	WV	3.7
41	Blacksville No 2	Consol	Monongalia	WV	3.5
45	Humphrey	Consol	Monongalia	WV	3.4
49	No 50 Mine	U.S.Steel	Wyoming	WV	3.1
57	Loveridge	Consol	Marion	WV	2.8
62	Shoemaker	Consol	Marshall	WV	2.7
65	Cumberland	U.S.Steel	Greene	PA	2.5
72	Dilworth	Consol	Greene	PA	2.4
73	McElroy	McElroy	Marshall	WV	2.3
76	Martinka	South Ohio	Marion	WV	2.3
80	Robinson Run	Consol	Harrison	WV	2.1
83	Maple Creek	U.S.Steel	Washington	PA	2.1

Source: "Facts about Coal, 1990", National Coal Association.

4. COAL CHARACTERISTICS

Coal is most commonly classified according to BTU (heat), ash, and sulphur content. Generally, the higher the BTU content and the lower the ash and sulphur content, the more desirable is the coal since less has to be burned to produce energy (high BTU) and there are fewer byproducts (ash) to dispose of than with less desirable coal. Sulphur content is important because the emission of sulphur into the atmosphere is thought to cause, or at least contribute to, acid rain. Therefore, the lower the sulphur content, the lower the amount of air pollution or, alternatively, the lower the amount of funds needed to control sulphuric emissions. Coal in the study area is generally classified as high BTU, medium ash, and medium sulphur (Table 5) which places it in the middle in terms of desirability. Study area coal is also high in volatility, which makes it especially valuable in coking operations. High vol coal shrinks in the coking ovens, keeping the walls of the ovens from splitting. It is usually blended with coal out of southern West Virginia to produce the optimum mix needed in coking operations.

TABLE 5
COAL RESERVES BY SULPHUR CONTENT
(Millions of Tons)

	Sulphur Content				
County	(0.4-1.0)	(1.1-3.0)	> 3.0	Unknown	Total
Allegheny	29	416	2	455	902
Fayette	20	867	173	17	1,077
Green	45	4,716	826	1,012	6,599
Somerset	62	1,171	61	4	1,298
Washington	145	2,710	550	245	3,650
Westmoreland	35	668	39	23	765
PA Subtotal:	336	10,548	1,651	1,756	14,291
Barbour	0	400	90	586	1,076
Harrison	0	225	219	0	444
Marion	107	1,500	1,036	70	2,713
Monongalia	65	2,375	708	0	3,148
Preston	0	91	55	1	147
Taylor	0	250	162	0	412
WV Subtotal:	172	4,841	2,270	657	7,940
Total:	508	15,389	3,921	2,413	22,231
Percent:	2.3%	69.2%	17.6%	10.9%	
United States					
Appalachia	32,856	54,902	72,183	29,696	189,638
Midwest	6,510	14,570	18,148	8,814	48,041
West	160,815	23,525	2,340	12,325	199,006
Total:	200,181	92,997	92,671	50,835	436,685
Percent:	46%	21%	21%	12%	

5. COAL MARKETS

The principal market for both study area and national coal is the electric generating industry. Coal is burned in power plants to convert water into steam, which in turn propels a turbine to produce electricity. The consumption of electricity has consistantly outpaced the growth in GNP. An increasing portion of electricity production is provided by coal-fired power plants.

The other major markets for study area coal are the steel industry and exports. The steel industry converts coal into coke, which is in turn used is used in the production of iron. The iron is subsequently to make steel. Coal that is exported is used by both foreign power plants to produce electricity and steel companies to produce coke.

Given the abundant reserves of coal in the country, the market to sell coal is very competitive. While the characteristics of the coal in terms of BTU, ash, and sulphur content are important, they are only three of a large number of factors that affect the marketability of coal. Most important among these other factors is the delivered price of coal, which is the summation of its production cost and its transportation cost. Lignite, which is a low-grade coal found primarily in the Texas area, has grown in use because its low delivered price to the Texas utilities more than compensates for it low BTU content (about half the national average). Likewise, coal in the Monongahela area has a certain market niche defined by its delivered price and characteristics. The market has shrunk recently because of the more stringent limitations on sulphuric emissions that has made it more economic to meet these levels by switching to low-sulphur coal rather than installing costly desulphurization equipment required when burning medium to high sulphur coal. In the long term, all plants are effectively required to install desulphurization equipment regardless of the sulphur content of the coal they burn so that the market for study area coal is likely to expand back into areas where it is competitive on a delivered price basis.

SECTION 4. HUMAN RESOURCES

1. POPULATION

The population of the study area in 1986 was 2.6 million, representing an overall population density of 254 persons per square mile. Over 80 percent of the population resides in the Pittsburgh area, with the remainder residing in the numerous small to medium sized communities located throughout the region. To a large extent even the well being of these smaller communities is linked to the economy of the Pittsburgh area.

The population of the study area declined by 7 percent between 1969 and 1986 (Table 6) while the population of the U.S. increased by 20 percent over the same period. The study area is a mature area that experienced its most rapid growth around the turn of the century when steel and other industries were established in the area. Up through the early 1980's the economy was basically in a steady state condition based on manufacturing that experienced alternating periods of minor growth or decline but with little long-term growth. This changed in the early 1980's with the rationalization of the steel industry that resulted in the closure of many area plants. Despite this, the area survived with the medical and educational sectors providing the underpinnings of the economy that were previously provided by steel and other industries. The long-term projections are for a continuation of the steady-state condition of the area. Projections indicate the area will not only lag the nation in population growth but also experience a modest decline.

TABLE 6
POPULATION BY COUNTY
HISTORIC AND PROJECTED

Area/County	Historic 1969	Historic 1983	Historic 1986	Projected 2000	Projected 2035
Lower Mon:					
Belmont	80,500	81,200	77,000	80,445	85,548
Columbiana	108,100	112,000	104,400	115,232	120,156
Jefferson	96,400	88,600	83,700	84,627	85,728
Monroe	15,700	17,100	15,800	18,575	19,263
Allegheny	1,606,600	1,429,000	1,371,300	1,387,650	1,412,901
Beaver	208,200	201,900	191,900	200,117	207,983
Washington	211,400	217,100	211,500	218,612	225,636
Westmoreland	374,600	391,800	380,200	395,734	407,882
Brooke	29,000	30,300	29,100	30,725	34,164
Hancock	39,800	39,500	37,900	40,136	43,502
Marshall	38,200	40,800	39,400	39,736	42,163
Ohio	62,900	60,000	58,100	56,676	62,344
Upper Mon:					
Fayette	156,000	160,000	154,200	161,167	162,655
Greene	36,400	41,100	40,500	43,358	45,231
Somerset	76,200	81,300	80,900	78,946	79,808
Barbour	13,800	16,600	16,000	16,524	18,058
Harrison	72,700	77,700	75,600	77,186	87,090
Marion	61,200	65,400	64,200	62,922	68,975
Monongalia	62,400	75,900	76,700	77,269	85,849
Preston	25,100	31,200	30,700	31,816	35,255
Taylor	14,500	16,800	16,200	16,985	18,603
Subtotals:					
Lower	2,871,400	2,709,300	2,600,300	2,668,265	2,747,270
Upper	518,300	566,000	555,000	566,173	601,524
Combined	3,389,700	3,275,300	3,155,300	3,234,438	3,348,794
U.S. Total	201,298,000	234,253,600	241,092,300	267,464,000	306,618,000

2. CHARACTERISTICS

The area population is below national averages in per capita income and education, and older in age. Per capita income in the study area is 91 % of the national average which, to a certain extent, reflects the loss of high paying manufacturing jobs over the past decade. The average age is older than the national average (Table 7) as many of the younger people have been forced to migrate to find employment. Educational levels are below the national average.

TABLE 7
POPULATION CHARACTERISTICS

	Study Area	U.S.
Per Capita Income **	$13,380	$14,609
Age Distribution:		
0 - 21 (yrs)	33%	36%
22 - 44 (yrs)	31%	33%
45 - 64 (yrs)	23%	20%
> 64 (yrs)	13%	11%
Education:		
Less then 12 Years	21%	17%
12 Years or More	66%	67%
16 Years or More	13%	16%

** 1986 Dollars

SECTION 5. ECONOMY

1. OVERVIEW

The economy of the study area is very similar to the economy of the nation as a whole. Highly diversified manufacturing complexes, urban service and trade centers, agricultural areas, and the depressed coal economies of Appalachia can all be found in the study area. The study area's economy has developed around its natural resources - water and coal, and the demands of larger regional economies driven by the steel and electric industries.

The most significant recent developments that affect the region's economy and use of the river system are the generation of electricity for sale to East Coast utilities and the reopening of several coke ovens to produce coke for steel plants located outside the region. Duquesne Light Company recently announced plans to reopen two power plants (Phillips and Brunot Island) and a coal mine (Warwick) in order to generate electricity for sale to General Public Utility Corporation near Philadelphia. U.S. Steel is currently in the process of expanding the number of operating coke ovens at its Clairton works in order to produce coke for its plants in Gary, Indiana and elsewhere. There are numerous other developments that indicate the regional economy may be on the verge of growing after years of decline. However, the two examples cited above are of particular importance because they illustrate the critical role of the navigation system to the area's economy. The coal shipped to the Phillips power plant and the Clairton coke plant will move by barge.

2. EMPLOYMENT AND INCOME

a. Current

The pattern of sectoral employment in the study area is similar to the national pattern (Table 8). The principal sources of employment are the service sector and retail and wholesale trades. Together, these two sectors provide 53 percent of study area employment. The comparable share for the U.S. is 47 percent. Manufacturing and mining (mineral extraction) provide 16 percent of study area employment, which is lower than expected given the great importance of these activities in the development of the region. The figure for the U.S. is also 16 percent. The percents of employment in other sectors are likewise comparable to the national figures.

TABLE 8
EMPLOYMENT BY SECTOR
STUDY AREA AND U.S.
1986

Industry	Study Area	%	U.S.	%
Farm	18,434	1.3	3,322,000	2.6
Agri., Forestry and Fishing	6,000	0.4	1,166,200	0.9
Mineral Extraction	25,886	1.9	1,034,700	0.8
Construction	73,336	5.3	6,697,500	5.3
Manufacturing	193,113	13.9	19,477,300	15.5
Trans., Utilities, and Communications	72,681	5.2	5,947,500	4.7
Ret. & Who. Trades	323,967	23.4	26,819,800	21.3
Finance, Insurance and Real Estate	91,768	6.6	9,716,800	7.7
Services	405,176	29.2	31,964,900	25.4
Total Government	176,052	12.7	19,666,000	15.6
Total	1,389,844	99.5	125,822,700	99.8

Sum of items is less than total because of suppression of certain data.

As shown in Table 9, the unemployment rate in 1989 for the study area was the same as the national rate - 5.3%. However, within the study area, the unemployment rate ranged from 4.9% in the lower portion (Pittsburgh area) to 7.7% in the upper portion. The upper portion includes a portion of the Appalachian region, an area of chronically high unemployment.

TABLE 9
UNEMPLOYMENT RATES IN 1989

Region	Rate
Study Area	5.3
Upper portion	7.7
Lower portion	4.9
U.S.	5.3

b. Historic

The economy of the study area suffered a severe shock in the early 1980's when many of the steel making facilities in the Monongahela Valley were closed. The closures were permanent and irreversible and resulted in the loss of over 60 thousand steel making jobs. Affecting fewer jobs but still of major local importance were similar decisions made by companies involved in other manufacturing activities, like the construction of electric generators (Westinghouse). These companies also permanently closed their factories in the Pittsburgh area, putting tens of thousands of people out of work. The statistics in Table 10 illustrate the affect of these closures on manufacturing employment. In 1986 manufacturing provided only 14 percent of employment compared to nearly 40 percent in 1969. Over 200,000 manufacturing jobs were lost during this period.

TABLE 10
EMPLOYMENT BY SECTOR
HISTORIC & PROJECTED

	Historic			Projected	
Industry	1969	1983	1986	2000	2035
Farm	22,845	19,612	18,434	18,827	16,583
Agri., For. and Fishing	2,560	4,262	6,006	7,566	8,936
Mining	26,522	29,357	25,886	33,198	30,378
Construction	68,999	62,594	73,336	78,576	71,359
Manufacturing	386,472	229,592	193,113	249,570	215,503
Trans., Uti. and Commun.	81,949	71,831	72,681	84,076	82,207
Ret. & Who. Trades	59,554	294,988	323,967	345,783	327,299
Fin., Insu. & Real Est.	46,977	65,910	91,768	83,724	79,291
Services	245,566	329,259	405,176	426,524	415,194
Total Gov.	176,757	180,687	176,052	167,964	150,831
Area Total	1,330,261	1,291,123	1,389,844	1,495,808	1,397,581
U.S. Total	89,993,000	106,891,000	125,822,700	138,338,000	145,187,600

While manufacturing provides only 14 percent of study area employment, it accounts for over 21 percent of study area income (Table 11). Growth in other sectors of the economy generally compensated for the loss in manufacturing jobs, so that total employment in the study area still managed to increase over the past decade. The major growth sectors were wholesale and retail trade; finance, insurance, and real estate; and services. These sectors provided an additional 424 thousand jobs from 1969 through 1986, over twice the number of jobs lost in manufacturing. However, these jobs on average pay only about one-half a manufacturing job.

TABLE 11
EMPLOYMENT and INCOME
1986

Industry	Employment	%	** Income (x 1000)	%
Farm	18,434	1.3	35,594	0.3
Agri., Forestry and Fishing	6,000	0.4	23,765	0.2
Mining	25,886	1.9	457,430	3.8
Construction	73,336	5.3	837,079	6.9
Manufacturing	193,113	13.9	2,584,195	21.3
Trans., Utilities, and Communications	72,681	5.2	906,742	7.5
Ret. & Who. Trades	323,967	23.4	1,910,328	15.7
Finance, Insurance and Real Estate	91,768	6.6	661,585	5.4
Services	405,176	29.2	3,233,270	26.6
Total Government	176,052	12.7	1,455,749	12.0
Study Area Total	1,389,844	99.5	12,070,143	99.7
U.S. Total	125,822,700	1.1	1,087,518,000	1.1

** 1972 Dollars

c. Projected

The employment and income projections used in the study were developed by the Bureau of Economic Analysis (BEA) section of the Department of Commerce. They are mostly commonly referred to by the acronym "OBERS" since they were originally developed by the Office of Business Economics and Economic Research Service. The OBERS projections are used in the development of waterway traffic forecasts as is described in the NAVIGATION SYSTEM STUDY Appendix.

The OBERS projections are prepared according to a "step-down" procedure. Basically, this means that national projections are developed first, and these are then distributed among the States to arrive at State-level projections and so on down to smaller geographic areas. The distribution is based on historic shares and trend analysis.

The projections used in this study were the "1985 OBERS" BEA Regional Projections. The base year for the projections was 1983 and the terminal year was 2035. Historic shares were based on data dating back to 1969.

The OBERS projections are for slow growth in employment at both the regional and national levels. Employment in the study area is projected to increase 205 thousand (16%) from the base year through the year 2000 and then decrease by nearly 100 thousand (7%) between 2000 and 2035. Nationally, employment is projected to increase 21 percent by the year 2000 and an additional 5 percent between 2000 and 2035. The principal reasons for the slow growth in employment are forecasts of slow population growth and limited expansion in labor force participation rates.

d. Track Record of Projections

The OBERS projections were based on historic data from 1969 to 1983. The data for 1986 shown in the tables are actual data; they are not projections nor were they a basis for the projections. These data represent a single year indication of the 'goodness' of the projections. The preliminary results indicate that BEA may have underestimated growth in the area.

The projected increase in employment was 36 thousand between 1983 and 1986. The actual growth in employment was 100 thousand jobs, or nearly three times the projected increase. The area has rebounded from the decimation of its manufacturing base much sooner and much more than expected.

The principal sectors of actual job growth were in wholesale and retail trade; finance, insurance, and real estate; and services. Employment in these sectors increased by 130 thousand (19%) over the 1983 levels. Employment in mining, manufacturing, and government declined by 44 thousand (10%) while employment in the remaining sectors increased slightly. The actual employment trends are consistent with the BEA projections, but the increases are greater than projected. Moreover, preliminary data shows a continuation of growth in employment for the Pittsburgh area with net increase of 47 thousand jobs between 1986 and 1989.

SECTION 6. UPPER AND LOWER PORTIONS OF STUDY AREA

1. GENERAL

The study area is best understood as consisting of two distinct economic areas: the Lower Study Area centered around Pittsburgh where the economy is (or was in the past) predominantly manufacturing in nature and the Upper Study Area along the middle to upper Monongahela River where the economy is predominantly mining in nature (Table 12). The counties included in each of these subregions are identified in Table 1. Because of their distinctiveness, they are discussed separately and in greater detail.

TABLE 12
EMPLOYMENT IN MINING AND MANUFACTURING
HISTORIC AND PROJECTED

Area/	Historic			Projected	
Industry	1969	1983	1986	2000	2035
Lower Mon:					
Mining	12,262	12,923	12,631	13,239	12,005
Manuf.	354,435	208,684	171,939	226,668	194,683
Upper Mon:					
Mining	14,260	16,434	13,255	19,959	18,373
Manuf.	32,037	20,908	21,174	22,902	20,865
Total:					
Mining	26,522	29,357	25,886	33,198	30,378
Manuf.	386,472	229,592	193,113	249,570	215,548
U.S.					
Mining	702,100	1,215,500	1,034,700	1,261,000	1,333,800
Manuf.	20,530,600	18,899,000	19,477,300	23,321,000	23,151,500

2. LOWER STUDY AREA

The two industries in the Lower Study Area that have the greatest impact on river traffic are steel and electric power. Both industries are major consumers of coal and users of the navigation system. A general overview of these industries is provided in the following paragraphs.

a. Steel Industry

Historically, the dominant manufacturing activity in the Pittsburgh area was steel production. Pittsburgh was known as the "Steel Capital of the World" for most of the last 100 years. The riverbanks along the Monongahela and Ohio Rivers were lined with steel mills. One of the major reasons the industry located in the area was the accessibility of coal for use in producing coke. Coke is used in the steel making process to reduce iron ore into iron. Iron is then processed further to produce steel. The initial market for steel was in the construction of the nations' basic infrastructure, such as the railroads. Later on the steel was used in the construction of the Panama Canal. The most important markets of recent years were the automobile, construction, appliance, and oil industries. Stagnation and decline in these industries as well as increased international competition and changes in steel making technology led to the rationalization of the steel industry in the early 1980's. The end result was the closure of many older plants of the kind typified by those in the Pittsburgh area. Between 1982 and 1983 over 50,000 steel industry jobs were lost in the Pittsburgh area alone. The decline in the steel industry both nationally and regionally is illustrated by the data in Table 13. From 1978 through 1986 U.S. raw steel production decreased by 40 percent. The comparable decline in Pennsylvania production was an even more severe 66 percent. Much of the reduction in Pennsylvania production was at Pittsburgh area plants.

TABLE 13
RAW STEEL PRODUCTION
(Million Tons)

State	1978	%	1986	%
Pennsylvania	28,070	20	9,492	12
Indiana	24,351	18	16,837	21
Ohio	21,268	15	14,552	18
Illinois	12,443	9	6,414	8
Michigan	10,789	8	7,475	9
Other	40,010	30	26,838	32
Total:	136,931	100	81,608	100

While the general expectation is that steel production will increase minimally if at all in the future, coke production in the Monongahela is expected to increase. USX recently reopened two coking ovens at its Monongahela Valley plant that will increase coal consumption by an additional 1.5 million tons a year. All of this coal is transported to the plant by barge and some of the coke is transported out by barge. The coke is transported to steel plants in Gary and other steel producing areas where the costs of producing coke are high or the construction of coking works difficult because of environmental requirements. Most of the coal transported to the area's coking facilities is transported by barge.

b. Electric Generating Industry

The electric generating industry is the major consumer of coal both regionally and nationally. The industry burns coal to generate electricity. Most new and planned power plants are designed as coal-fired plants or as plants that can be converted to coal use as market conditions dictate.

Because they are local monopolies, power companies are closely regulated by state governments. As a result, their service areas are usually defined within a single state boundaries. However, they may be linked with power companies in other states through power pools. Power pools range in cooperative efforts from sharing of power and perhaps jointly constructing new plants to total control of the operations of the individual power companies. The power pools in the Pittsburgh area are considered "tight" power pools in that operations of several individual companies are controlled by a single dispatch. The major power pools that operate within the study area are listed in Table 14. Also included in the table are system coal burns and barge receipts of coal. These companies consumed over 30 million tons of coal in 1986 with nearly 20 million tons transported by barge.

TABLE 14
MAJOR ELECTRIC UTILITY COMPANIES

System	Companies	(Thousands of Tons) Coal Burned	Barge Receipts
Allegheny Power System:		15,011.6	7,947.8
	West Penn Power		
	Mon Power		
	Potomac Edison		
Ohio Edison:		11,215.6	6,991.0
	Ohio Edison		
	Pennsylvania Power		
Duquesne Light:		4,494.8	3,240.7
	Duquesne Light		
Totals		30,722.0	18,179.5

The end-use markets for electricity are the industrial, commercial, and industrial sectors of the economy. Nationally, the industrial sector is the largest of the three sectors in terms of electricity consumption. Its importance within the study area was even greater, given the study area's relatively high levels of manufacturing activity and steel production. The loss of a major part of its industrial market in the early 1980s left many area electric utilities with excess capacity. However, since the Pittsburgh area plants are predominantly coal-fired and much more efficient to operate than the oil-fired plants characteristic of the East Coast, the utilities were able to market electricity on the East Coast. This allowed them to not only maintain but increase their rates of plant utilization. The results are high coal burns and barge shipments of coal.

The utility market for study area coal is partially defined by the needs of the electric industry to meet sulphur emission standards. Legislation was enacted in the Clean Air Act Amendments of 1990 that further reduce the volume of sulphur emissions by power plants. The legislation provides the electric industry with the option of meeting the new emission standards either by installing desulphurization equipment (scrubbers) or by burning low sulphur coal. Installing scrubbers is least disruptive to the market for study area coal since power plants will be able to continue to burn medium sulphur coal and still meet emission standards. Under existing legislation, all power plants must be fitted with scrubbers when they are renovated or replaced so the immediate installation of scrubbers merely speeds the pace of compliance. Switching to low sulphur coal is most disruptive to the market for study area coal since only a small amount is found in the study area. For many plants, switching to low sulphur coal is cheaper than installing scrubbers.

Some markets have probably been temporarily "lost" to study area coal because of the new Clean Air legislation. However, additional switching by plants that receive study area coal is expected to minimal, particularly for barge served plants. Many of the plants that receive study area coal are already equipped with scrubbers or have indicated they would install them if necessary. In the long term, the Department of Energy (DOE) expects the demand for high-sulphur coal to rebound, as more new coal-fired plants may choose to use stack gas scrubbers or one of the advanced "clean coal" technologies.

3. UPPER STUDY AREA

a. Mining

In contrast to the Pittsburgh area, coal mining is the most important economic activity in the portion of the study area upstream of Pittsburgh on the Monongahela River. Coal has been produced in the area for over 150 years. A listing of the major coal producers in the area along with their production levels is provided in Table 15.

TABLE 15
MAJOR COAL PRODUCERS
STUDY AREA PRODUCTION
(Thousands of Tons - 1985)

Company	Amount
Consol	16,435.7
Bethenergy	4,024.0
U.S. Steel Mining	3,768.7
Peabody	2,564.5
Emerald Resources	1,767.2
Anker Energy	1,517.1
LTV Coal/Steel	1,158.0
Shannopin Mining	1,104.5
Mathies	1,094.2
John McCall Coal	933.6
Kitt Energy	781.5
Duquesne Light	773.2
Preston Energy	739.1
NSM/PBS Coal	676.4
Penn Allegheny Coal	592.0
Others	10,948.3

A detailed discussion of study area coal reserves, production, characteristics, and markets is provided in the section on Natural Resources. In brief summary, the study area contains 5 percent of U.S. reserves, produces 60 million tons or 6 percent of annual U.S. production, is high in BTUs with medium sulphur and ash, and is consumed mainly in the steel and electric generating industry. The lower section of the study area near Pittsburgh contains twice the reserves of the upper section, but the upper section produces more coal. The county with the highest production is Monongalia, WV, which is on the border with Pennsylvania and is dissected by the Monongahela River. Production in the West Virginia portion of the study area grew by over 5 million tons from 1975 to 1987 while in the Pennsylvania portion it declined by over 10 million tons. Generally speaking, production is expected to continue moving up river as mines closer to Pittsburgh and to the river are depleted. The reserves of the area are equivalent to one thousand years of production at current levels.

SECTION 7. OUTLOOK

1. GENERAL

The study area economy is projected to grow in the future but at slower rate than the rest of the country. This is consistent with the historic rate of growth and, in fact, the projections are largely an extrapolation of past growth into the future. Growth in the study area affects the expected amounts of cargo transported into the area for internal consumption, such as coal moving to power plants for the generation of electricity to satisfy local demands. However, the study area economy has diminished in importance in determining the amount of traffic moved on the Lower Monongahela River at the expense of regional, national, and international markets. The amount of coal barged to area coke plants is driven by national as opposed to local levels of steel production. Likewise, the amount of coal barged to area power plants is driven by electricity demands along the East Coast as well as within the study area. This broadening of markets increases the opportunity for growth in electricity exports from the study area and in coal consumption by local power plants. The export market for coal is similarly affected by national and even international developments, such as the construction of coal-fired plants in other countries and the prices of oil and natural gas. The growth in importance in regional, national, and international markets in determining levels of local river traffic increases the potential for higher traffic volumes in the future, but makes the uncertainty of volumes in any one year or series of years even greater because of an expanded list of determining factors.

2. RECENT DEVELOPMENTS

Although it is too soon to know with certainty, recent developments seem to indicate that the study area has successfully restructured its economy and may be in a position to grow at a rate greater than the extrapolated values indicate. The area regularly rates high on "desirability of living" lists in terms of housing affordability, crime rates, climate, education, and health care. The local economy is much more diversified than in the past when its fortunes were tied to the steel industry. It has few military bases and defense related jobs, and so is unlikely to be significantly affected by the closure of bases and reductions in military expenditures now being considered. The possibility of higher growth than projected appears reasonable in light of recent events while the possibility of lower growth appears minimal.

LOWER MONONGAHELA RIVER
NAVIGATION SYSTEM STUDY

APPENDIX

PLAN FORMULATION

U.S. Army Engineering District, Pittsburgh
Corps of Engineers
Pittsburgh, Pennsylvania

MONONGAHELA RIVER NAVIGATION SYSTEM
PENNSYLVANIA
LOCKS AND DAMS 2, 3 AND 4

APPENDIX

PLAN FORMULATION

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PLAN FORMULATION APPENDIX

1. GENERAL

This appendix describes the process used to arrive at the final array of plans for the Lower Monongahela River navigation study. It begins with a description of the development of the most probable without project condition ("without" plan) that would exist in the absence of public law and policy, continues with the development of a range of alternative plans, and ends with the identification of the "best" array of alternatives. The final array of plans was carried forward for analysis in other areas of importance, such as environmental impacts. The comprehensive evaluation of the alternatives and the selection of the "recommended" plan are described in the MAIN REPORT.

The planning horizon for this study is the 50 year period beginning in 2002 and ending in 2051. All estimates are expressed in October 1991 price levels and all values, as appropriate, were discounted using a rate of 8 3/4 percent.

a. National Objectives

The principal Federal objective of water and related resources planning is to identify the most cost effective investment from a Federal perspective while at the same time protecting the nation's environment. Investments are measured as increases in the net value of the national output of goods and services, expressed in monetary units. It is, therefore, the goal of all Corps' studies to alleviate problems and realize opportunities related to the output of goods and services or to increase economic efficiency. Protection of the nation's environment is accomplished pursuant to national environmental statutes, applicable Executive Orders, and other Federal planning regulations. The Principles and Guidelines for Water and Related Land Resources Planning established four accounts to facilitate the orderly evaluation of each plan. These accounts are: National Economic Development (NED); Environmental Quality (EQ); Regional Economic Development (RED); and Other Social Effects (OSE).

b. **Study Objectives**

The primary objective of this study was to determine the navigational needs on the Lower Monongahela River and to develop the best plan to address those needs. This study addressed only those problems and needs related to navigation. Other problems or needs that affect or could be affected by solutions to navigation problem, or that reflect an alternative use of the same resource, have and will, continue to receive appropriate consideration.

An examination of the existing problems of the study area indicated a need for more specific planning objectives. These objectives reflect not only the overall objectives established for the Locks and Dams 2, 3 and 4 study, but also national, state and local objectives, whenever possible. The specific planning objectives of this study are as follows:

a. To ensure the safe and reliable operation of the Lower Monongahela River Navigation System into the future.

b. To minimize inefficiencies to towing operations related to the Lower Monongahela River Navigation System.

c. To maintain or improve, where possible, the river's present water quality, fishery and recreational values.

c. **Plan Formulation Process**

The plan formulation process began with a review of the problems with the existing navigation projects, as identified in the STRUCTURAL CONDITION APPENDIX and the NAVIGATION SYSTEM ANALYSIS APPENDIX. The problems and associated study objectives provided a basis for developing the "without" plan. Non-structural measures were developed as possible means of addressing navigation problems and eliminating, or deferring, the time that more expensive structural measures would have to be implemented. Non-structural measures were included as part of the "without" plan when economically justified. The "without" plan was evaluated in terms of economic feasibility and completeness in solving the problems at the projects. The findings indicated that while the work efforts of the "without" plan were economically justified, several significant problems remained. The study then focused on the development and evaluation of alternatives that resolve all of the problems and that might prove better than the "without" plan. The process concluded with refinement of the best plans according to all pertinent planning objectives.

Navigation benefits for the "without" plan and all alternatives were developed by the Ohio River Division Navigation Planning Center in Huntington and project costs by the Cost Estimating Section of Engineering Division in Pittsburgh. Details are contained in the NAVIGATION SYSTEM ANALYSIS APPENDIX and in the COST ANALYSIS APPENDIX.

2. "WITHOUT" PLAN

The "without" plan is used to quantify and describe solutions to the water resource problems and needs of the study area likely to be implemented in the absence of specific federal authorizations. The "without" plan also serves as the baseline against which the benefits, costs and socio-environmental impacts of each alternative plan are measured.

Initially the "without" plan was interpreted to mean that the Lower Monongahela River projects would be maintained under ordinary operations and maintenance (O&M) funding with major repairs performed on an emergency basis. However, analysis of the structural conditions of the projects indicated a large number of serious problems that made the structural integrity of the projects uncertain. Reliance on normal O&M to keep the projects operational was expected to result in numerous failures of major project components, particularly portions of a lock wall or dam section, at some time during the analysis period. Such a "without" plan was considered to be contrary to the basic directive from Congress to maintain cost effective navigation through sound management of the inland waterway system, consistent with the overall public interest. As a result, it was concluded that continued operation under O&M was not the most probable "without" plan. Instead, the "without" plan would be whatever measures were necessary to maintain reliable navigation service, provided these measures were economically justified.

The measures necessary to keep the projects operational and the timing of their implementation were based on a structural analysis of the projects (STRUCTURAL CONDITION APPENDIX). The amount and timing of work required at each of the projects in the "without" plan are summarized below.

a. **Locks 2**

(1) Condition Summary

The item of greatest concern is the floodway bulkhead for the auxiliary chamber which serves a several purposes. During flooding, it allows for flows to pass through the auxiliary chamber, thereby reducing river levels and flood damages. It also serves as an emergency lock closure that could prevent a loss of pool and as a maintenance closure. This outdated structure is marked with several significant defects. Both support piers contain large vertical cracks that threaten its structural integrity. Furthermore, misalignments of bulkheads have occurred during placement. Such misalignments must be corrected manually, therefore posing potential safety problems and encroaching on valuable timely placement. On one recent occasion, the bulkhead actually fell into the lock chamber when it was being positioned for use. Clearly, this is not a reliable system to provide for the important functions for which it is designed and required.

The lockwalls are in generally good condition, although the present surface condition of the lock wall concrete is in need of repair. There is minor cracking at the gate recesses and extensive spalling at some of the monolith joints within the chambers. Portions of the lock wall surface mortar have eroded away, giving the walls an exposed aggregate appearance.

(2) Potential Consequences

The condition of the old floodway bulkhead is an immediate concern. Continued use raises the very real possibility of failure during placement. Such failure would cause increased flooding and could result in injury or even loss of life. Worsening of the spalling and erosion of the surface mortar are also concerns, although of less urgency. However, if left unchecked, monolith damage could become severe enough to become safety hazards to navigation. Tow impacts could accelerate such damage to the point where repair and unscheduled lock closures occur during the latter half of the analysis period.

(3) Work Requirements

The first area of work would be the area of most critical concern, the auxiliary chamber floodway bulkhead system. As a prelude to the construction of Dam 2 (see paragraph 2.b.{2} below), this old and unreliable structure would be replaced. The need to use the floodway will be increased during the dam construction due to river constrictions caused by the use of cofferdams (see the HYDRAULICS APPENDIX). This accelerated schedule for construction of the bulkhead has two advantages over delaying it until the rehabilitation - a more reliable system will be in place to reduce flood flows during the construction of Dam 2 and will be available during the 50-year analysis period for use as an emergency closure. It is estimated that this new system would reduce potential flood damages during the construction of Dam 2 by approximately $2.1 million (Attachment 1). The bulkhead would be replaced with a steel bulkhead system similar to that being installed at the new Point Marion L&D.

The District expects that the concrete and machinery at Locks 2 would require major rehabilitation in about thirty years, or by the year 2022. At that time, the concrete in the locks would be about 70 years old and the service provided could prove to be unreliable. This rehabilitation is viewed as the most reasonable approach to assuring reliable service levels at this facility. The specific items included in this rehabilitation are summarized in Table 1 and described in detail in Attachment 2 to this appendix.

Table 1
Rehabilitation of Locks at L&D 2 in 2022

1. Replace middle wall building.
2. Resurface top of lock walls.
3. Reface lock walls and install wall armor.
4. Reface and resurface guide and guard walls.
5. Install floating mooring bitts.
6. Rebuild miter sills.
7. Replace miter gates.
8. Replace miter gate operating machinery.
9. Replace gate anchors and pintles.
10. Replace culvert valves and operating equipment.
11. Install new hydraulic system.
12. Replace lock power and lighting system.
13. Replace air and water systems.
14. Replace tow haulage system.

b. **Dam 2**

(1) Condition Summary

The primary area of concern with Dam 2 is the very poor foundation condition. The dam and apron are supported by timber piles and stone-filled timber cribs, respectively. The foundation material supplies lateral support that is critical to the stability of this structure. However, a substantial washout of the stone fill material was discovered by soundings. Divers have reported missing timbers and fill material washed out all the way to the downstream face of the dam in many areas. They also noted strong currents coming out from two holes under the dam, suggesting the existence of missing fill material under the entire cross section of dam. Missing foundation material decreases the support and increases the loading on the piles and increases the likelihood of pile failure, which in turn could lead to dam movement and breaching.

The seriousness of the foundation condition is further exemplified by District stability analyses. These analyses show that, <u>even if full foundation support is assumed</u>, the piles are overloaded <u>by 8 kips per pile (kpp) laterally</u> (allowable load of 6 kpp vs. actual load of 14 kpp) under current design criteria when ice or impact loads are considered. Furthermore, these analyses show that the piles are overloaded even more in both tension and compression for design loads when loss of supporting fill is assumed. These concerns led the District to complete interim scour protection downstream of the dam in 1987, however, there was no provision for repairing voids in the foundation of the dam. The scour protection was placed within the O&M program and therefore repairing the voids would have been far too costly. Furthermore, such repair would have been relatively ineffective in terms of increasing the reliability of the dam. However, this limited work effort was considered as an acceptable interim solution until comprehensive improvements could be made.

All concrete is non-air entrained and unreinforced. In 1978, uneven flow over the dam crest was observed, suggesting concrete damage or settlement of sections of the dam or apron. The concrete damage could be due to either deterioration or impacts.

(2) Potential Consequences

If not corrected, the extremely poor foundation conditions could allow for movement of the dam sections and loss of pool at any time. Emergency repair costs and corresponding navigation impact costs were calculated for a hypothetical dam failure situation. It is theorized that a breach of the dam would affect a 100' section. It would take about two months to repair under emergency conditions and cost approximately $7 million. A two month loss of pool with restrictions on river traffic would also result higher transportation costs that, along with reduced availability of river water, would cost the regional economy about $32 million.

(3) Work Requirements

Due to the extensive voids in the foundation material, remedial work will be required by the year 2002 in order to extend its useful life. Two alternatives were considered - filling the voids with grout and complete replacement. Grouting alone would not provide for a reliable structure owing to the high pile loads. The wood piles would require augmenting by pin piles, a costly procedure. Furthermore, the old structure with non-air entrained concrete would be retained. This would reduce the reliability of the overall structure. Thus, total replacement of Dam 2 is required to provide for a reliable structure. The new fixed crest dam would be founded on firm rock at the existing location. The length would remain basically unchanged while the width would increase to approximately 93 feet, including stilling basin.

c. **Locks 3**

(1) Condition Summary

Of the 24 lock and dam projects in the Pittsburgh District, L&D 3 has the locks considered to be in the worst condition from both foundation and concrete deterioration standpoints. WES completed two Condition Surveys, one in 1976 prior to a major rehabilitation and the other in 1988 as part of this study effort. The 1988 report is summarized in the STRUCTURAL CONDITION APPENDIX.

There are two major areas of concern with the foundation conditions at Locks 3. The first is the poor quality foundation material over the majority of the lock site. This material is highly weathered and fractured and does not provide a solid base for the lock walls. Furthermore, at least one monolith bears on coal, a very poor and unreliable foundation material. The second is a weak foundation material-concrete interface. Approximately 400' of the lower middle wall was placed in the wet by dumping concrete into wooden forms during the 1920-1923 modification of the large chamber, resulting in a very poor foundation contact.

The poor stability conditions were partially corrected during the 1978-1980 rehabilitation. Extensive monolith wall areas were stabilized with rock anchors, including about 550 feet of the retaining wall for the land chamber flume and the following monoliths: L39 thru L45 (land wall); M3 thru M26 (middle wall) and; R12 - R23 (river wall). These anchors provided additional resistance to both sliding and overturning movements. A total of 212 anchors were installed, of which 167 were installed using polyester resin grout with a single level of corrosion protection. Due to the extremely poor stability conditions, the resulting stability safety factors after the anchor installation were still below those recommended by current criteria. Furthermore, based on information obtained subsequent to this installation, the District believes that these anchors cannot be counted on to provide adequate resistance. A more detailed discussion of the major rehabilitation work accomplished and its temporary nature is provided in the STRUCTURAL CONDITIONS Appendix.

The concrete at Locks 3 is unreinforced and non-air entrained. The 1976 WES Condition Survey found that concrete deterioration extended from two to six feet into the walls. Additional pockets of concrete, estimated at 10-20% of the total concrete volume, is unsatisfactory due to construction techniques used in the original construction. During the '78-'80 rehabilitation work, broken timbers and other miscellaneous material that had fallen into the concrete during the original construction were discovered. It was not practical to replace all deteriorated concrete during the major rehabilitation as a major reconstruction effort at considerable cost and extended lock and project closures would have been required. The condition was temporarily addressed by refacing or resurfacing most of the lock wall vertical and horizontal faces. Generally a 1 ft. thick cover was placed above lower pool level, mainly to restore the surface to a serviceable condition free of gouges that barges could catch upon impact and to provide protection to the underlying deteriorated concrete. This cover is primarily designed to prevent further deterioration of the interior concrete and can not resist structural loadings. Substantial volumes of interior deterioration remain, as evidenced by severe cracking in the middle wall gallery and subsequent telescoping of internal cracks throughout the new cover. In addition, the rehabilitation did not permanently resolve a critical stability problem in the retaining wall on the land side of the land wall filling flume.

When viewed from the top of the lock walls, the concrete looks reasonably good. However, this is misleading as the overlay masked many problems, not correct them. The fact remains that a significant portion of the wall volume at Locks 3 is deteriorated and thereby limited in load resistance capacity.

(2) Potential Consequences

Due to the generally poor foundation and concrete conditions, extensive portions of all walls are susceptible to unacceptable movement at any time. As concluded in the WES 1988 Condition Survey, the major concern "...is that one or several of the concrete defects could connect up with a structural crack propagating through a monolith, as a result of a boat or barge impact, and contribute to failure of a monolith that could result in closure of a chamber or loss of pool." Thin unreinforced sections around pipe galleries and culverts are particularly vulnerable. Modern projects are designed to withstand larger impact loads associated with the increase in tow sizes over time. In addition, the excessive loading on the retaining wall in the land wall flume could cause movement and failure of the flume. Emergency repair costs were estimated for hypothetical failures of wall monoliths. It is theorized that such failures would occur in groups of two or three monoliths, cost $5 - $10 million to repair under emergency conditions and result in the closure of one or both lock chambers for up to three months. A three month closure of this project would result in about $50 million in higher transportation costs that would be passed on to the regional economy.

(3) Work Requirements

Severe foundation and concrete deterioration problems must be corrected by the year 2002 to ensure reliable navigation. At a minimum, the lock walls require stabilization with rock anchors, and substantial portions of the old concrete need to be replaced with air-entrained concrete by the beginning of the analysis period. However, the installation of additional anchors is not practical due to the poor quality concrete throughout the lock walls. The lock wall concrete would be nearly 100 years old in the year 2002 and susceptible to excessive damage by the drilling and stressing required for anchor installation. Thus, the only way to attain satisfactory stability is to reconstruct the walls. The walls would be constructed to current design criteria using air entrained concrete. Consideration was given to staging the construction and replacing the most critical sections. However, portions of all walls are in critical need of upfront repair, making total upfront reconstruction of all walls the most practical and cost effective strategy.

In total, five alternative reconstruction plans were considered for Locks 3. Two would have resulted in a single chambered facility (either a 56' x 720' or 84' x 720' chamber). The 56' x 720' single chambered alternative was economically inferior due to increased navigation delays resulting from traffic growth and river closures during maintenance work. The 84' x 720' lock size would have increased the capacity of the site and was outside of existing authorities. Therefore, both single chambered alternatives were dropped from further consideration. Three other alternatives that would provide lock chambers that are the same size as the existing chambers were considered and are described below.

i. Rebuild-in-Place without Temporary Chamber (WO-1)

In this alternative, all three walls would be removed and reconstructed in the existing positions. All walls would be gravity type founded on rock. The major disadvantage of this alternative is that the removal of the middle wall would force a shutdown of both chambers for a period of 2 1/2 years and two 6 month closures of the auxiliary chamber. Such closures would be unacceptable to the navigation industry since it would entirely close this section of the river and add $150 million per year to the navigation costs. Therefore this alternative was rejected.

ii. Rebuild-in-Place With Temporary Chamber (WO-2)

This alternative is identical to the above with the exception that it would involve the construction of a 56' x 720' temporary lock chamber riverward of the river wall and removal of a portion of the existing fixed crest dam. Such modifications to Dam 3 are reasonable in light of its poor condition and its reconstruction planned for it in the "without" plan as described below. This temporary chamber would be utilized during the 2 1/2 year period when the locks are being reconstructed. Chamber walls and the filling and emptying flume for this chamber would be constructed of circular steel sheet pile cells and the gate monoliths would be conventional reinforced concrete. Removal of a segment of the fixed crest dam would occur after the gate monoliths and chamber walls were in place. Once removal and reconstruction of the land, middle and river walls were complete and the newly constructed lock chambers were operational, removal operations could begin to eliminate all unnecessary cells and monoliths in the temporary chamber that could not be reused for the Stage 1 cofferdam for the dam reconstruction. The total replacement cost for the locks, including the temporary lock chamber is $260 million. Delays to navigation would occur due to interference between traffic and construction equipment. This delay cost is estimated to be approximately $2 million on an annual basis.

iii. Replace-in-Kind (WO-3)

This alternative incorporates a reconstruction strategy that provides a 56' x 720' chamber available for traffic without utilizing a temporary lock chamber. The locks would be gravity type founded on rock and repositioned riverward such that the new middle wall is constructed between the existing middle and river walls. By so doing, traffic can be maintained in the existing land chamber while a new 56' x 720' river chamber is being constructed. However, stabilization measures must be completed for the middle wall since the river chamber will be dewatered. The new river chamber would be constructed first and would be sized at 56' x 720'. The chamber face of the proposed river wall will be located approximately 35 ft. riverward from the chamber face of the existing river wall, hence a portion of the dam would require removal. The proposed river wall and middle wall can be constructed in the Stage 1 lock cofferdam. The existing river wall must be removed and the hydraulic and electrical systems for the newly constructed lock must be made operational to allow traffic to be diverted riverward into the new lock. Work would begin on the proposed 56' x 360 ' land chamber only after the new main chamber is put into operation. The existing land and middle walls would be removed and the proposed land wall would be located 56 ft. landward of the new middle wall. This arrangement would position the chamber face of the proposed land wall approximately 34 ft. riverward of the chamber face of the existing land wall. The proposed rear face of the land wall footing would be aligned almost flush with the existing land wall face. It appears as though the existing land wall can remain in place during construction to act as a temporary retaining structure, hence avoiding the expense of placing a temporary steel sheet pile retaining wall and/or considerable excavation to reduce the slope of the backfill to a safe level to allow for foundation preparation and land wall construction. Once backfilling was completed, work could begin on the new esplanade and land wall building. All new systems would be installed at the new facility, including electrical, mechanical, hydraulic, water distribution and sewage disposal. The total replacement cost of the locks is $205 million. The delays to navigation would be on the same order as WO-2 or approximately $2 million annually.

The total costs of the lock reconstruction alternatives are summarized in Table 2.

Table 2
Lock 3 Replacement Costs of "Without" Alternatives
(Millions of October 1991 dollars)

Alternative	Lock	Delays
WO-1 Rebuild in Place without temp. chamber	205	375
WO-2 Rebuild in Place with temp. chamber	260	5
WO-3 Replace in kind	205	5

The selection of lock reconstruction strategy must also consider the impacts on Dam 3, which is discussed below.

d. **Dam 3**

(1) Condition Summary

The general condition of Dam 3 is very similar to that of Dam 2 - extremely poor. The stability of Dam 3 is seriously compromised as evidenced by missing timbers from the cribbing and voids under the apron. Scour is also a problem downstream of the dam. Although there have not been reports of flow under the dam, fill material may be missing. However, even if no fill is missing, District stability computations show that the piling are overloaded both axially and laterally when ice/impact loads are considered. For example, the allowable vs. actual maximum pile loadings for this structure are 60 kpp vs. 68 kpp compression, 6 kpp vs. 13 kpp lateral and 0 kpp (no tension pile loads are allowed in this type of structural design) vs. 23 kpp tension. Furthermore, the abutment piling is extremely overloaded, 60,000 lb/pile allowable vs. 139,000 lb/pile compression, 0 lb/pile vs. 47,000 lb/pile tension and 6,000 lb/pile vs. 13,000 lb/pile lateral load.

All concrete is non-air entrained and unreinforced. There are large cracks and concrete breakouts in the dam apron. The abutment concrete is also in very poor condition.

(2) Potential Consequences

As with Dam 2, the extremely poor foundation conditions demand extensive repairs by the turn of the century. Without these repairs, movement of sections of the dam and loss of pool could occur at any time. Emergency repair costs and corresponding navigation impact costs were calculated for a hypothetical dam failure situation. It is theorized that a breach of the dam would affect a 100' section and would take about two months to repair under emergency conditions and cost approximately $7 million. A two month loss of pool would also result in higher transportation costs that, along with reduced availability of river water, would cost the regional economy about $33 million.

(3) Work Requirements

As with Dam 2, the poor condition of the foundation and concrete necessitates extensive remedial work. Again, grouting the foundation voids and total reconstruction were the two alternatives considered. Grouting was rejected since augmentation with pin piles would be required. Furthermore, the old non-air entrained concrete would be retained, which would reduce the reliability of the overall structure. Thus, total replacement of Dam 3 in-kind is required to provide for a reliable structure. The new structure will be a concrete gravity type founded on sound rock. The dam width, including stilling basin, will be approximately 73 ft. The dam crest will be modeled after that of the Grays Landing structure. A three-stage cofferdam will be utilized for the removal and replacement.

Both Locks and Dam 3 would be replaced by the beginning of the analysis period in the "without" plan. The reconstruction of Dam 3 would be the same with any of the three lock reconstruction schemes except that the length of the Dam 3 would vary. Lock reconstruction strategy WO-3 would move the locks riverward and thereby shorten the length of the dam by approximately 35'. The existing length would be maintained with reconstruction policies WO-1 or WO-2. The construction cost of the new dam is $80 million in the WO-3 alternative and $85 million in the WO-1 and WO-2 alternatives.

A summary of the total costs for the three possible reconstruction plans is shown in Table 3.

Table 3
L&D 3 Replacement Costs of "Without" Alternatives
(Millions of October 1991 dollars)

Alternative	Lock	Dam	Delays	Total	
WO-1 Rebuild in Place without temp. chamber	205	85	375	665	
WO-2 Rebuild in Place with temp. chamber	260	85	5	350	
WO-3 Rebuild in kind	205	80	5	290	* **least cost**

Each of these three alternatives would provide the same benefits. Therefore, the least costly strategy in terms of construction and disruptions to traffic, WO-3, is the most cost effective and the recommended replacement of Locks 3 in the "without" plan.

e. **Locks 4**

(1) Condition Summary

In general, Locks 4 are considered to be in fair to poor condition with primary deficiencies due to pile loadings and concrete deterioration. The 12" diameter wood piles supporting the lockwalls are intended to be end bearing but it is not known if the piles were driven to rock. This uncertainty, combined with the age of the piles, reduces their reliability to adequately resist normal loads. Furthermore, District computations indicate that the majority of the lock wall pile loads are very near the allowable limit for wood piles. These high loadings have been in effect since 1967 when pool 4 was raised six feet to accommodate modernization of the middle Monongahela River. This increased loading condition was accepted at the time under the assumption that corrective action would be taken within a 25 year period. In addition, the pile cap for these walls is also considered a potential problem area. The cap is a 4 foot thick unreinforced concrete beam at the base of the wall monoliths. With the high pile loads that are transferred to it, this cap is subject to tensile loads that could provide a source of cracks that propagate through the monolith. Under normal design, the cap would be designed with steel reinforcement to resist the tension.

The upper guard wall, founded on stone filled cribbing, is leaning toward the land chamber. The lower guide wall is also leaning riverward due to the loads imparted by the backfill and land side railroad loading behind the guide wall.

All lock walls are unreinforced and non-air entrained concrete. They are considerably spalled and eroded with deterioration penetrating several feet. The ceiling and floor of the galleries have longitudinal cracks as well as occasional transverse cracks, which is made more serious by the absence of reinforcing steel to control the cracking in these relatively thin concrete wall sections. There is extensive leakage into the middle and river wall galleries. There has been relative movement between the monoliths in the middle wall both in the pipe gallery and the culvert. Most of the lock wall monoliths contain cracks which threaten the structural integrity of these monoliths.

(2) Potential Consequences

The extensive cracking and extremely high pile loading could result in monolith movements requiring emergency repair at any time. Such movements would probably be started by barge impact, result in safety hazards and render one or both locks inoperable. As with Locks 3, thin unreinforced sections around the pipe galleries and culverts are particularly vulnerable.

(3) Work Requirements

The condition of the non-air entrained concrete throughout the lock walls must be addressed with a major rehabilitation by the year 2002. The primary item of work would be the removal of deteriorated surface concrete and replacement with air-entrained concrete. A minimum of one foot will be removed from damaged surfaces, normal for this type of work. Thin unreinforced sections each wall may need to be totally reconstructed. Such reconstruction would involve replacing a section of monolith beginning at the pipe gallery floor elevation and extending up to the top of the monolith. A total of 900' of wall has been identified as subject to such reconstruction, 600' in the land wall, 100' in the middle wall and 200' in the river wall. The primary purpose of this work is to protect the underlying deteriorated and cracked concrete from further damage by freeze-thaw and tow impacts.

The work items included in the rehabilitation are listed in Table 4 and described in detail in Attachment 3.

Table 4
Rehabilitation of Locks at L&D 4 in 2002

1. Replace land wall and middle wall building.
2. Replace upper guard wall.
3. Stabilize lower guide wall.
4. Rebuild portions of land wall, middle wall, and river wall pipe galleries.
5. Resurface top of lock walls.
6. Reface lock walls and install wall armor.
7. Reface and resurface guide and guard walls.
8. Install floating mooring bitts.
9. Rebuild top of miter and maintenance sills.
10. Replace miter gates.
11. Replace miter gate operating machinery.
12. Replace gate anchors and pintles.
13. Replace culvert valves and operating equipment.
14. Replace esplanade.
15. Install new hydraulic system.
16. Replace lock power and lighting system.
17. Replace air and water systems.
18. Replace tow haulage system.

The surface concrete applied in this rehabilitation will be considered reliable for about a 25 year period, normal for this type of work. Thereafter, additional work will be required. A second rehabilitation of the surface concrete would not provide for adequate reliability as substantial amounts of damaged non air-entrained concrete would remain in place. The only way to ensure that the project functions without incident during the second half of the analysis period is to schedule a complete replacement to be completed by 2027.

Three replacement alternatives were considered. Two would provide a single chamber, either a 56' x 720' or a 84' x 720'. As for Locks 3, both were eliminated. The 84' x 720' alternative was outside of existing authorities and the 56' x 720' was economically inferior due to high navigation delays resulting from traffic growth and river closures during maintenance work. One alternative that would provide 56' x 720' and 56' x 360' lock chambers was formulated that would allow navigation to use the large chamber at all times during construction. This alternative is analogous to the "replace-in-kind" alternative at Locks 3. There were no "rebuild-in-place" alternatives considered since, as at Locks 3, a temporary 56' x 720' lock chamber riverward of the existing river chamber would be required for such a strategy to be competitive with the "replace-in-kind" alternative. However, it is not possible to construct a 56' wide temporary chamber riverward of the existing river chamber without modifying the existing gated dam (the fixed weir riverward of the existing river wall is only 43'wide). As described below, Dam 4 is to be maintained throughout the analysis period and, therefore, modification for a temporary chamber is not considered to be structurally prudent. Consequently, a "replace-in-kind" strategy was selected to reconstruct Locks 4.

Locks 4 reconstruction would involve the extension of the existing "stub" river wall to full length to create a new river wall, founded on firm rock. The existing river wall and fixed weir that connects the stub wall to the existing river wall would be removed. A new middle wall would be constructed in the existing river chamber area to accommodate a new 56' x 720' river chamber. The existing middle wall would require stabilization once the concrete struts on the lock floor are removed and the river chamber dewatered. During these activities, traffic would be maintained in the 56' x 720' land chamber. Once the new river chamber is completed, the old 56' x 720' chamber would be closed and replaced with a new 56' x 360' chamber. The construction would include the removal of the existing middle wall and construction of a new land wall. New electrical, mechanical, hydraulic and water systems would be installed. A pervious backfill protected with stone slope protection would be placed between the new land wall and the existing land wall.

f. **Dam 4**

(1) Condition Summary

Dam 4 is in good condition with minor deficiencies including broken baffles and scoured derrick stone downstream of the dam. The scour may be caused by a higher than optimum elevation of the dam apron, a part of the original structure that was incorporated into the reconstructed dam.

(2) Potential Consequences

Due to its sound condition, no significant consequences are foreseen during the analysis period.

(3) Work Requirements

The broken baffles and worn derrick stone would be repaired during the rehabilitation of Locks 4 in 2002.

g. **Summary of Work Required in the "Without" Plan**

The timing and scale of work required to ensure that the Lower Monongahela River projects provide for safe and reliable navigation in the future are summarized in Table 5.

Table 5
Timing and Scale of Work in "Without" Plan

Project	Work Effort	Timing
L&D 2		
locks	rehab	2022
dam	replace	2002
L&D 3		
locks	replace	2002
dam	replace	2002
L&D 4		
locks	rehab/replace	2002/2027
dam	minor repairs	2002

h. **Non-Structural Measures in the "Without" Plan**

Even with the major work effort represented by the "without" plan, the small size of the locks at the projects would continue to cause navigation problems. As a result, a number of nonstructural measures were considered as means to increase the efficiency of the existing locks to process traffic. These measures included:

i) Use of of various lockage policies to maximize tonnage processed;

ii) Use of helper or switchboats to minimize processing times.

The existing condition includes different lockage policies at L&D 3 and L&D 4. Because of an unusually short upstream approach area, tows at L&D 3 are limited in length to those that can lock through the project in a single lockage operation. In effect, the operation is equivalent to ready-to-serve (RTS) which requires extensive use of towboats. There are no similar restrictions at L&D 4 and tows are allowed to double lock through the project.

With the replacement of L&D 3 in the "without" plan, the upstream approach area will be improved and large tows will be allowed to approach and double lock through the project. Since double locking is more cost effective than reconfiguring tows for single lockages at low levels of delay, it is expected that large tows will opt to double lock until delays become significant, at which time other policies may become more cost effective. Allowing double lockages at L&D 3 represents a non-structural measure that increases the efficiency of the system during the early years in the project life.

However, as traffic and delays increase over time, the cost effectiveness of the double lockage policy diminishes. A number of alternatives were explored to keep traffic moving without major delays. The alternatives included two types of helper boat operations and one type of change in operations. The helper boat operations differed according the extent they would be used to extract and remove barges from the lock: one plan had helper boats extracting barges from the lock and securing them along the lock wall for reassembly; the second plan had the helper boats extracting barges and removing them to reassembly areas away from the project. The change in operations involved a shuttle type of operation, whereby tows would downsize to pass through L&D 3, L&D 3 pool, and L&D 4 as small tows that could lock through the chambers in a single lockage, similar to what they are currently doing at L&D 3. Upon completion of the shuttle, the tows would be reconfigured into larger tows for the continuation of their journey. This type of operation was shown to increase the capacity of the system and to be more cost effective than either of the helper boat plans (NAVIGATION SYSTEMS ANALYSIS APPENDIX). Based on a timing analysis, it was included as part of the "without" plan.

The use of helper boats was also analyzed for L&Ds 3 and 4 during times when one of the chambers is closed for ordinary maintenance and repairs. The results indicated that helper boats are justified when the main chambers are closed and all traffic must pass through the auxiliary. Based on the economic analysis, helper boats were incorporated as part of the "without" plan during closures beginning in the year 2002. The analysis and results of the evaluation of nonstructural measures is described in detail in the NAVIGATION SYSTEMS ANALYSIS APPENDIX. The timing and type of non-structural actions that were included as part of the "without" plan are summarized in Table 6.

Table 6
Non-Structural Measures in "Without" Plan

Project	Measure	Timing
L&D 3	1. Change lockage policy to double lockages	2002
	2. Use helper boats during closure of main	2002
	3. Change to Lower Mon ready-to-serve	2016
L&D 4	1. Use helper boats during closure of main	2002
	2. Change to Lower Mon ready-to-serve	2016

i. **Other Components of the "Without" Plan**

The development of the "without" plan includes several general assumptions concerning the inland waterway navigation system. These are:

(1) All existing waterway projects or those under construction are considered to be in place and will be operated and maintained through the period of analysis. New locks include those at Gallipolis and Olmsted on the Ohio, L&Ds 7 and 8 on the Monongahela, and Winfield on the Kanawha.

(2) Waterway user taxes would continue in the form of the towboat fuel tax prescribed by Title XIV of Public Law 99-662, the Water Resources Development Act of 1986.

(3) Alternative surface transportation systems are assumed to have sufficient capacity to move future traffic at current rates.

(4) Preventive maintenance policy measures for navigation projects are assumed to be in place over the period of analysis. The goal of this policy is to improve the dependability and reliability of the navigation system by minimizing unexpected and unplanned outages. This would be accomplished through a regular schedule of inspections and maintenance.

(5) All reasonable nonstructural measures for improving lock efficiency that are within the purview of the Corps were assumed to implemented at the appropriate time. Generally, these consist of either the use of helper boats or specific lockage policies at projects where they were shown to be justified.

j. **Evaluation of "Without" Plan**

The "without" plan for the Lower Monongahela River is an amalgamation of structural and non-structural measures that allow navigation to continue at about current levels of efficiency for the first half of the period of analysis and at a diminished level of efficiency for the remaining time. Construction and rehabilitation solve the structural problems, but not the navigation problems. Non-structural measures such as changes in lockage policies and the use of helper boats help defer the time when delays become significant, but do not eliminate delay problems over the period of analysis. Moreover, the use of helper boats further complicates traffic congestion problems in the area. Despite this, the "without" plan is justified by the benefits it provides in the form of continued navigation service. As shown in Table 7, the benefits exceed the costs by a ratio of 4.7 to 1.

Table 7
Benefits and Costs of "Without" Plan
(Millions of October 1991 Dollars; 8 3/4 %)

Benefits	265.8
Costs	56.1
Net Benefits	209.7
B/C Ratio	4.7

Note: Average Annual Values.

k. **Mon-Upper Ohio System Analysis**

Benefits provided by the Lower Monongahela River projects are contingent upon the provision of adequate navigation service at projects elsewhere on the river system. The system that defines the area of principal traffic flows of Lower Monongahela River traffic is the entire Monongahela River and the upper portion of the Ohio River within the Pittsburgh District. Approximately 90 percent of Lower Monongahela traffic moves entirely within this area.

In order to continue to provide navigation service on this "system", some type of major maintenance, rehabilitation or replacement will be required at nearly all of the projects at sometime in the future. To determine if this work is justified, the annual costs necessary to continue the operation and maintenance of the system were estimated and compared to the annual benefits provided by the system. This can be viewed as an analysis of the "Without Project Condition for the System."

Expenditures at the projects were considered for the period extending from 1994 though 2051, with all costs discounted to the year 2002 equivalents in order to be consistent with figures in the Lower Monongahela Feasibility Report. Costs were estimated at October 1991 price levels. The discount rate was 8 3/4%.

Maintenance of the system will require the reconstruction of major portions of L&Ds 2, 3, and 4 over the 1996 to 2004 time period with other rehabilitation and replacement work scheduled further in the future. In addition, it is expected that major portions of the three Upper Ohio River projects, Emsworth, Dashields, and Montgomery, will need to be replaced over the 2020 to 2035 time period.

Rehabilitations and repairs during the time period 1994-2015 are included as indicated in the ORD MAJOR REHABILITATION SCHEDULE, dated 11 September 1991. Other rehabilitations are scheduled when projects are about 60 years old. The work items and time schedules necessary to ensure continued operation of the system are listed in Table 8.

All types of expenditures were considered, including ordinary operations and maintenance, and extraordinary maintenance, as well as rehabilitation and replacement costs. Costs for the Lower Monongahela River projects are those that appear in the Feasibility Report. Costs for other items were either estimated by Engineering Division or by Planning Division based on Engineering Division costs for similar items.

Costs for the work necessary for the continued operation of the system are listed in Table 8. The present worth and annual equivalent of each cost are also included, along with annual Operation and Maintenance (O&M) costs. O&M costs were based on the most recent expenditures at the projects and modified to account for the scheduled major rehabilitation or replacement.

Benefits provided by the "system" were estimated by the Navigation Planning Center in Huntington, WV, using the same system models and inputs as used in the Lower Monongahela River study. The estimated benefits of the navigation system are $777.5 million.

TABLE 8
AVERAGE ANNUAL COSTS FOR THE
MONONGAHELA AND OHIO RIVER SYSTEM (1)
DURING THE PERIOD 1994-2052 WITH BASE YEAR 2002
(Cost in Millions)
October 1991 Cost Levels

Structure	Orig Const	Future Action Item	Year(s)	Const Cost (2)	Pres Worth Total	Ann Equiv of Pres Worth	Oper & Maint L/D	Total Aver Ann Cost L/D
Tygart Lake	1938	Rehabilitate Dam	1994-1998	$ 15.0 (3)	$24.0	$2.1	$0.9	$ 3.1
		Rehabilitate Dam	2034-2038	15.0 (3)	0.6	0.1		
Opekiska L&D	1967	Rehabilitate L&D	2028-2029	45.0	4.7	0.4	0.5	0.9
Hildebrand L&D	1960	Rehab. Dam Gates & Machinery	2007-2011	10.0	4.5	0.4	0.6	2.0
		Rehabilitate Locks	2018-2019	40.0	11.4	1.0		
Morgantown L&D	1950	Replace Lock Gates Machinery	2004-2007	10.0	7.2	0.7	0.7	3.3
		Construct Emerg. Closure	2005-2007	5.0	3.4	0.3		
		Rehab. Dam Gates & Machinery	2007-2011	10.0	5.4	0.5		
		Rehabilitate Locks	2016-2017	40.0	12.3	1.1		
Point Marion Lock	1996	None Necessary	-	-	-	-	0.8	0.9
Point Marion Dam	1959	Rehabilitate Dam	2024-2025	10.0	1.5	0.1		
Grays Landing L&D	1995	None Necessary	-	-		-	0.8	0.8
Maxwell L&D	1963	Rehabilitate L&D	2028-2030	75.0	7.5	0.7	1.2	1.9
Mon Locks 4	1932	Rehabilitate Locks (4)	2000-2002	48.7	50.9	4.5	1.1	8.7
		Replace Locks (4)	2023-2037	229.7	34.5	3.1		
Mon L&D 3	1907	Replace L&D In-Kind (4)	1997-2002	283.2	355.4	31.6	1.1	32.7
Mon Dam 2	1906	Replace Dam In-Kind (4)	1996-2000	57.1	69.4	6.2	1.1	8.4
Mon Locks 2	1953	Rehabilitate Locks (4)	2020-2022	56.9	12.1	1.1		
Lower Mon	-	Other-Primarily PED (4)	1996-2022	63.7	69.2	6.1	-	6.1

(1) The Ohio River System is defined as the upper portion of the river incl. Emsworth, Dashields, Montgomery, New Cumberland, Pike Island and Hannibal L&Ds.
(2) Cost Incluses 17.5 % E&D and Const. Mgmt. (3) Const. Cost is $40M with 40% of total cost allocated to navigation.
(4) Components of the "Without Project Condition" defined for Mon L/Ds 2, 3 and 4.

TABLE 8

AVERAGE ANNUAL COSTS FOR THE

MONONGAHELA AND OHIO RIVER SYSTEM (1)

DURING THE PERIOD 1994-2052 WITH BASE YEAR 2002

(Cost in Millions)

October 1991 Cost Levels

(Cont.)

Structure	Orig Const	Future Action Item	Year(s)	Const Cost (2)	Pres Worth Total	Ann Equiv of Pres Worth	Oper & Maint L/D	Total Aver Ann Cost L/D
Emsworth Dams	1938	Rehabilitate Dams	1994-2001	$ 50.0	$71.2	$6.4	$1.7	$18.8
Emsworth Locks	1922	Rehab. Filling/Emptying System	1996-2001	20.0	26.0	2.3		
		Repair Lockwalls	1998-2000	5.0	6.2	0.6		
		Replace Locks and Main Channel Dam, Restore Back Channel Dam	2028-2029	485.0	87.5	7.8		
Dashields L&D	1929	Rehab. Filling/Emptying System	2001-2005	15.0	13.3	1.2	1.5	5.4
		Replace L&D In-Kind	2025-2029	260.0	30.8	2.7		
Montgomery L&D	1936	Rehabilitate Dam	2000-2006	30.0	24.7	2.2	1.6	10.0
		Rehab. Filling/Emptying System	2000-2004	15.0	13.3	1.2		
		Replace L&D In-Kind	2030-2034	715.0	55.8	5.0		
New Cumberland L&D	1963	Repair Dam/Abutment	2009-2013	15.0	6.8	0.6	1.5	3.3
		Rehabilitate L&D	2023-2025	90.0	13.7	1.2		
Pike Island L&D	1932	Rehabilitate Dam	2011-2015	15.0	5.8	0.5	1.4	2.7
		Rehabilitate Locks	2026-2028	75.0	8.9	0.8		
Hannibal L&D	1975	Rehabilitate L&D	2035-2037	90.0	5.0	0.4	1.3	1.7

(1) The Ohio River System is defined as the upper portion of the river incl. Emsworth, Dashields, Montgomery, New Cumberland, Pike Island and Hannibal L&Ds.

(2) Cost Incluses 17.5 % E&D and Const. Mgmt.

The benefits provided by the system are $778 million annually. The comparable annual costs are $111 million. The difference, or net benefits, are $667 million, and the benefit to cost ratio is 7.0 to 1 (Table 9). The results clearly indicate that continued operation of the system is economically justified.

Table 9
Benefits and Costs of "System"
(Millions of October 1991 Dollars; 8 3/4%)

Benefits	$777.5
Costs	110.7
Net Benefits	666.8
B/C Ratio	7.0

3. DEVELOPMENT OF ALTERNATIVE REPLACEMENT PLANS

a. General

Because of the high cost of maintaining the existing system and forecasts that navigation problems would become increasingly severe over time, alternative replacement plans were developed and evaluated for the lower river to determine if solutions to these residual navigation problems were justified. The development of these alternatives and their reduction down to a final array of plans was accomplished through an iterative process. The process consisted of determining the potential replacement sites for each lock and dam project as well as sites to replace two projects with one project. The potential sites and their possible use in navigation plans were used to develop an array of project variations, which were screened based on costs and navigability considerations. The process concluded with the formulation and refinement of replacement plans, each comprised of two or three navigation projects.

b. Site Selection

The entire 41.5 mile stretch of the lower Monongahela River from the "Point" in Pittsburgh, Pa. to L&D 4 was examined for possible project sites. Selection of a site was based on a number of criteria including approach conditions, shoreside development at the site, and shoreside development along the pool. A straight approach of approximately one-half mile was the desirable minimum both upstream and downstream of a project, but is especially critical upstream because river currents make it more difficult to control tows moving with the currents, particularly during high water. Also of considerable importance in the site selection process was potential interference in lock approaches due to the existence of docks, launching ramps, bridges, etc. Ease of vehicular access to the site was also considered as was shoreside development along the navigation pool, particularly if a project site would require relocations or cause increased flooding in the area because of a change in pool.

Thirteen potential project sites were identified as a result of this effort (Table 10). Several sites were considered as possible replacement sites for more than one project and as parts of plans to eliminate projects. Six sites were designated as possible replacement locations for L&D 2, seven sites for L&D 3, and three sites for L&D 4. In addition, three sites were identified as possible sites for one project to replace the two projects at L&Ds 2 and 3, and three sites for one project to replace the two projects at L&Ds 3 and 4. Although the twisting Monongahela River does not offer many reasonable replacement sites for a locks and dam project, the identified replacement sites offer a range of reasonable alternatives. Potential sites are depicted on Plates 1-5 in Attachment 4.

Table 10
Potential Project Sites

	Site (r.m.)	L&D 2	L&D 3	L&D 4	L&Ds 2 and 3	L&Ds 3 and 4
1	4.5	x				
2	6.9	x				
3	11.2	x			x	
4	12.3	x				
5	17.8	x	x		x	
6	22.2	x	x		x	
7	23.8		x			
8	24.6		x			
9	26.1		x			
10	26.8		x			x
11	30.7		x	x		x
12	34.0			x		x
13	41.5			x		

Note: x indicates consideration.

A more detailed description of the evaluation of alternative replacement sites is provided in the following paragraphs. The pool changes specified account for the retention of the Emsworth design pool elevation of 710.0 and Pool 4 design elevation of 743.5.

(1) L&D 2 Replacement Sites

i) r.m. 4.5 Site. - The locks would be located on the right bank within a 1.5 mile stretch of straight river (r.m. 3.5 to r.m. 5.0). The line of sight in the upstream approach extends for only approximately .4 of a mile and is located on the inside of a right hand curve causing unsafe cross currents for the tows approaching the lock. The downstream approach would be adequate with a line of sight of .5 of a mile. Vehicular access would have to be attained through an LTV Coking facility and would require passage over a number of tracks of the Monongahela Connecting Railroad. The coal dock for the coking plant, located in the downstream approach, would have to be relocated.

With the replacement of Locks and Dam 2 at this site, the pool would be raised 8.7 feet from this location to existing Locks and Dam 2 at r.m. 11.2 assuming no change to Pool 2. A number of docks, ramps and outfalls as well as the communities of Homestead, Rankin, Braddock and the City of Pittsburgh would be affected by this raise in pool elevation.

Disruption of existing navigation traffic during construction of the locks and dam would be minimal.

ii) r.m. 6.9 Site. - The right bank locks would be located within a straight stretch of river that extends from r.m. 6.2 to r.m. 7.6. The upstream approach includes approximately .5 of a mile of a straight line of sight and comes out of a left-hand curve and through the navigation span of a highway bridge. The downstream approach would provide a line of sight of approximately .6 of a mile after traversing two structures (one highway bridge and one railroad bridge). Vehicular access would have to be built along the Chessie Railroad tracks either landward or riverward and would require one railroad crossing. The Chessie Railroad river/rail transloading dock in the downstream approach would require relocation.

Replacing Locks and Dam 2 at this site would require the pool to be raised 8.7 feet from r.m. 6.9 to r.m. 11.2 assuming no change to Pool 2. Riverside docks, ramps and outfalls as well as the communities of Homestead, Rankin, Braddock and the City of Pittsburgh would be affected by this pool elevation raise.

Existing navigation traffic would have to exercise some caution but would experience minimal delays during construction of the locks. The locks cofferdam would be located within .3 mile of the bridge channel span in the upstream end of the locks.

iii) r.m. 11.2 Site. - The existing locks for Locks and Dam 2 are located on the right bank. The locks are relatively new and require only a rehabilitative effort in the near future. The existing upper approach is maintained through two railroad bridges whose channel span are located on the right bank and furnishes a line of sight of approximately 1.3 miles. The downstream approach gives a line of sight of approximately .6 of a mile. Existing vehicular access would be maintained but the existing aged dam requires replacement.

With the replacement of the dam only at this site as a Locks and Dam 2 replacement option with a new fixed crest dam, the pool would remain unchanged.

Disruption of existing navigation traffic would be non-existent during construction of the dam but would be encountered during the rehabilitation of the locks.

iv) r.m. 12.3 Site. - The locks would be located along the right bank within a 1.4 mile straight stretch of river that extends from r.m. 11.5 to r.m. 12.9. The line of sight in the upstream approach extends for approximately .8 of a mile after coming out of the outside of a gradual left hand curve. The downstream approach would provide a line of sight of approximately 1.5 miles. The Union Railroad river/rail transloading dock on the abutment side of the river would require relocation. Vehicular access to the locks would have to be made over a very steep terrain and over numerous railroad tracks in the U.S.X. railroad yard, the P&LE Railroad and the Chessie Railroad mainlines.

Replacing Locks and Dam 2 at this site would require the pool to be lowered 8.7 feet from existing Locks and Dam 2 (r.m. 11.2) to r.m. 12.3. One dock (Union RR) would be affected by the pool lowering and some dredging would also be needed to maintain a navigable channel.

Existing navigation traffic would experience delays and would have to exercise extreme caution during construction of the locks. Because of the locks cofferdam the tows would be required to go from mid channel to the right bank channel spans of the two railroad bridges in a very short distance. Once they reached the channel spans they would then have to flank to approach existing locks 2. This maneuver, required during the locks and dam construction, would be very slow.

v) r.m. 17.8 Site. - The right bank locks would be located on the inside of a right hand curve that extends from r.m. 17.4 to r.m. 18.5. The line of sight in the upstream approach extends for only approximately .4 of a mile. Unsafe cross currents, although dissipating as tows approach the lock, would be encountered. The downstream approach provides a line of sight of only approximately .4 of a mile. The St. Clair Supply Co. dock would be interfering with the downstream approach and would require relocation. Access to the locks could be attained via an existing road to the river downstream of the locks and then constructed along the river.

The replacement of Locks and Dam 2 at this site would require the lowering of Pool 2 by 8.7 feet from r.m. 11.2 to r.m. 17.8. Docks, mooring areas, water intakes, ramps, parks, marinas and outfalls would be affected by the pool lowering. To continue to maintain a navigable channel for navigation, where the pool would be lowered, dredging would be necessary.

Disruption of existing navigation traffic during construction of the locks and dam would be minimal.

vi) r.m. 22.2 Site. - The locks would be located along the left bank within a 1.5 mile straight stretch of river that extends from r.m. 21.5 to r.m. 23.0. The line of sight in the upstream approach extends for over 1.5 miles while the downstream approach extends for approximately .4 of a mile. The Howell Bros. dock and Consol's mooring area would require relocation because of their location in the upstream approach. Vehicular lock access would require the construction of an access road out of West Elizabeth along the river for approximately .5 of a mile. Consolidation Coal Co. dock on the abutment side would need to be relocated.

With the replacement of Locks and Dam 2 at this site, Pool 2 would be lowered 8.7 feet from existing Locks and Dam 2 (r.m.11.2) to r.m. 22.2. A number of docks, mooring areas, ramps, water intakes, marinas, and outfalls would be affected by the pool lowering. Dredging would be needed to maintain a navigable channel where the pool was lowered.

During construction of the locks and dam, disruption of existing navigation traffic would be minimal.

(2) L&D 3 Replacement Sites

i) r.m. 17.8 Site. - The right bank locks would be located on the inside of a right hand curve that extends from r.m. 17.4 to r.m. 18.5. The line of sight in the upstream approach extends for only approximately .4 of a mile. Unsafe cross currents, although dissipating as tows approach the lock, would be encountered. The downstream approach provides a line of sight of only approximately .4 of a mile. The St. Clair Supply Co. dock would be interfering with the downstream approach and would require relocation. Access to the locks could be attained via an existing road to the river downstream of the locks and then constructed along the river.

With the replacement of Locks and Dam 3 at this site, existing Pool 2 from r.m. 17.8 to existing Locks and Dam 3 (r.m. 23.8) would be increased by 8.2 feet assuming no change to Pool 3. Docks, mooring areas, water intakes, ramps, parks, marinas and outfalls would be affected by the pool raise. The communities of Glassport, Clairton, and Elizabeth would also be effected.

Disruption of existing navigation traffic during construction of the locks and dam would be minimal.

ii) r.m. 22.2 Site. - The locks would be located along the left bank within a 1.5 mile straight stretch of river that extends from r.m. 21.5 to r.m. 23.0. The line of sight in the upstream approach extends for over 1.5 miles while the downstream approach extends for approximately .4 of a mile. The Howell Bros. dock and Consol's mooring area would require relocation because of their location in the upstream approach. Vehicular lock access would require the construction of an access road out of West Elizabeth along the river for approximately .5 of a mile. Consolidation Coal Co. dock on the abutment side would need to be relocated.

The replacement of Locks and Dam 3 at this site would require raising Pool 2, 8.2 feet from r.m. 22.2 to r.m. 23.8 assuming no change to Pool 3. A number of docks, mooring areas, ramps, water intakes, marinas, and outfalls would be affected by the pool raise as well as the community of Elizabeth.

During construction of the locks and dam, disruption of existing navigation traffic would be minimal.

iii) r.m. 23.8 Site. - The new locks would be located on the right bank where the existing locks are now located. The upstream approach would remain unchanged with a line of sight of .8 of a mile coming out of a gradual right hand curve. The downstream approach would provide a line of sight of approximately 2 miles. The existing vehicular access would be maintained.

Existing navigation traffic would experience some delays and would have to exercise some caution during the construction of the locks. One lock chamber would be open to traffic at all times.

iv) r.m. 24.6 Site. - The right bank locks, located on a jut of land, would be located within a straight stretch of river that extends from r.m. 22.5 to r.m. 25.5. The upstream approach includes approximately a 1 mile line of sight coming out of a very very gradual left hand curve. The downstream approach gives a very adequate 1.8 mile line of sight. Vehicular access would be excellent with the close proximity to a highway along the river but would have to attain a crossing over the P&LE railroad. The Ashland Oil Co. dock would require relocation upstream because of its location within approximately 200 feet of the upstream side of the dam. The Lock 3 Coal, Gas & Oil dock would also require relocation because of being in the upstream lock approach.

Replacing Locks and Dam 3 at this site would require the pool to be lowered 8.2 feet from existing Locks and Dam 3 (r.m. 23.8) to r.m. 24.6 assuming no change to Pool 2. One dock and one marineways would be affected by the pool lowering and some dredging would also be needed to maintain a navigable channel.

Disruption of existing navigation traffic during construction of the locks and dam would be minimal.

v) r.m. 26.1 Site. - The locks would be located along the left bank within a 1.3 mile straight stretch of river that extends from r.m. 25.3 to r.m. 26.6. The locks are located on the inside of a left hand curve. Although the line of sight in the upstream approach extends for approximately 1.5 miles, the approach would contain hazardous cross currents. The downstream approach extends for approximately .6 of a mile. Although the Duquesne Light Co. dock in the downstream approach would not require relocation, its proximity could cause some additional approach time for upbound tows. A marina located on the opposite bank and just .3 of a mile above the dam would require relocation further upstream. Vehicular lock access would be very difficult to attain with the access road be constructed over numerous railroad tracks including Conrail's mainline.

With the replacement of Locks and Dam 3 at this site, Pool 3 would be lowered 8.2 feet from r.m. 23.8 (existing Locks and Dam 3) to r.m. 26.1 assuming no change to Pool 2. A number of docks, and water intakes as well as a mooring area and marineway would be affected by the pool lowering. Dredging would also be required to maintain a navigable channel.

There would be minimal disruption of existing navigation traffic during construction of the locks and dam.

vi) r.m. 26.8 Site. - The locks would be located along the left bank within a 1.5 mile straight stretch of river that extends from r.m. 26.0 to r.m. 27.5. The upstream approach includes approximately a 1 mile line of sight. The downstream approach provides a line of sight of approximately .8 of a mile. Vehicular access would be very difficult to attain requiring the crossing of numerous railroad tracks including Conrail's mainline.

With the replacement of Locks and Dam 3 at this site, Pool 3 would be lowered 8.2 feet from existing Locks and Dam 3 (r.m. 23.8) to r.m. 26.8 assuming no change to Pool 2. A number of docks and water intakes as well as a marina, mooring area and marineway would be affected by the pool lowering. To maintain a navigable channel, dredging would be necessary.

Disruption of existing navigation traffic during construction of the locks and dam would be minimal.

vii) r.m. 30.7 Site. - The right bank locks would be located within a 2 mile straight stretch of river that extends from r.m. 29.8 to r.m. 31.8. The line of sight in the upstream approach extends for .9 of a mile coming out of a gradual left hand curve and creating unsafe cross currents. The downstream approach provides a .6 of a mile line of sight. Vehicular lock access would be attained from a elevated highway in close proximity and would require a crossing of the P&LE railroad.

The replacement of Locks and Dam 3 at this site would require the lowering of Pool 3 by 8.2 feet from r.m. 23.8 to r.m. 30.7 assuming no change to Pool 2. Docks, mooring areas, water intakes, ramps, marinas and outfalls would be affected by the pool lowering. To continue to maintain a navigable channel, where the pool would be lowered, dredging would be necessary.

(3) L&D 4 Replacement Sites

i) r.m. 30.7 Site. - The right bank locks would be located within a 2 mile straight stretch of river that extends from r.m. 29.8 to r.m. 31.8. The line of sight in the upstream approach extends for .9 of a mile coming out of a gradual left hand curve and creating unsafe cross currents. The downstream approach provides a .6 of a mile line of sight. Vehicular lock access would be attained from a elevated highway in close proximity and would require a crossing of the P&LE railroad.

With the replacement of Locks and Dam 4 at this site, existing Pool 3 from r.m. 30.7 to existing Locks and Dam 4 (r.m. 41.5) would be increased by 16.6 feet. A highway bridge and numerous docks, mooring areas, water intakes, ramps, marinas and outfalls would be affected by the pool raise. The communities of New Eagle, Monongahela, Donora, Webster, Monessen, North Charleroi, and Charleroi would also be affected.

Disruption of existing navigation traffic during construction of the locks and dam would be minimal.

ii) r.m. 34.0 Site. - The locks would be located on the right bank within a 1.5 mile straight stretch of river that extends from r.m. 33.5 to r.m. 35.0. The upstream approach includes approximately a 1 mile line of sight. The downstream approach extends for approximately .8 of a mile. Forward Township Park and launching ramp is located in the area of the proposed locks and would require relocation. Vehicular access would be attained easily with an existing road off State Route 136 and utilizing an existing crossing of the P&LE Railroad.

With the replacement of Locks and Dam 4 at this site, Pool 3 would be raised 16.6 feet from r.m. 34.0 to r.m. 41.5 (existing Locks and Dam 4). A highway bridge, docks, mooring areas, ramps, water intakes, marinas and outfalls would be affected by the pool raise. The communities of Donora, Webster, Monessen, North Charleroi, and Charleroi would also be affected by a raise in pool.

There would be minimal disruption of existing navigation traffic during construction of the locks and dam.

iii) r.m. 41.5 Site. - The new locks would be located on the right bank where the existing locks are now located. The upstream approach would remain unchanged with a line of sight of approximately 1 mile. The downstream approach would provide a line of sight of approximately .4 of a mile and would be traversing the navigation span of one highway bridge. The existing vehicular access would be maintained.

The pool would remain unchanged with the replacement of the locks only at this site.

Existing navigation traffic would experience some delays and would have to exercise some caution during the construction of the locks. One lock chamber would be open to traffic at all times.

(4) L&Ds 2 & 3 Replacement Sites

i) r.m. 11.2 Site. - The existing locks for Locks and Dam 2 are located on the right bank. The locks are relatively new and require only a rehabilitative effort in the near future. The existing upper approach is maintained through two railroad bridges whose channel span are located on the right bank and furnishes a line of sight of approximately 1.3 miles. The downstream approach gives a line of sight of approximately .6 of a mile. Existing vehicular access would be maintained but the existing aged dam requires replacement.

The replacement of Locks and Dams 2 & 3 at this site would most likely require a new gated dam at Locks and Dam 2 and the removal of Locks and Dam 3. A railroad bridge and a number of docks, mooring areas, ramps, water intakes, marinas, and outfalls as well as the communities of Duquesne, McKeesport, Glassport, Clairton, Elizabeth, New Eagle, Donora, Webster, Monessen and North Charleroi would be affected by the pool raising and/or lowering. Some dredging would also be required to maintain a navigable channel.

Disruption of existing navigation traffic would be non-existent during construction of the dam but would be encountered during the rehabilitation of the locks.

ii) r.m. 17.8 Site. - The right bank locks would be located on the inside of a right hand curve that extends from r.m. 17.4 to r.m. 18.5. The line of sight in the upstream approach extends for only approximately .4 of a mile. Unsafe cross currents, although dissipating as tows approach the lock, would be encountered. The downstream approach provides a line of sight of only approximately .4 of a mile. The St. Clair Supply Co. dock would be interfering with the downstream approach and would require relocation. Access to the locks could be attained via an existing road to the river downstream of the locks and then constructed along the river.

The replacement of Locks and Dams 2 & 3 with one structure at this site would require a lowering of Pool 2 by 8.7 feet from existing Locks and Dam 2 (r.m. 11.2) to r.m. 17.8 and a raising of the pool by 8.2 feet from r.m. 17.8 to existing Locks and Dam 3 (r.m. 23.8) assuming no change in Pool 3. Docks, mooring areas, water intakes, ramps, parks, marinas and outfalls would be affected by the pool raising and lowering. The communities of Glassport, Clairton, and Elizabeth would also be affected by the pool raise. To continue to maintain a navigable channel, where the pool would be lowered, dredging would be necessary.

Disruption of existing navigation traffic during construction of the locks and dam would be minimal.

iii) r.m. 22.2 Site. - The locks would be located along the left bank within a 1.5 mile straight stretch of river that extends from r.m. 21.5 to r.m. 23.0. The line of sight in the upstream approach extends for over 1.5 miles while the downstream approach extends for approximately .4 of a mile. The Howell Bros. dock and Consol's mooring area would require relocation because of their location in the upstream approach. Vehicular lock access would require the construction of an access road out of West Elizabeth along the river for approximately .5 of a mile. Consolidation Coal Co. dock on the abutment side would need to be relocated.

The replacement of Locks and Dam 2 & 3 at this site would require a pool lowering of 8.7 feet from r.m. 11.2 to r.m. 22.2 and then a pool increase of 8.2 feet from r.m. 22.2 to r.m. 23.8 assuming no change in Pool 3. A number of docks, mooring areas, ramps, water intakes, marinas, and outfalls would be affected by the pool raising and lowering. The community of Elizabeth would also be affected by a pool raise. Dredging would be needed to maintain a navigable channel where the pool was lowered.

During construction of the locks and dam, disruption of existing navigation traffic would be minimal.

(5) L&Ds 3 & 4 Replacement Sites

i) r.m. 26.8 Site. - The locks would be located along the left bank within a 1.5 mile straight stretch of river that extends from r.m. 26.0 to r.m. 27.5. The upstream approach includes approximately a 1 mile line of sight. The downstream approach provides a line of sight of approximately .8 of a mile. Vehicular access would be very difficult to attain requiring the crossing of numerous railroad tracks including Conrail's mainline.

With the replacement of Locks and Dam 3 & 4 at this site, Pool 3 would be lowered 8.2 feet from existing Locks and Dam 3 (r.m. 23.8) to r.m. 26.8 assuming no change in Pool 2 and raised 16.6 feet from r.m. 26.8 to existing Locks and Dam 4 (r.m. 41.5). A highway bridge, docks, mooring areas, water intakes, ramps, marinas, and outfalls would be affected by the pool raising and lowering. The communities of New Eagle, Monongahela, Donora, Webster, Monessen, North Charleroi, and Charleroi would also be affected by a pool raise. To maintain a navigable channel, dredging would be necessary.

Disruption of existing navigation traffic during construction of the locks and dam would be minimal.

ii) r.m. 30.7 Site. - The right bank locks would be located within a 2 mile straight stretch of river that extends from r.m. 29.8 to r.m. 31.8. The line of sight in the upstream approach extends for .9 of a mile coming out of a gradual left hand curve and creating unsafe cross currents. The downstream approach provides a .6 of a mile line of sight. Vehicular lock access would be attained from a elevated highway in close proximity and would require a crossing of the P&LE railroad.

The replacement of Locks and Dams 3 & 4 with one structure at this site would require the lowering of Pool 3 by 8.2 feet from existing Locks and Dam 3 (r.m. 23.8) to r.m. 30.7 assuming no change in Pool 2 and raising by 16.6 feet from r.m. 30.7 to existing Locks and Dam 4 (r.m. 41.5). A highway bridge, and numerous docks, mooring areas, water intakes, ramps, marinas, and outfalls would be affected by the pool raising and lowering. The communities of New Eagle, Monongahela, Donora, Webster, Monessen, North Charleroi, and Charleroi would also be affected by a pool raise. To maintain a navigable channel, dredging would be necessary.

Disruption of existing navigation traffic during construction of the locks and dam would be minimal.

iii) r.m. 34.0 Site. - The locks would be located on the right bank within a 1.5 mile straight stretch of river that extends from r.m. 33.5 to r.m. 35.0. The upstream approach includes approximately a 1 mile line of sight. The downstream approach extends for approximately .8 of a mile. Forward Township Park and launching ramp is located in the area of the proposed locks and would require relocation. Vehicular access would be attained easily with an existing road off State Route 136 and utilizing an existing crossing of the P&LE Railroad.

With the replacement of Locks and Dam 3 and 4 at this site with a single structure, Pool 3 would be lowered 8.2 feet from r.m. 23.8 (existing Locks and Dam 3) to r.m. 34.0 assuming no change in Pool 2 and then raised 16.6 feet to r.m. 41.5. A highway bridge, docks, mooring areas, ramps, water intakes, marinas and outfalls would be affected by the pool raising and lowering. The communities of Donora, Webster, Monessen, North Charleroi, and Charleroi would also be affected by a raise in pool. Dredging would be necessary, where the pool level was lowered, to continue to maintain a navigable channel.

There would be minimal disruption of existing navigation traffic during construction of the locks and dam.

c. **Development and Screening of Project Variations**

A total of 39 project variations were developed using the 13 sites. A "project variation" is specified by dam type and other design features relating primarily to pool changes. All sites included at least two project variations, one with a fixed crest dam and one with a gated dam, with three exceptions: 1) the existing site of L&D 3 (r.m. 23.8); 2) a potential site at r.m. 24.6, and; 3) at the existing site of L&D 4 (r.m. 41.5). At the former two sites, a fixed crest dam was determined to be the most cost effective replacement alternative while at the latter, the existing gated dam was utilized. All of the variations included twin 84' x 720' locks at L&Ds 3 and 4.

Costs were estimated for each of the project variations with the results listed in Table 11. For example, there were six project variations for the r.m. 17.8 site (a fixed crest dam and a gated dam as replacements for L&D 2, L&D 3 and L&Ds 2 and 3). In conjunction with a consideration of river bank developments affected by the pool level changes and general navigation conditions, the costs were used to eliminate project variations. As a result, 14 of the 39 project variations were eliminated and 25 were retained. The project variations that were eliminated as a result of this effort are indicated in the table by an asterisk (*) following the cost estimate. The project variations are illustrated in PLATES 6 through 18 in Attachment 4.

Table 11
Locations and Cost Estimates for Project Variations
(Millions of October 1991 Dollars; 8 3/4 %)

Location - (r.m.)		Type of Dam	Locks and Dam 2	Locks and Dam 3	Locks and Dam 4	Locks and Dams 2&3	Locks and Dams 3&4
			Preliminary Project Costs				
1	4.5	Fixed Crest	385 *				
		Gated	315				
2	6.9	Fixed Crest	275 *				
		Gated	265				
3	11.2	Fixed Crest	90				
		Gated				350	
4	12.3	Fixed Crest	380				
		Gated	385 *				
5	17.8	Fixed Crest	280	280		335	
		Gated	300 *	275		330	
6	22.2	Fixed Crest	355 *	325		395	
		Gated	395 *	335		405	
7	23.8	Fixed Crest		390			
8	24.6	Fixed Crest		390			
9	26.1	Fixed Crest		365			
		Gated		425 *			
10	26.8	Fixed Crest		345			530 *
		Gated		385 *			470
11	30.7	Fixed Crest		240	370 *		420 *
		Gated		270 *	295		315
12	34.0	Fixed Crest			395 *		460 *
		Gated			280		350
13	41.5	Existing Gated			195		

Note: * indicates eliminated from consideration.

d. **Modeling of Project Variations for Navigation**

The project variations were evaluated for navigability using a tow simulation model developed by the Hydraulics Laboratory, Waterway Experiment Station (WES) located in Vicksburg, Mississippi. The model was operated by pilots from the Pittsburgh area to obtain navigational entrance conditions for each modeled site.

The project variations modeled by WES are indicated in Table 12 by an "x". Five alternatives were modeled for L&D 2, eight for L&D 3, three for L&D 4, four for single projects to replace L&Ds 2 and 3, and two to replace both L&Ds 3 and 4. Utilizing the results of the tests and pilot's comments about each modeled site, eleven project variations were retained for further analysis. The 14 project variations projects eliminated as a result of WES modeling are indicated by an "*" in the table.

Table 12
Project Variations modeled by WES

Location (r.m.)		- Type of Dam	Locks and Dam 2	Locks and Dam 3	Locks and Dam 4	Locks and Dams 2&3	Locks and Dams 3&4
1	4.5	Gated	x *				
2	6.9	Gated	x *				
3	11.2	Fixed Crest	x				
		Gated				added	
4	12.3	Fixed Crest	x				
5	17.8	Fixed Crest	x *	x *		x *	
		Gated		x *		x *	
6	22.2	Fixed Crest		x		x	
		Gated		x		x	
7	23.8	Fixed Crest		added			
8	24.6	Fixed Crest		x			
9	26.1	Fixed Crest		x *			
10	26.8	Fixed Crest		x			
		Gated					x
11	30.7	Fixed Crest		x *			
		Gated			x *		x*
12	34.0	Gated			x		added
13	41.5	Existing Gated			x		

Note: * indicates eliminated from consideration.
added indicates not modeled by WES.

Because of the iterative nature of the planning process, three project variations were added after the WES modeling: 1) the replacement project for L&Ds 3 at the existing site (r.m. 23.8); 2) the replacement project for L&Ds 2 and 3 with a single project with a gated dam at the existing site of L&Ds 2 (r.m. 11.2); and 3) the replacement project for L&Ds 3 and 4 with a gated dam at r.m. 34.0. Since these were either an existing site or similar to modeled project variations, the results of WES modeling were considered applicable to these project variations. These alternatives (indicated in table by "added") increased the total to 14 project variations at 8 sites.

The alternatives retained for further analysis are summarized below:

L&D 2 - A new fixed crest dam (utilizing the existing locks) at the existing site of Locks and Dam 2, r.m. 11.2 and new locks and a fixed crest dam at r.m. 12.3.

L&D 3 - New locks and a fixed crest or gated dam at r.m. 22.2. Also new locks and a fixed crest dam at r.m. 24.6 and at r.m. 26.8. Added was new locks and fixed crest dam at r.m. 23.8.

L&D 4 - New locks and a gated dam at r.m. 34.0 and new locks (utilizing the existing gated dam) at existing Locks and Dam 4, r.m. 41.5.

L&Ds 2 and 3 - New locks and a fixed crest or gated dam at r.m. 22.2. Added new locks and gated dam at r.m. 11.2.

L&Ds 3 and 4 - New locks and a gated dam at r.m. 26.8. Added new locks and gated dam at r.m. 34.0.

e. **Final Screening of Project Variations**

The final screening of project variations was based on more detailed construction costs along with estimates of real estate costs and the cost to adjust shoreside facilities to new pool levels. As a result, the number of project variations was reduced from 14 to 9 (Table 13).

Table 13
Final Screening of Project Variations

Location (r.m.)		Type of Dam	Locks and Dam 2	Locks and Dam 3	Locks and Dam 4	Locks and Dams 2&3	Locks and Dams 3&4
1	11.2	Fixed Crest	x				
		Gated				x	
2	12.3	Fixed Crest	x *				
3	22.2	Fixed Crest		x		x	
		Gated		x *		x *	
4	23.8	Fixed Crest		x			
5	24.6	Fixed Crest		x			
6	26.8	Fixed Crest		x *			
		Gated					x*
7	34.0	Gated			x		x
8	41.5	Existing Gated			x		

Note: * indicates eliminated from consideration.

The final array of sites and project variations for inclusion as parts of navigation plans are listed in Table 14.

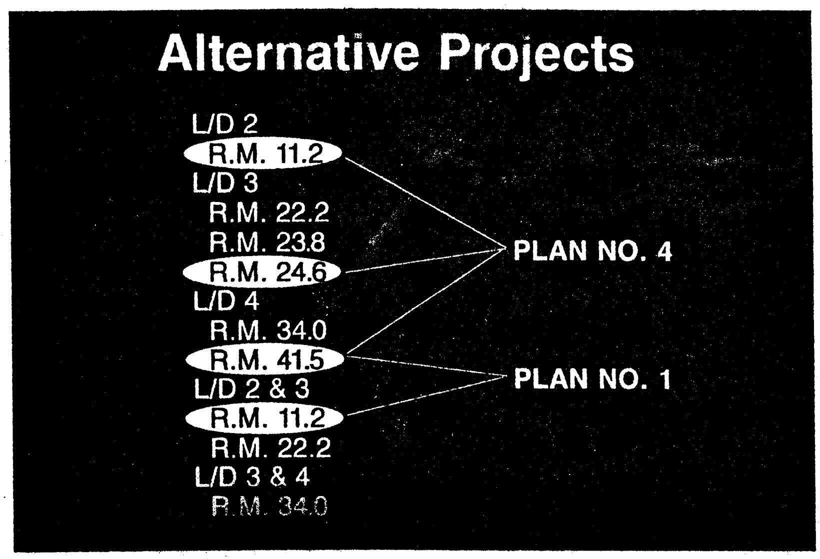
Table 14
Final Sites and Project Variations

Project / Site	Characteristics of Project
Locks and Dam 2	
r.m. 11.2	New fixed crest dam and existing locks.
Locks and Dam 3	
r.m. 22.2	New twin locks and a fixed crest dam.
r.m. 23.8	" "
r.m. 24.6	" "
Locks and Dam 4	
r.m. 34.0	New twin locks and a gated dam.
r.m. 41.5	New twin locks and existing gated dam.
Locks and Dam 2 & 3	
r.m. 11.2	New gated dam and existing locks.
r.m. 22.2	New twin locks and a fixed crest dam.
Locks and Dam 3 & 4	
r.m. 34.0	New twin locks and a gated dam.

f. **Configuration of Project Variations into Plans**

The project variations were developed based on general considerations of how they might eventually be combined to provide navigation on the lower river. Seven alternative plans were developed using combinations of the nine project variations. Three of these plans included three projects to replace the existing three ("3 for 3" plans) and four included two projects to replace the existing three ("2 for 3" plans). An illustration of the combination process is provided in Figure 1.

Figure 1
Combination of Project Variations into Plans



Specifics of the seven plans and the "without" plan are displayed in detail in Table 15. Bold type was used in the table to highlight areas in which the plans differ from the "without" plan. Illustrations of the plans in terms of location and pool change as compared to the "without" plan are provided in shown in Exhibits 1-7 in Attachment 5.

TABLE 15

DESCRIPTION OF FINAL EIGHT PLANS

L/D 2	WITHOUT	PLAN #1	PLAN #2	PLAN #3	PLAN #4	PLAN #5	PLAN #6	PLAN #7
LOCKS								
Location	11.2	11.2	11.2	11.2	11.2	22.2	11.2	11.2
Size								
Main	720 x 110	720 x 110	720 x 110	720 x 110	720 x 110	720 x 84	720 x 110	720 x 110
Aux	360 x 56	360 x 56	360 x 56	360 x 56	360 x 56	720 x 84	360 x 56	360 x 56
Action	Rehab	Rehab	Rehab	Rehab	Rehab	Replace	Rehab	Rehab
Year	2022	2022	2022	2022	2022	2002	2022	2022
DAM								
Type	Fixed	Gated	Fixed	Fixed	Fixed	Fixed	Fixed	Gated
Action	Replace	Replace	Replace	Replace	Replace	Replace	Replace	Replace
POOL								
Raise	None	5.0'	None	None	None	8.2'	None	5.0'
Limits	----	11.2 to 23.8	----	----	----	22.2 to 23.8	----	11.2 to 23.8
Lower	None	3.2'	None	None	None	8.7'	None	None
Limits	----	23.8 to 41.5	----	----	----	11.2 to 22.2	----	----

TABLE 15 (cont)

DESCRIPTION OF FINAL EIGHT PLANS

	WITHOUT	PLAN #1	PLAN #2	PLAN #3	PLAN #4	PLAN #5	PLAN #6	PLAN #7
L/D 3								
LOCKS								
Location	23.8	----	22.2	23.8	24.6	----	34.0	34.0
Size								
Main	720 x 56	----	720 x 84	720 x 84	720 x 84	----	720 x 84	720 x 84
Aux	360 x 56	----	720 x 84	720 x 84	720 x 84	----	720 x 84	720 x 84
Action	Replace	----	Replace	Replace	Replace	----	Replace	Replace
Year	2002	----	2002	2002	2002	----	2002	2002
DAM								
Type	Fixed	----	Fixed	Fixed	Fixed	----	Gated	Gated
Action	Replace	----	Replace	Replace	Replace	----	Replace	Replace
POOL								
Raise	None	----	8.2'	None	None	----	16.6'	16.6'
Limits	----	----	22.2 to 23.8	----	----	----	34.0 to 41.5	34.0 to 41.5
Lower	None	----	None	None	8.2'	----	8.2'	3.2'
Limits	----	----	----	----	23.8 to 24.6	----	23.8 to 34.0	23.8 to 34.0

TABLE 15 (cont)

DESCRIPTION OF FINAL EIGHT PLANS

	WITHOUT	PLAN #1	PLAN #2	PLAN #3	PLAN #4	PLAN #5	PLAN #6	PLAN #7
L/D 4								
LOCKS								
Location	41.5	41.5	41.5	41.5	41.5	41.5	----	----
Size								
Main	720 x 56	720 x 84	720 x 84	720 x 84	720 x 84	720 x 84	----	----
Aux	360 x 56	720 x 84	720 x 84	720 x 84	720 x 84	720 x 84	----	----
Action	Rehab	Replace	Replace	Replace	Replace	Replace	----	----
Year	2002	2002	2002	2002	2002	2002	----	----
Action	Replace	----	----	----	----	----	----	----
Year	2027	----	----	----	----	----	----	----
DAM								
Type	Gated	Gated	Gated	Gated	Gated	Gated	----	----
Action	None	None	None	None	None	None	----	----
POOL								
Raise	None	None	None	None	None	None	----	----
Limits	----	----	----	----	----	----	----	----
Lower	None	None	None	None	None	None	----	----
Limits	----	----	----	----	----	----	----	----

4. EVALUATION OF PRELIMINARY PLANS

a. **General**

The preliminary plans were screened by comparing the benefits and costs of each plan. Costs are detailed in the COST ANALYSIS APPENDIX and the ENGINEERING TECHNICAL APPENDIX and include all projected federal and non-federal expenditures. Benefits include the reduction in transportation costs due to improvements in the inland waterway navigation system and savings in future investments due to the early replacement of shoreside facilities to accommodate changes in pool elevations. Both benefits and costs are expressed in October 1991 dollars and were annualized using a 50-year economic life, an interest rate of 8 3/4 percent, and a base year of 2002. The "without" plan is included in the following tables for comparison purposes.

Preliminary screening of the 7 alternatives indicated that improvements involving new sites could prove very costly because of the need to adjust bridges to changes in pool. Because these alternatives possess many desirable features and the existing clearance seemed unnecessarily restrictive, navigation interests requested a lowering of the required bridge clearances on the Monongahela River from 47 feet to 42.5 feet. The letters of request were forwarded to the Commander, Second Coast Guard District and on November 15, 1990 the required bridge clearances on the Monongahela River was officially reduced from 47.0 feet to 42.5 feet. The effect of the lower bridge clearance was to enhance the feasibility of the 2 for 3 plans by reducing the number, and therefore the cost of bridge adjustments.

b. **Costs**

(1) Construction Costs

A line item listing of the construction costs for the alternative plans is provided in Table 16. Non-federal and federal costs for adjusting shoreside facilities to new pool elevations are included in the table. The 50 percent share of construction costs that is cost-shared and funded out of the Inland Waterway Trust Fund is included as a federal cost.

The costs of the plans range from $740 million to $1.5 billion. The major cost items are construction of locks and dam structures and relocations. Although the locks and dam replacement costs of a 2 for 3 plan would be lower than a 3 for 3 plan because of the elimination of one structure, the savings are at least partially offset by higher dredging and relocation costs.

Table 16

LOWER MONONGAHELA RIVER NAVIGATION STUDY
(October 1991 Cost Level)
FINAL SCREENING LEVEL ESTIMATES

CODE OF ACCOUNT	DESCRIPTION	W/O PLAN	PLAN 1*	PLAN 2	PLAN 3	PLAN 4	PLAN 5	PLAN 6	PLAN 7
		<------------------------(All costs shown are in $1,000's of dollars.)------------------------>							
01	LANDS AND DAMAGES **	$7,900	$3,100	$83,900	$7,900	$4,300	$83,900	$5,300	$5,700
02	RELOCATIONS								
	Utilities	$0	$10,915	$0	$0	$0	$0	$0	$0
	Structures	$0	$460	$2,250	$0	$0	$5,225	$39,902	$43,567
	Railroad	$0	$19,260	$0	$0	$0	$507	$670	$19,930
	Highway	$0	$0	$400	$0	$0	$400	$28,874	$28,874
	Major Storm Sewers	$0	$1,230	$850	$0	$0	$850	$140,770	$165,245
03	RESERVOIRS								
	Remove L/D #2	$0	$0	$0	$0	$0	$9,660	$0	$0
	Remove L/D #3	$0	$7,000	$7,000	$0	$7,000	$7,000	$7,000	$7,000
	Remove L/D #4	$0	$0	$0	$0	$0	$0	$10,432	$10,432
04	DAMS								
	Gated Dam at L/D #2	$0	$98,000	$0	$0	$0	$0	$0	$98,000
	Fixed Crest Dam at L/D #2	$28,583	$0	$28,583	$28,583	$28,583	$0	$28,583	$0
	Fixed Crest Dam at L/D #3	$36,876	$0	$0	$33,910	$0	$0	$0	$0
	Modify Dam(W/ Lock 4 Contract)	$0	$2,200	$2,200	$2,200	$2,200	$2,200	$0	$0
	Gated Dam at alternate site	$0	$0	$0	$0	$0	$0	$52,541	$52,541
	Fixed Crest Dam at alt. site	$0	$0	$26,024	$0	$49,138	$26,146	$0	$0
05	LOCKS								
	Rehab Locks at L/D #2	$40,000	$40,000	$40,000	$40,000	$40,000	$0	$40,000	$40,000
	Floodway Bulkhead at L/D #2	$3,600	$3,600	$3,600	$3,600	$3,600	$0	$3,600	$3,600
	Modify Locks(With Dam Contract)	$0	$11,300	$0	$0	$0	$0	$0	$11,300
	Twin 84x720 at L/D #3	$0	$0	$0	$168,028	$0	$0	$0	$0
	Replace L/D #3 in kind	$119,980	$0	$0	$0	$0	$0	$0	$0
	Twin 84x720 at L/D #4	$0	$184,000	$184,000	$184,000	$184,000	$184,000	$0	$0
	Rehab Locks at L/D #4	$30,736	$0	$0	$0	$0	$0	$0	$0
	Replace L/D #4 in kind	$134,488	$0	$0	$0	$0	$0	$0	$0
	Twin 84x720 at alternate site	$0	$0	$96,024	$0	$126,267	$94,629	$102,930	$102,930
06	FISH AND WILDLIFE FACILITIES	$800	$1,200	$650	$800	$1,400	$1,200	$1,200	$1,200
09	CHANNELS AND CANALS	$0	$27,000	$0	$0	$0	$39,200	$45,600	$2,850
16	BANK STABILIZATION	$0	$4,315	$453	$0	$0	$453	$647	$4,436
18	CULTURAL RESOURCES	$1,280	$780	$930	$1,280	$1,280	$930	$1,380	$1,380
20	PERMANENT OPERATING EQUIPMENT	$486	$325	$486	$486	$486	$325	$325	$325
30	PLANNING, ENGINEERING AND DESIGN	$40,150	$32,220	$36,640	$42,450	$40,995	$37,937	$86,868	$93,725
31	CONSTRUCTION MANAGEMENT	$30,060	$42,085	$27,467	$31,800	$30,710	$28,431	$65,125	$71,267
	CONTINGENCIES	$264,342	$134,468	$214,213	$245,951	$211,995	$246,110	$600,884	$623,920
SUBTOTAL, FEDERAL COSTS		$739,281	$623,458	$755,670	$790,988	$731,954	$769,103	$1,262,631	$1,388,222
SUBTOTAL, NON-FEDERAL COSTS		$0	$111,217	$1,570	$0	$10,274	$83,944	$100,275	$114,452
TOTAL, FEDERAL AND NON-FEDERAL COSTS		$739,281	$734,675	$757,240	$790,988	$742,228	$853,047	$1,362,906	$1,502,674

* Refer to Engineering Technical Appendix for detailed estimates.

** Refer to Real Estate Appendix for detailed estimates.

(2) Project Costs

Project costs are all costs either directly or indirectly related to the implementation of the plans including construction costs, potential flood damages during construction, the cost of operating and maintaining the projects (O&M), and the cost of non-structural measures to increase operating efficiencies (helper boats). O&M costs are the ordinary costs of keeping the projects operational. Potential flood damage costs are the cost of potential flood damages that are a byproduct of construction activity. The cost of non-structural measures include the cost of towboats for speeding lockage operations.

Project costs do not include costs for bringing industry or individuals into compliance with local, state, or federal regulations. Facility relocations or alterations will be in-kind and will not include betterments. Construction of the altered or new facility shall meet current engineering desing standards that are required by law or regulation. However, facilities or utilities will not be altered or constructed at project cost to serve the owner in another manner or to a higher degree of serviceability than the existing facility or utility. For example, project funds will not be used to separate a combined sewer/storm system to independent storm and sanitary lines or to construct additional facilities to upgrade a utility to meet EPA requirements where these requirements are not currently being met. These costs, if incurred, are not a result of proposed construction activity but rather of the enforcement of unrelated regulations.

It should be noted that Duquesne Light Company and Allegheny Power System (West Penn Power Company) have expressed concern that any change to the lock and dam system regulating the river may have an adverse impact on the operation of the Elrama and Mitchell coal fired electrical generating plants. This is because the heated water discharges from these power plants are regulated by permits with Pennsylvania Department of Environmental Resources with water quality thermal variances. A change in the prescribed conditions of the thermal variances could result in the imposition of more restrictive operating criteria or ultimately result in the requirement of constructing cooling towers at an estimated cost of $60 M for each plant. The thermal loading of the Monongahela River in the study reach will not be worsened by the selected plan or any of the alternative plans. All of the alternative plans, including the "without" plan, will change the physical configuration of the navigation structures and modify the conditions under which the Pennsylvania Department of Environmental Resources issued thermal variances. For this reason the potential need for cooling towers at each plant was not identified as a project cost.

Project costs were converted into economic costs to provide a basis for comparing expenditures that may be scheduled at different points in time, depending on the plan. The conversion was accomplished by discounting expenditures in a given year into present worth values. Expenditures that occur prior to the base year are higher in terms of present worth than the actual expenditure because of the time value of money whereas those after the base year are lower. The difference between the present worth and actual expenditure for those expenditures that occur prior to the base year was designated as interest during construction (IDC). Calculation of economic costs (IDC and present worth) are shown in Attachment 6. Economic costs were then annualized using standard statistical techniques.

Annual costs not directly related to the construction cost were calculated as follows. O&M costs are the annual costs of staffing, dredging, and performing any other normal work required to keep the projects operational. O&M costs are lower for the 2 for 3 plans Plan 1, 5-7) than for the 3 for 3 plans because of less staffing and maintenance. A detailed breakdown of O&M costs is provided in Attachment 7. Flood damage costs are the annualized increase in potential flood damages during construction of the projects. Although no long-term changes in potential flood damages are expected as a result of the plans, there is a higher short term potential because of the need for cofferdams during construction. Cofferdams have the effect of raising backwater during periods of high flows and thereby increasing potential flood damages. The problem is exacerbated during construction of a fixed crest dam since a partially completed fixed crest provides less capability to pass high flows than a partially completed gated dam. The cost was measured as the increase in potential flood damages during construction as compared to expected flood damages in the absence of construction activity (Attachment 8). The final cost item is the cost for helper boats (if needed and justified) to speed the lockage process and reduce delays when the locks become congested. The use of helper boats was shown to be justified in the future as a means of reducing tow delays (NAVIGATION SYSTEM ANALYSIS APPENDIX).

The three least costly plans in terms of average annual costs are the "without" Plan, Plan 1 (2 for 3), and Plan 4 (3 for 3). A summary of the costs of all seven plans is provided in Table 17.

Table 17
Average Annual Costs of Preliminary Plans
(Millions of October 1991 Dollars; 8 3/4%)

Plan	Constrn Costs 1/	Interest during Constrn	Total Invest	Average Annual Costs: Invest	O&M	Flood Damages	Helper Boats	Total
W/O	$474.2	$107.9	$582.1	$51.7	$3.3	$1.0	$0.1	$ 56.1
1	681.1	123.2	804.3	71.4	2.3	0.5	0.0	74.2
2	709.8	197.2	907.0	80.6	3.3	1.0	0.0	84.9
3	743.7	170.9	914.6	81.2	3.3	1.0	0.0	85.5
4	694.5	146.4	840.9	74.7	3.3	1.0	0.0	79.0
5	844.3	204.7	1,049.0	93.2	2.2	0.9	0.0	96.3
6	1,311.8	392.0	1,703.8	151.4	2.2	0.5	0.0	154.1
7	1,450.7	450.5	1,901.2	168.9	2.3	0.9	0.0	172.1

1/ Adjusted for present worth.
NOTE: O&M for plans 1 & 7 include $ 0.1 M for maintenance of Turtle Creek with additional channel cleanout necessitated because of the increase in slackwater with the proposed new pool. Details can be found in the ENGINEERING TECHNICAL APPENDIX and in Section 7-3 of the Main Report.

c. **Benefits**

Benefits from the plans were evaluated in the areas of improvements to navigation efficiency and advanced replacement (modernization) of shoreside facilities. Improvements in navigation efficiency were measured as the reduction in transportation costs with an improved navigation system. Transportation costs would be reduced because of lower delays, less fleeting, the use of larger barges and tows, the elimination of the need for double lockages, and, in the case of the 2 for 3 plans, the elimination of a lockage cycle (see NAVIGATION SYSTEM ANALYSIS APPENDIX). All alternatives were evaluated on the basis of twin 84' x 720' locks at L&Ds 3 and 4.

Advanced replacement benefits were calculated as the savings in future investments in shoreside facilities because of their up-front replacement to accommodate pool changes or construction at new sites. In general, the more extensive and costly the shoreside adjustments, the higher are the advance replacement benefits. Overall, the benefits of modernizing shoreside facilities are equal to about 20 percent of the costs. The calculation of advanced replacement benefits is documented in the Attachment 9.

The total benefits attributable to the improvement plans are the incremental benefits plus the base amount of benefits provided by the Lower Monongahela projects in the "without" plan. Displaying the navigation benefits in this manner clearly shows the contribution of all plans to the total economic benefits of the Lower Monongahela River Subsystem. The navigation benefits provided by the projects in the "without" plan amount to $265.8 million average annual. The "without" plan does not provide any advanced replacement benefits since it does not affect pool elevations so that the total base benefits are $265.8 million. The incremental benefits of the improvement plans are $32 - 40 million, which, when added to the $265.8 million base benefits, provide benefits for the improvement plans of about $300 million annually (Table 18).

Table 18
Average Annual Benefits of Preliminary Plans
(Millions of October 1991 Dollars; 8 3/4%)

Plan	System Navigation Benefits	Advanced Replacement Benefits	Increment over W/O	Lower Mon Benefits
W/O	$3,544.9	$ 0	$ ---	$265.8
1	3,581.6	2.0	38.7	304.5
2	3,579.9	*	35.0	300.8
3	3,577.6	0	32.7	298.5
4	3,579.9	*	35.0	300.8
5	3,584.1	1.0	40.2	306.0
6	3,581.7	3.5	40.3	306.1
7	3,581.7	3.1	39.9	305.7

Note: * denotes less than $50 thousand.

d. **Comparison of Benefits and Costs**

(1) Total Net Benefits

Net benefits (benefits minus costs) are an indication of the overall economic efficiency of a plan. Positive net benefits indicate that the a plan is economically feasible whereas negative net benefits indicate the opposite. All of the plans provide positive net benefits (Table 19). Plan 1, a 2 for 3 plan, provides the highest net benefits followed by Plan 4, a 3 for 3 plan.

Table 19
Net Benefits of Preliminary Plans
(Millions of October 1991 Dollars; 8 3/4 %)

Plan	Lower Mon Annual Benefits	Annual Costs	Net Benefits	
W/O	$265.8	$ 56.1	$209.7	
1	304.5	74.2	230.3	**(1)**
2	300.8	84.9	215.9	
3	298.5	85.5	213.0	
4	300.8	79.0	221.8	**(2)**
5	306.0	96.3	209.7	
6	306.1	154.1	152.0	
7	305.7	172.1	133.6	

(1) - Highest net benefits; also best 2 for 3 Plan.
(2) - Second highest net benefits; also best 3 for 3 Plan.

(2) Incremental Net Benefits

Incremental benefits and costs were computed as the increase in benefits and costs for a plan over the benefits and costs of the "without" plan. The amount that the incremental benefits exceed (or are exceeded by) the incremental costs are designated as incremental "net" benefits. Positive incremental net benefits indicate that each additional dollar in costs over the amount spent in the "without" plan provides more than an additional dollar in benefits and, therefore, the plan is economically superior to the "without" plan. Plan 1 through 5 are all in this category. Negative net benefits indicate the opposite: the plans are economically inferior to the "without" plan. Such is the case for Plans 6 and 7. Plan 1 provides the highest incremental net benefits and Plan 4 provides the second highest net benefits. Incremental benefits, incremental costs, and incremental net benefits for each plan are listed in Table 20.

Table 20
Incremental Net Benefits of Preliminary Plans
(Millions of October 91 Dollars; 8 3/4 %)

Plan	Annual Benefits	Annual Costs	Net Benefits
"Without"	-	-	-
1	38.7	18.1	20.6 *
2	35.0	28.8	6.2
3	32.7	29.4	3.3
4	35.0	22.9	12.1 **
5	40.2	40.2	0.0
6	40.3	98.0	-57.7
7	39.9	116.0	-76.1

* highest incremental net benefits; also best 2 for 3 Plan.
** second highest incremental net benefits; also best 3 for 3 Plan.

e. **Summary of Best Preliminary Plans**

The best two preliminary plans (Plans 1 and 4) were carried forward for additional analysis. The best plans not only provide the highest net benefits, but also represent the two basic types of plans for improvement: 1) two projects to replace three projects; and 2) three projects to replace three projects. This was important given the uncertainty of how any one type of plan would measure against environmental, acceptability, and other decision-making criteria.

5. DEVELOPMENT OF FINAL PLANS

The economic analysis of the improvement plans displayed thus far was based on the construction of twin 84' x 720' locks in the year 2002. Twin 84' x 720' locks were selected for three reasons: first, 84' x 720' locks are becoming the standard on the Monongahela River and the project upstream (Maxwell L&D) has twin 84' x 720' locks; second, it was felt that the use of any lock size common to all plans was appropriate for the initial screening; and third, it was a measure designed to keep the evaluation manageable in terms of time and money. Lock size and timing optimization was accomplished for the final two plans as described below.

a. **Lock Size**

Alternative lock sizes were examined for L&Ds 3 and 4 that were consistent with the size of the main locks at upstream and downstream projects: 84' x 720' and 110' x 720'. All of the alternatives include main chambers with dimensions of one of these sizes. Most of the variation in lock size alternatives are in the size of the auxiliary lock which range from none at all to one equal in size to the main lock. A total of ten lock size combinations were evaluated.

(1) Benefits

The efficiency of the navigation system would improve with the construction of larger locks through the elimination of refleeting, by allowing for the use of larger barges and tows, by reducing delays, by eliminating the need for double lockages, and, in the case of the 2 for 3 plan (Plan 1) through the elimination of a lockage cycle. Plan 1 provides $3 - 7 million more in benefits than Plan 4, primarily because of the elimination of a lockage cycle and the avoidance of lock closures. Locks measuring 110' in width provide about $2 million more in benefits than 84' wide locks because of larger tows and less refleeting. Larger auxiliary locks provide $0.5 - 1 million more in benefits than smaller locks, primarily because of reduced delays while the main lock is closed.

A summary of the benefits of the 2 for 3 plan (Plan 1) and 3 for 3 plan (Plan 4) with different locks sizes is provided in Table 21. A detailed description of the analysis is provided in the NAVIGATION SYSTEM ANALYSIS APPENDIX.

Table 21
Benefits of Lock Size Alternatives
(Millions of October 1991 Dollars; 8 3/4%)

Lock Size	Plan 1*	Plan 4
Single 84x720	301.4	293.6
84x720 & 56x360	302.3	296.1
84x720 & 84x410	303.3	297.7
84x720 & 110x410	304.0	298.6
Twin 84x720	304.5	300.8
Single 110x720	303.4	296.9
110x720 & 56x360	303.8	298.1
110x720 & 84x410	304.5	299.5
110x720 & 110x410	305.3	301.4
Twin 110x720	305.8	302.3

* - Includes $2.0 million of advance replacement benefits.

(2) Costs

Lock construction costs vary with the size and number of locks, as shown in Table 22. The costs for two lock projects assume that both are constructed as part of the same work effort. The lock costs were substituted for the costs of twin 84' x 720' locks used in all preceding analysis to obtain new total costs, which were annualized using standard techniques. Annual costs are lower for Plan 1 even when total costs are higher than in Plan 4 because a significant portion of the costs are for shoreside facility adjustments which are made by numerous individuals around the time the pools are changed (2001). In contrast, Plan 4 includes higher government expenditures for navigation structures which require long construction periods and thus incur high interest during construction charges. Annual costs of the lock size alternatives are listed in Table 22.

Table 22
Costs of Lock Size Alternatives
(Millions of October 1991 Dollars; 8 3/4%)

Lock Size	L&D 3 Cost	L&D 4 Cost	Total Plan 1	Annual Cost	Total Plan 4	Annual Cost
Single 84x720	175.0	205.0	709.7	71.8	692.2	73.6
84x720 & 56x360	190.0	220.0	724.7	73.3	722.2	76.9
84x720 & 84x410	195.0	225.0	729.7	73.8	732.2	77.9
84x720 & 110x410	220.0	255.0	759.7	76.7	787.2	83.8
Twin 84x720	200.0	230.0	734.7	74.2	742.2	79.0
Single 110x720	195.0	225.0	757.2	73.8	732.2	77.9
110x720 & 56x360	210.0	245.0	791.0	75.7	767.2	81.6
110x720 & 84x410	220.0	255.0	742.2	76.7	787.2	83.8
110x720 & 110x410	240.0	275.0	794.8	78.7	827.2	88.1
Twin 110x720	255.0	290.0	853.0	80.2	852.2	90.7

(3) Net Benefits

The benefits and costs of the lock size alternatives for the 2 for 3 (Plan 1) and 3 for 3 (Plan 4) plans are summarized in Table 23. Both benefits and costs increase with the size of the locks. The lock size combination that provides the highest net benefits is the twin 84' x 720' locks, which is therefore the optimum size to be included as parts of the improvement plans. A detailed analysis of the benefits of different lock sizes is provided in the NAVIGATION SYSTEM ANALYSIS APPENDIX.

Table 23
Benefits, Costs, and Net Benefits of Alternative Lock Sizes
(Millions of October 1991 Dollars; 8 3/4%)

	Plan 1			Plan 4		
Lock Size	Annual Benefits	Annual Costs	Net Benfts	Annual Benefits	Annual Costs	Net Benfts
Single 84x720	$301.4	$71.8	$229.6	$293.6	$73.6	$220.0
84x720 & 56x360	302.3	73.3	229.0	296.1	76.9	219.2
84x720 & 84x410	303.3	73.8	229.5	297.7	77.9	219.8
84x720 & 110x410	304.0	76.7	227.3	298.6	83.8	214.8
Twin 84x720 *	304.5	74.2	230.3	300.8	79.0	221.8
Single 110x720	303.4	73.8	229.6	296.9	77.9	219.0
110x720 & 56x360	303.8	75.7	228.1	298.1	81.6	216.5
110x720 & 84x410	304.5	76.7	227.8	299.5	83.8	215.7
110x720 & 110x410	305.3	78.7	226.6	301.4	88.1	213.3
Twin 110x720	305.8	80.2	225.6	302.3	90.7	211.6

*** optimum lock size.**

b. **Timing for Construction of Second Lock**

The lock size analysis indicated that twin 84' x 720' locks are the optimum size locks. However, it does not indicate the optimum time for construction of the locks. While one large lock may be needed at the beginning of the project life to provide the benefits of a modernized system, construction of the second lock may not be initially justified. The optimum time for construction of the second lock was estimated based on a comparison of the incremental benefits and costs of providing a second lock at different years in the future. The optimum year was designated as the year when net benefits were maximized. The analysis was performed using data for Plan 1; however, the findings are considered valid for Plan 4 as well.

The two major factors driving the optimum time for constructing the second lock are the additional costs of constructing the second lock as a stand-alone item in the future and the first closure of the other lock for maintenance. The higher the additional costs of stand-alone work, the lower is the initial economic advantage of deferral. Also, the sooner a maintenance closure is scheduled, the higher are the benefits for construction of the second lock early in the project life.

The estimated cost of constructing the second lock is an additional $25 million if it is part of the initial work effort and $105 million if it is deferred work. This is because the majority of the costs of constructing a double lock at the site will still be incurred initially in order to construct one fully functional riverward chamber with complete mechanical systems, buildings, and site work. Since there is no standard design for a single chamber riverward lock, it was assumed that to provide access and to pass flow the landward location of the future chamber would have a concrete weir and service bridge across it. Additional costs to be considered if construction of the second lock landward is delayed are the second mobilization and demobilization, removal of the weir and service bridge, no reuse of portions of the cofferdam in-place or cofferdam materials, construction of the landwall building, new lock gates and machinery, new hydraulic system and valves. The overall smaller quantities would mean higher unit prices for all features of work and the limited availability of disposal areas in the future would impact on all excavation and removal costs. This does not include any additional real estate costs in the future or additional model studies required for design.

The first maintenance closure of a lock is in the year 2007. Without a second lock, lock closure would prevent traffic from moving in the area, thereby reducing the benefits of the system.

Based on the estimated 1 3/4 years for construction, the second lock could be completed as late as the end of 2003 and still be part of the initial work effort. Completion after that was assumed to be a stand-alone effort, or deferral. As shown in the table, annual costs decline through 2003 because of discounting and then increase significantly as construction becomes a stand-alone effort. They then resume their decline due to discounting. Annual benefits also decline at a moderate rate due to discounting until 2008, when they decline significantly. This reflects the loss in benefits for avoiding river closure in 2007. Benefits after that follow the same downward and cyclical trend.

As summarized in Table 24, the analysis indicated that the optimum time for completion of the second lock is early in the project life. Early completion avoids the high costs of deferred construction and river closure.

Table 24
Timing Analysis for Construction of Second Lock
(Millions of October 1991 Dollars; 8 3/4%)

Year Second lock is Operational	Increases over Single Lock Costs and Benefits: Cost of Construction	Annual Ave Cost	Annual Ave Benefit	Net Benefit
2002	$ 25.0	$ 2.5	$ 3.1	$ 0.6
2003	25.0	2.3	3.0	0.7
2004	25.0	2.1	2.9	0.8
2005	105.0	8.2	2.9	-5.3
2006	105.0	7.5	2.8	-4.7
2007	105.0	7.0	2.8	-4.2
2008	105.0	6.4	2.1	-4.3
2009	105.0	5.9	2.1	-3.8
2010	105.0	5.4	2.0	-3.4
2011	105.0	4.9	2.0	-2.9
2012	105.0	4.6	2.0	-2.6

c. **Timing of New Locks at L&D 4**

The locks at L&D 4 are proposed for replacement by the year 2027 in the "without" condition and by 2002 in the 2 for 3 (Plan 1) and 3 for 3 plan (Plan 4). The timing of the replacement in the "without" plan was driven by the condition of the locks, in the 2 for 3 plan by the need to adjust the sill depth of the locks to accommodate the change in pool, while in the 3 for 3 plan it was to provide a completely modernized system comparable to the other improvement plans. Since the net benefits of the 3 for 3 plan (Plan 4) and the 2 for 3 plan (Plan 1) are relatively close, the sensitivity of Plan 4 to deferred construction of the locks at L&D 4 was examined. The sensitivity consisted of deferring construction of the locks at L&D 4 until the year 2027, the same year they would be replaced in the "without" plan.

Deferring construction reduces the economic costs of the project because a dollar in the future is worth less than a dollar at present. However, deferral also reduces the benefits of the project because small locks continue to constrain traffic for an additional 25 years. The benefits and costs of the 3 for 3 improvement plan (Plan 4) with and without deferral are shown in Table 25. The results suggest that deferral of the construction of the locks at L&D 4 is a more economical plan than up-front replacement.

Table 25
Timing Analysis for Construction of Locks at L&D 4
(Millions of October 1991 Dollars; 8 3/4%)

Plan	Benefits	Costs	Net Benefits
4	$300.8	$79.0	$221.8
4 Deferred	289.0	62.9	226.1

Note: Construction in 2027 requires rehabilitation in 2002 - same as in the "without" plan.

d. **Congestion Fees**

A non-structural "with" project condition is the management of demand by the use of congestion or lockage fees. Congestion fees are lockage charges designed to discourage marginal traffic off the river and thereby reduce traffic delays. Since they are only marginally effective in economic terms, they were not included in the final array of plans (Table 26).

Table 26
User Charges
Millions of October 1991 Dollars

Alternative	Benefits	Costs	Net Benefits	Increment over w/o
"Without"	$265.8	$56.1	$209.7	-
User Charges	277.0	56.1	220.9	11.2
Plan 1	304.5	74.2	230.3	20.6
Plan 4	300.8	79.0	221.8	12.1
Plan 4 Deferred	289.0	62.9	226.1	16.4

6. SUMMARY DESCRIPTION OF FINAL ALTERNATIVES

The final plans carried forward for further evaluation were the "without" Plan, Plan 1 (2 for 3), Plan 4 (3 for 3), and Plan 4 Deferred (L&D 3 replaced up-front and L&D 4 replaced in 2027). The "without" Plan provides a baseline for comparison purpose and also can be implemented in the absence of new congressional authorizations. Plan 1 is the best 2 for 3 plan and also provides the highest net benefits. Plan 4 Deferred is the best 3 for 3 plan and is nearly identical to the "without" Plan except for the size of the locks. While Plan 4 provides lower net benefits than Plan 4 Deferred, it would provide an immediate improvement to the projects, while minimizing disruptions to shoreside interests. All of the alternatives have features that could weigh in their favor when criteria other than economics are considered.

A summary description of the important features of the final alternatives is provided in Table 27 with the major differences between the"without" plan and the other three alternatives highlighted in bold type. The single most important difference is in the number of navigation projects on the river segment under study. The current number of projects is three; of the final alternatives, the"without" Plan, Plan 4, and Plan 4 Deferred are 3 for 3 plans and Plan 1 is a 2 for 3 plan. The 2 for 3 plan (Plan 1) provides for the construction of a gated dam at L&D 2, the elimination of L&D 3, and the construction of twin 84' x 720' locks at L&D 4 with all construction completed by 2002. The "without" Plan and Plan 4 Deferred are identical except for the size of the replacement locks at L&Ds 3 and 4 and in the location of L&D 3. The "without" Plan and Plan 4 differ in these two areas as well as in the timing of replacement of L&D 4.

In terms of improvement to the navigation system, Plan 1 is the best of the alternatives. It simplifies the system by removing one project altogether and provides larger locks at the one remaining small project, with all work accomplished by the year 2002. Plan 4 is similar to Plan 1 except that it enlarges rather than removes the middle project. Plan 4 Deferred is a combination of Plan 4 and the "without" plan; it provides the larger locks in Plan 4 but according to the replacement timing in the "without" plan. As a result, the Locks 4 are not enlarged until the year 2027. The "without" plan maintains, but does not improve, the system.

The evaluation of the final four alternatives in environmental and other accounts is summarized in the Main Report.

Table 27
Description of Final Alternatives

	"Without" (3 for 3)	Plan 1 **(2 for 3)**	Plan 4 (3 for 3)	Plan 4 Deferred
L&D **2**				
Locks				
Size	110x720 56x360	same	same	same
Action	rehab	same	same	same
Year	2022	same	same	same
Dam				
Type	Fixed Crest	**Gated**	same	same
Action	replace	same	same	same
Year	2002	same	same	same
Pool				
Change	none	**+5'**	none	none
L&D **3**				
Locks				
Size	56x720 56x360	**none**	**Twin 84x720**	**Twin 84x720**
Action	replace	**eliminate**	same	same
Year	2002	same	same	same
Dam				
Type	Fixed Crest	**none**	same	same
Action	replace	**eliminate**	same	same
Year	2002	same	same	same
Pool				
Change	none	**-3.2'**	**(-8.2' for 0.8 miles)**	
L&D **4**				
Locks				
Size	56x720 56x360	**Twin 84x720**	**Twin 84x720**	same
Action	rehab	**replace**	**replace**	same
Year	2002	same	same	same
Size	56x720 56x360	**n.a.**	**n.a.**	**Twin 720x84**
Action	replace	**n.a.**	**n.a.**	same
Year	2027	**n.a.**	**n.a.**	same
Dam				
Type	Gated	same	same	same
Action	none	same	same	same
Year	none	same	same	same
Pool				
Change	none	same	same	same

Note: n.a. denotes not applicable.

7. SENSITIVITY ANALYSIS

Project benefits are calculated on the basis of the "most probable" with project and without project conditions. However, given the uncertainty inherent in any analysis, the following sensitivities are specified in the Engineering Regulations (ER 1105-2-100) for establishing a reasonable range of project benefits for navigation studies:

a. Current rates, fleet - compute benefits for the recommended alternative on the basis of tonnage over time, current rates, and current fleet characteristics.

b. No growth beyond 20-year period - compute the benefits for alternatives carried forward for final display assuming no growth in tonnage or changes in fleet characteristics beyond 20 years in the future.

In addition, three sensitivities were performed that are not specified in the regulations:

c. No growth in traffic - benefits with no growth in traffic levels.

d. High traffic growth - benefits if traffic exceeds most probable projections.

e. Low traffic growth - benefits if traffic lags most probable projections.

Benefits for these alternatives were estimated using the system modeling techniques described in the NAVIGATION SYSTEMS ANALYSIS APPENDIX. The results for each alternative and their implications for plan selection are described in the following paragraphs.

a. **Current Rates, Fleet**

Changes in the fleet due to the provision of larger locks are an important benefit of the plans. They are particularly important for plans that include the upfront modernization of all projects (Plans 1 and 4) as compared to the deferral plan (Plan 4 Deferred). While Plan 1 remains the preferred plan with the current fleet, the advantage over Plan 4 Deferred is less than with a modern fleet (Table 28).

Table 28
Sensitivity of Benefits to Towing Fleet
Millions of October 1991 Dollars

Alternative	Current Fleet Net Benefits	Current Fleet Rank	"With" Fleet Net Benefits	"With" Fleet Rank
"Without"			$209.7	4
Plan 1	$223.8	2	230.3	1
Plan 4	215.3	3	221.8	3
Plan 4 Deferred	224.4	1	226.1	2

b. **No Growth in Traffic after 20 Years**

The uncertainty of any forecast increases as the forecast year extends further into the future. Given this, the forecasts were held constant after 20 years into the project life to determine if the recommended plan is still justified or whether some other plan becomes the NED plan. The analysis indicates that future growth tends to improve the benefit advantage of the upfront modernization plans (Plans 1 and 4) compared to the deferral plan (Plan 4 Deferred). Nonetheless, Plan 1 remains both justified and the NED plan even with "no growth" in traffic after 20 years.

Table 29
Sensitivity of Plan Selection to No Traffic Growth after 20 Years
Millions of October 1991 Dollars

Plan	Most Probable Net Benefits	Most Probable Rank	No Growth after 20 years Net Benefits	No Growth after 20 years Rank
"Without"	$209.7	4		
1: 2 for 3	230.3	1	218.7	1
4: 3 for 3	221.8	3	210.3	3
4: Deferred	226.1	2	217.6	2

c. **No Growth in Traffic**

Traffic was held constant throughout the project life to assess the effect of traffic growth on the merits of the recommended plan. The results indicate that this scenario favors the plan that defers work into the future - Plan 4 Deferred - by a small margin over the recommended plan (Table 30).

Table 30
Sensitivity of Benefits to No Growth in Traffic
Millions of October 1991 Dollars

	Most Probable		No Growth	
Alternative	Net Benefits	Rank	Net Benefits	Rank
"Without"	$209.7	4		
Plan 1	230.3	1	208.9	2
Plan 4	221.8	3	200.8	3
Plan 4 Deferred	226.1	2	210.9	1

d. **High Traffic Forecasts**

Traffic forecasts that are 15 percent higher than the most probable forecasts were evaluated for their affect on plan selection. High forecasts favor the plans that include upfront construction (Plans 1 and 4) over deferral (Plan 4 Deferred). Plan 1 remains the economically preferred plan under this scenario (Table 31).

Table 31
Sensitivity of Plan Selection to High Traffic Forecasts
Million of October 1991 Dollars

	Most Probable		High Forecasts	
Alternative	Net Benefits	Rank	Net Benefits	Rank
"Without"	$209.7	4		
Plan 1	230.3	1	261.8	1
Plan 4	221.8	3	252.7	2
Plan 4 Deferred	226.1	2	246.3	3

e. **Low Traffic Forecasts**

Traffic forecasts that are 15 percent lower than the most probable forecasts were evaluated for their affect on plan selection. The findings indicate that the slow, continuous growth has virtually the same affect on all the plans. Plan 1 continues to provide the highest benefits and by about the same margin as with the most probable forecasts (Table 32).

Table 32
Sensitivity of Plan Selection to Low Traffic Forecasts
Million of October 1991 Dollars

	Most Probable		Low Forecasts	
Alternative	Net Benefits	Rank	Net Benefits	Rank
"Without"	$209.7	4		
Plan 1	230.3	1	224.4	1
Plan 4	221.8	3	216.1	3
Plan 4 Deferred	226.1	2	221.9	2

ATTACHMENT 1

L&D 2 FLOODWAY BULKHEAD ANALYSIS

ATTACHMENT 1

L&D 2 FLOODWAY BULKHEAD ANALYSIS

1. GENERAL

The first item of work scheduled in the construction of the Lower Monongahela River projects is the construction of a new floodway bulkhead system at L&D 2. The bulkhead system will allow the auxiliary lock to be used as a floodway during construction of the dam when high waters threaten to cause flood damages. The project currently has a bulkhead system, but it is cumbersome and undependable due to its age and inherent deficiencies in design which causes misalignment of the bulkheads onto the rail tracks needed to place it into position. It is a make-shift operation of modifications and add-ons that partially collapsed in 1984 when its clutch failed and one of its panels crashed onto the lock wall. Other serious deficiencies include large vertical cracks in the supporting piers which may indicate a lack of structural integrity and the risk of collapse. Replacement of the bulkhead system is especially critical prior to the construction of the new dam at L&D 2 because the cofferdams erected to allow construction of the dam will increase the risk of flooding. While the cofferdams provide a safe and dry working environment during construction, they also restrict water flows to a narrow stretch of river and thereby increase backwater during high flows. A floodway bulkhead system will reduce the damages caused by high flows by providing an additional 56-feet weir (width of lock).

The bulkhead system is a horizontally stationary structure that is positioned overhead of the upstream area of the auxiliary lock. It operates in a manner similar to an overhead garage door opener, with the door gliding up and down along tracks. The bulkhead is placed into operation by lowering it into the river in the area between the guidewalls. The effect is blockage of flows into the lock which allows both sets of gates to be opened. The bulkhead is then raised and water is free to flow through the chamber. The bulkhead system is employed frequently to convert the lock into a floodway during periods of high flows (three times in 1990). During the three year construction period it is anticipated that the bulkhead and emergency floodway will be needed approximately eleven times. This will not only reduce flooding to the communities and businesses along the river, but also the expected number of times that the dam 2 construction cofferdams are overtopped. After the construction period, the bulkhead will be used for emergency closures to avoid loss of pool. The costs, flood reduction, and emergency closure benefits are described in more detail below.

2. COSTS

The first cost of the floodway bulkhead system is $6.4 million. Construction is currently scheduled for 1996 in order for the system to be available when construction of the dam commences in 1997. The average annual equivalent cost is $593,000.

3. FLOOD REDUCTION BENEFITS

There are two classes of flood damages that result from the combination of dam construction and high water: 1) damage at work site due to overtopping of cofferdam; and 2) damages to upstream communities. Based on hydrologic data, the cofferdam is expected to be overtopped six times without the bulkhead system during the construction period and three times with it. The estimated loss per overtopping is $70,000, so that the benefit in the form of reduced losses attributable to the bulkhead system is $210,000. Damages to upstream communities are expected to be lower with the bulkhead system because the use of the auxiliary lock as a floodway will reduce backwater during high water about two feet. Using traditional estimation techniques, the expected reduction in damages with the bulkhead system are about $2.1 million for two years ($1 million per year). This is about the same as the reduction in damages for two one-year floods. The expected reduction in damages with a bulkhead system should a less frequent flood occur are much greater. The reduction for a ten-year flood is $3.6 million, for a twenty-year flood is $4.4 million, and for a fifty-year flood is $5.5 million. Conversely, expected damages would be higher by these amounts if the bulkhead system is not operational. The average annual equivalent benefit is $19,000 for reduced cofferdam overtopping and $182,000 for reduced upstream flood damages. The average annual equivalent benefits of reducing flood damages associated with different frequency floods are listed in Table 1.

Table 1
Reduction in Flood Damages
(Thousands of Dollars; Oct 91; 8 3/4%)

Flood Frequency	Prevented Damages	Average Annual Equivalent
0.5	930.1	82.6
1	1,185.8	105.3
10	3,550.6	315.4
20	4,417.1	392.4
50	5,456.6	484.8
100	7,356.5	653.6

Post-construction use of the bulkhead system to convert the lock into a floodway is expected to be minimal with the replacement of the fixed crest dam with a gated dam at L&D 2. A gated dam will allow much greater control over river stages than a fixed crest dam, limiting the need for an emergency floodway. Therefore, there are no expected future benefits for use of the bulkhead to create an emergency floodway.

4. EMERGENCY CLOSURE BENEFITS

Long term use of the bulkhead system would be an insurance system to prevent loss of pool due to an inability to close the gates of the auxiliary chamber because of an accident. The lack of a bulkhead system resulted in the loss of the L&D 8 pool in 1968 when a tow damaged the upstream gates and they could not be closed. In addition to closing the river to navigation, loss of pool means the sudden and unexpected loss of water to municipal and industrial users. At Mon L&D 2 it is expected that it would take about one month to restore the pool if it is lost unexpectedly. The restoration time could be longer or shorter depending on a number of factors including the weather and location of the repair fleet (upstream or downstream) at the time of the accident. The reduction in navigation benefits due to a 30 day loss of pool in 2002 is estimated at $14.5 million which is equivalent to an average annual value of $1.3 million. Therefore, if the bulkhead system prevented a loss of pool in 2002, the annual navigation benefit would be $1.3 million or about 2 1/2 times the annual cost.

5. COMPARISON OF BENEFITS AND COSTS

The first cost of constructing the bulkhead system is $6.4 million and the time required for construction is one year. Amortizing over 50 years at a discount rate of 8 3/4% yields an average equivalent cost of $593,000. Deferring construction until 2022 when the locks are rehabilitated reduces the present worth of the first costs to $1,010,000 and the average equivalent value to $94,000. The economic cost of upfront versus deferred construction is $5,389,000 and the average annual equivalent is $500,000.

Benefits for an expected reduction in damages due to cofferdam overtoppings are $210,000 and the average annual equivalent value is $19,000. The benefits of a reduction in expected upstream flood damages during the L&D 2 dam construction period due to the use of the emergency floodway are $2.1 million and the average annual equivalent is $182,000. The reduction in damages for different levels of flooding are listed in Table 1. The benefit for prevention of a loss of pool are $14.5 million ($1.3 million annual equivalent) for an accident in 2002 and $21.7 million ($2.7 million present worth and $235,000 annual equivalent) for an accident in 2027.

ATTACHMENT 2

REHABILITATION OF L&D 2

ATTACHMENT 2

REHABILITATION OF L&D 2

The work to be accomplished during the rehabilitation of the locks at L&D 2 is summarized in Table 1 and described in the following paragraphs.

Table 1
Rehabilitation of Locks at L&D 2 in 2022

1.	Replace middle wall building.
2.	Resurface top of lock walls.
3.	Reface lock walls and install wall armor.
4.	Reface and resurface guide and guard walls.
5.	Install floating mooring bitts.
6.	Rebuild miter sills.
7.	Replace miter gates.
8.	Replace miter gate operating machinery.
9.	Replace gate anchors and pintles.
10.	Replace culvert valves and operating equipment.
11.	Install new hydraulic system.
12.	Replace lock power and lighting system.
13.	Replace air and water systems.
14.	Replace tow haulage system.

1. Replacing Middle Wall Building. The middle wall operation building will be located approximately midway between the lock gates and will be a two story structure, housing the power distribution center, mechanical room, electrical room, office, rest rooms and a lunch room.

2. Resurfacing Top of Lock Walls. The top concrete surfaces of the lock, guide and guard walls are generally in good condition; however, dissolution of the limestone coarse aggregate is evident throughout the entire lock structure. Some surfaces contain aggregate popouts and hairline cracking. The WES Condition Survey report of March, 1988 has indicated the depth of damaged concrete on the surfaces to be negligible; however, in order to address surface deterioration which is probable to occur up to the point in time at which the rehabilitation contract would be awarded, work must be done.

The repair work would consist of placing new top concrete surfaces on the land, middle and river walls, upper and lower guide walls and upper and lower guard walls after removing the deteriorated concrete.

A new one-foot thick, minimum, reinforced concrete overlay would be placed on top of all walls. New top corner protection would also be installed and anchored in the new concrete.

3. Refacing Lock Walls and Installing Wall Armor. As is the case with the horizontal surfaces, only minor deficiencies currently exist on the lock wall faces; however, random monolith joints exhibit excessive deterioration. Some cracking is evident but is now confined to localized areas. The March, 1988 Condition Survey by WES indicates the depth of damaged concrete to be 0.1 ft. or less but recommends that these surface cracks be mapped for future reference to correlate hairline cracks in the pipe galleries and the filling and emptying culverts.

The repair work would consist of refacing the deteriorated concrete faces of the lock, guide and guard walls for the entire length of the respective walls. The refacing would be accomplished by first removing the deteriorated concrete to sound concrete; installing steel dowels; erecting reinforcing steel and wall armor; erecting formwork; and placing new structural concrete for a minimum depth of one foot.

Wall armor would be installed on the chamber faces of the walls in all critical areas which would be susceptible to tow impact damage.

4. Refacing and Resurfacing Guide and Guard Walls. The chamber faces of the guide and guard walls are spalled and cracked especially at monolith joints but, in general, the concrete is in fair to good condition. The March, 1988 WES Condition Survey indicates the depth of damaged concrete to be negligible; however, in order to address anticipated future damage from weathering and gouges from tow impacts, work will be required.

The repair work would consist of refacing and resurfacing the chamber faces of the guide and guard walls that have signs of deterioration. The refacing concrete would be at least 12-inches thick, reinforced and anchored to the existing concrete.

5. Installing Floating Mooring Bitts. In order to upgrade the existing mooring facilities of the lock chamber and in compliance with OCE policy of "...eliminating the practice of Government personnel handling lines from transiting vessels" six floating mooring bitts generally conforming with details given in ETL 1110-2-247 would be added on the middle and river walls.

6. Rebuilding Miter Sills. This work would involve the removal of the upper and lower miter sills in both chambers and replacing the sills at the existing locations.

7. Replacing Miter Gates. This work would involve the removal of the upper and lower miter gates and installing the replacement gates; The quoin seals would also be replaced as well as the bubbler systems which would be replaced with increased-capacity units.

8. Replacing Gate Operating Machinery. This remedial work would consist of removing the existing gate operating machinery in both chambers and replacing it with new machinery, including new electrically controlled units.

9. Replacing Gate Anchorages and Pintles. The existing gate anchorages will be replaced with new eye bars, pin plates, anchor bolts, pintles, etc. All deteriorated concrete in the gate recesses will be removed to its full depth and replaced.

10. Replacing Culvert Valves and Operating Equipment. The existing butterfly valves will be removed and replaced with new valves. The valve frames would be refurbished as necessary by diver's reports. The valve operating machinery would be replaced with new machinery which would incorporate solenoid operated control valves and valve interlocks. New bar screens would be installed in all intake ports.

11. Installing New Hydraulic System. The existing system would be replaced with an entirely new hydraulic system, including piping and controls. The new hydraulic system would utilize a package type pumping unit located near each gate leaf to serve each miter gate and the local filling or emptying valve.

12. Replacing Lock Power and Lighting System. The remedial work would consist of replacing the existing electrical system for the lock chambers, including the installation of lighting standards, fixtures, wiring, and controls.

13. Replacing Air and Water Systems. The existing compressed air system would be upgraded by replacement with all new piping and fittings. The existing raw water system would be upgraded by replacement with a new pump and all new waterlines.

14. Replacing Tow Haulage System. The existing system would be removed and totally replaced with a modern system.

ATTACHMENT 3

REHABILITATION OF L&D 4

ATTACHMENT 3

REHABILITATION OF L&D 4

The work to be accomplished during the rehabilitation of the locks at L&D 4 is summarized in Table 1 and described in the following paragraphs.

Table 1
Rehabilitation of Locks at L&D 4 in 2002

1. Replace land wall and middle wall building.
2. Replace upper guard wall.
3. Stabilize lower guide wall.
4. Rebuild portions of land wall, middle wall, and river wall pipe galleries.
5. Resurface top of lock walls.
6. Reface lock walls and install wall armor.
7. Reface and resurface guide and guard walls.
8. Install floating mooring bitts.
9. Rebuild top of miter and maintenance sills.
10. Replace miter gates.
11. Replace miter gate operating machinery.
12. Replace gate anchors and pintles.
13. Replace culvert valves and operating equipment.
14. Replace esplanade.
15. Install new hydraulic system.
16. Replace lock power and lighting system.
17. Replace air and water systems.
18. Replace tow haulage system.

The main features of work in the Rehabilitation Plan would consist of resurfacing and refacing lock walls, including installing armor on wall areas subject to severe barge impact; rebuilding portions of the pipe galleries in each of the three walls; removal and replacement of the upper guard wall; stabilizing the lower guide wall; replacing lock gates and operating machinery; installing floating mooring bitts; rehabilitation of the miter and maintenance sills; replacing gate anchorages and concrete; replacing culvert valves and operating machinery; replacing worn and deteriorated mechanical and electrical components, including installation of a new hydraulic system; installing a new power and lighting system; removal and replacement of the lock buildings including the land wall and middle wall buildings and control shelters; replacing the tow haulage system. The specific items are described below.

1. Replace Landwall and Middle Wall Buildings. The landwall service building will be located on the esplanade approximately at the existing location. The building will be a single story structure identical to that described in the rehab at Locks and Dam 2. The middle wall operations building will be a two story structure identical to that proposed for Locks and Dam 2.

2. Replace Upper Guard Wall. The upper guard wall is currently tilting noticeably to the extent that a stabilization plan was proposed by the District for temporary measures but was never implemented. This plan would totally remove the upper guard wall and replace it with a gravity type concrete cap wall founded on intermittent circular steel sheetpiling cells enclosing steel bearing piles, all driven to rock. Because of its susceptibility to impact, the upstream end cell will be 33'6" in diameter and will be filled with concrete to resist impact loads.

3. Stabilize Lower Guide Wall. Instrumentation readings have been taken to monitor potential movement along the lower guide wall. Records indicate that movement has, in fact, occurred. To address this problem and to improve overall wall stability, earth would be removed behind the entire length of the lower guide wall down to approximate elevation 723, which is approximately 26 feet below the top of wall elevation. The bank would be laid back at approximately a 2.5:1 slope and protected with stone protection.

4. Rebuild Portions of Landwall, Middle Wall and River Wall Pipe Galleries. All lock walls will be refaced and resurfaced by removing and replacing a 12 inch minimum depth of concrete. By so doing, some pipe gallery walls will be reduced to such critical thicknesses that crack propagation during the removal process as well as the drilling and dowelling process is highly probable. The chamber face of the landwall pipe gallery is now only 2'9" in places, which would be reduced to 1'9" or less after the face removal. This critical section extends for approximately 600 ft. Similarly, the middle wall gallery contains a critical area extending approximately 100 ft. in which the wall thickness, after removal of a 12 inch face, would only be 12 inches. The chamber face of the river wall gallery contains a critical area extending approximately 200 ft. which is similar to the landwall condition. The wall thickness, after removal, would be 1'9". To correct this condition, this plan would remove the front and top gallery walls and reconstruct by dowelling and replacing with high quality, air-entrained concrete. Reinforcement would be provided around the reconstructed gallery faces. To maintain lock operations, all piping would be temporarily relocated either on the esplanade or on top of the monoliths until the galleries would be rebuilt. New piping systems would then be installed.

5. <u>Resurfacing Top of Lock Walls</u>. The concrete on and near the top surfaces of the guide, guard, and lock walls is generally in fair to poor condition according the WES Condition Survey of March, 1988. Concrete damage is considered extensive covering greater than 50 percent of these surfaces.

The repair work would consist of placing new top concrete surfaces on the land, middle and river walls, upper and lower guide walls and upper and lower guard walls after removing the deteriorated concrete.

A new one-foot thick, minimum, reinforced concrete overlay would be placed on top of all walls. Top corner protection would also be installed and anchored in the new concrete. Any structural cracks which may have developed in the lock wall recesses would be repaired and all recess frames and covers would be replaced. This work would be performed from the top of the walls and would have little impact on the lock operation.

6. <u>Refacing Lock Walls and Installing Wall Armor</u>. The vertical surfaces of the guide, guard, and lock walls above lower pool elevation are generally in poor condition according to the 1988 WES Condition Survey. Damage is extensive covering about 80 percent of these surfaces, however near surface damage is limited. Generally, the deterioration has penetrated to about 0.5 ft. with a maximum of 1.4 ft. in the middle wall.

The repair work would consist of refacing the deteriorated concrete faces of the lock, guide and guard walls as described in the rehab of Locks and Dam 2.

7. <u>Refacing and Resurfacing Guide and Guard Walls</u>. The concrete on both the vertical and horizontal surfaces of the guide and guard walls is generally in poor condition and would be rehabilitated according to the procedure described under the rehabilitation of Locks and Dam 2.

8. <u>Installing Floating Mooring Bitts</u>. In order to upgrade the existing mooring facilities of the lock chamber and in compliance with OCE policy of "...eliminating the practice of Government personnel handling lines from transiting vessels" six floating mooring bitts (three each on the middle and river walls) generally conforming with details given in ETL 1110-2-247 would be added on the middle and river walls.

9. <u>Rebuilding Top of Miter and Maintenance Sills</u>. This work would involve the removal of the deteriorated concrete along the upstream, top surfaces of the sills. As a minimum, a 12-inch wide by 12-inch deep area would be sawcut along the top surfaces of the sills at the gate leaf interfaces. The existing anchor bolts would be removed and new ones installed by drilling and grouting.

10. Replacing Miter Gates. This work would involve the removal of the upper and lower miter gates and installing the replacement gates; The quoin seals would also be replaced as well as the bubbler systems which would be replaced with increased-capacity units.

11. Replacing Gate Operating Machinery. This work would consist of removing the existing gate operating machinery in both chambers and replacing it with new machinery, including new electrically controlled units.

12. Replacing Gate Anchorages and Pintles. The existing gate anchorages will be replaced with new eye bars, pin plates, anchor bolts, pintles, etc. All deteriorated concrete in the gate recesses will be removed to its full depth and replaced.

13. Replacing Culvert Valves and Operating Equipment. The existing butterfly valves will be removed and replaced with new valves. The valve frames would be refurbished as necessary by diver's reports. The valve operating machinery would be replaced with new machinery which would incorporate solenoid operated control valves and valve interlocks. New bar screens would be installed in all intake ports.

14. Replace Esplanade. Prior to removal and reconstruction of the landwall service building, the esplanade concrete would be totally removed and replaced with a new reinforced concrete slab and sloped wall, beginning and ending approximately at the existing locations. The drainage ditch would be replaced and a thrust block provided if deemed necessary by slope stability.

15. Installing New Hydraulic System. The existing system would be replaced with an entirely new hydraulic system, including piping and controls. The new hydraulic system would utilize a package type pumping unit located near each gate leaf to serve each miter gate and the local filling or emptying valve.

16. Replacing Lock Power and Lighting System. The remedial work would consist of replacing the existing electrical system for the lock chambers, including the installation of lighting standards, fixtures, wiring and controls.

17. Replacing Air and Water Systems. The existing compressed air system would be upgraded by replacement with all new piping and fittings. The existing raw water system would be upgraded by replacement with a new pump and all new waterlines.

18. Replacing Tow Haulage System. The existing tow haulage system will be totally removed and replaced with a new, modern system.

ATTACHMENT 4

POTENTIAL PROJECT SITES

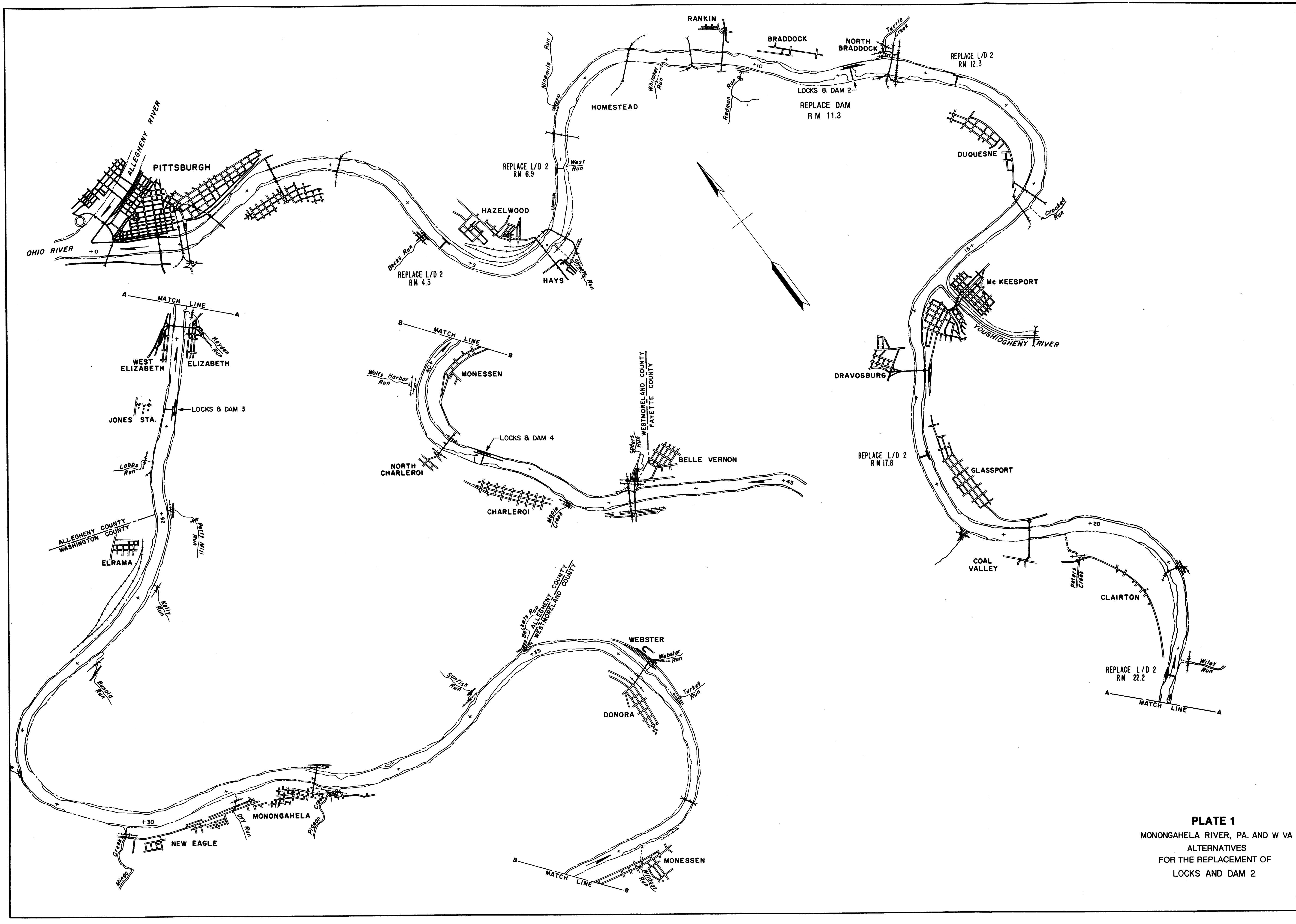


PLATE 1

MONONGAHELA RIVER, PA. AND W VA
ALTERNATIVES
FOR THE REPLACEMENT OF
LOCKS AND DAM 2

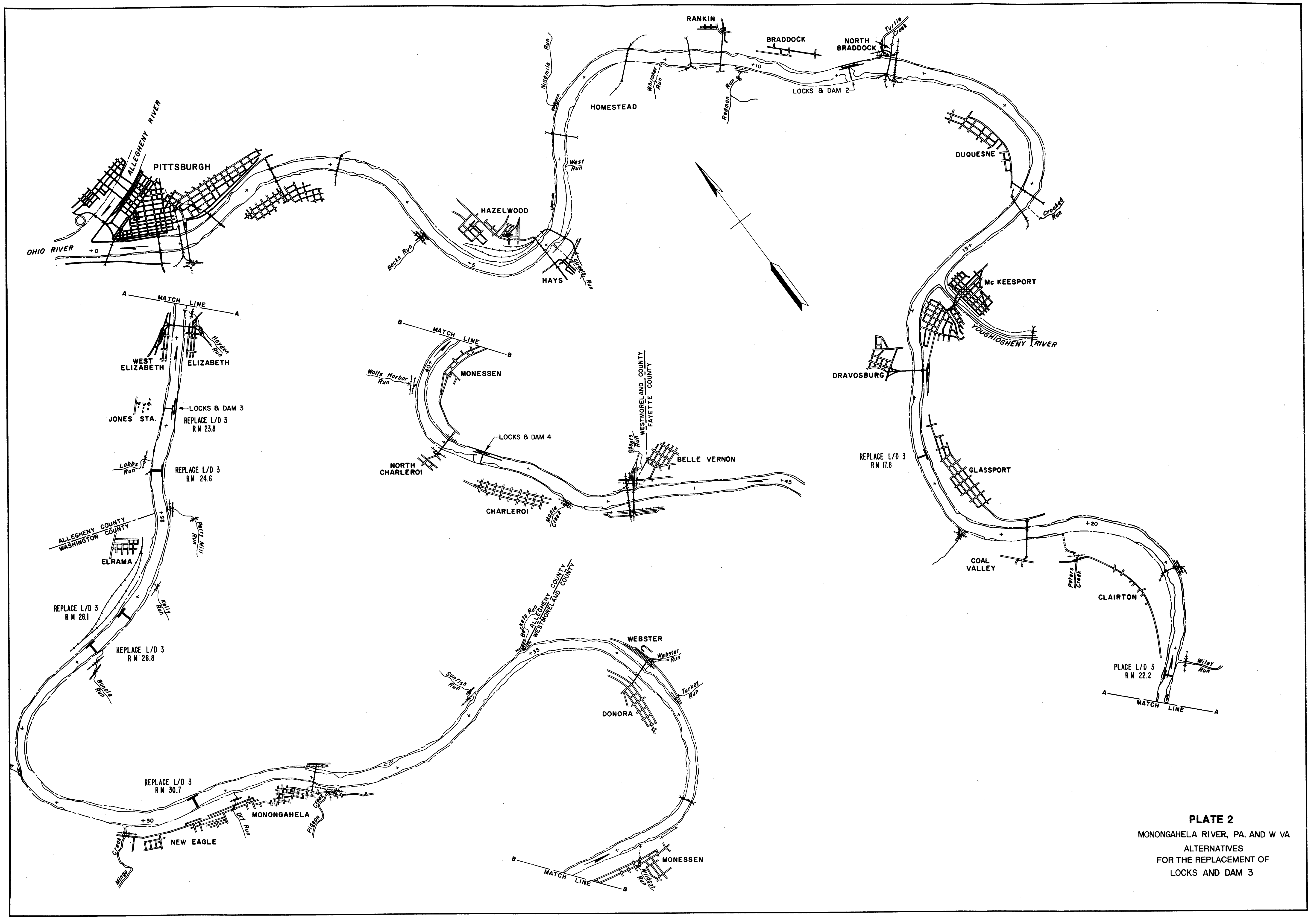


PLATE 2

MONONGAHELA RIVER, PA. AND W VA

ALTERNATIVES
FOR THE REPLACEMENT OF
LOCKS AND DAM 3

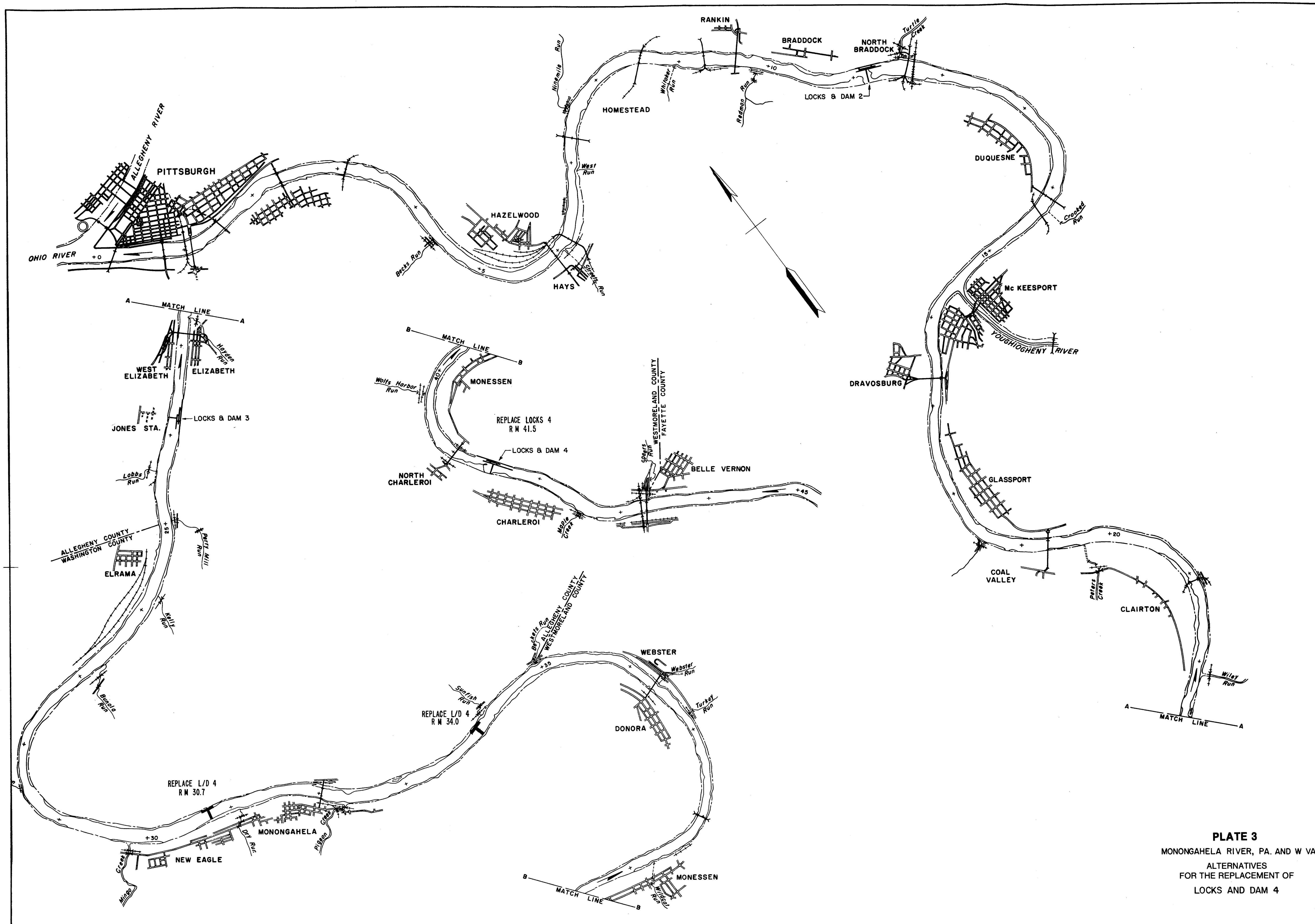


PLATE 3

MONONGAHELA RIVER, PA. AND W VA

ALTERNATIVES
FOR THE REPLACEMENT OF
LOCKS AND DAM 4

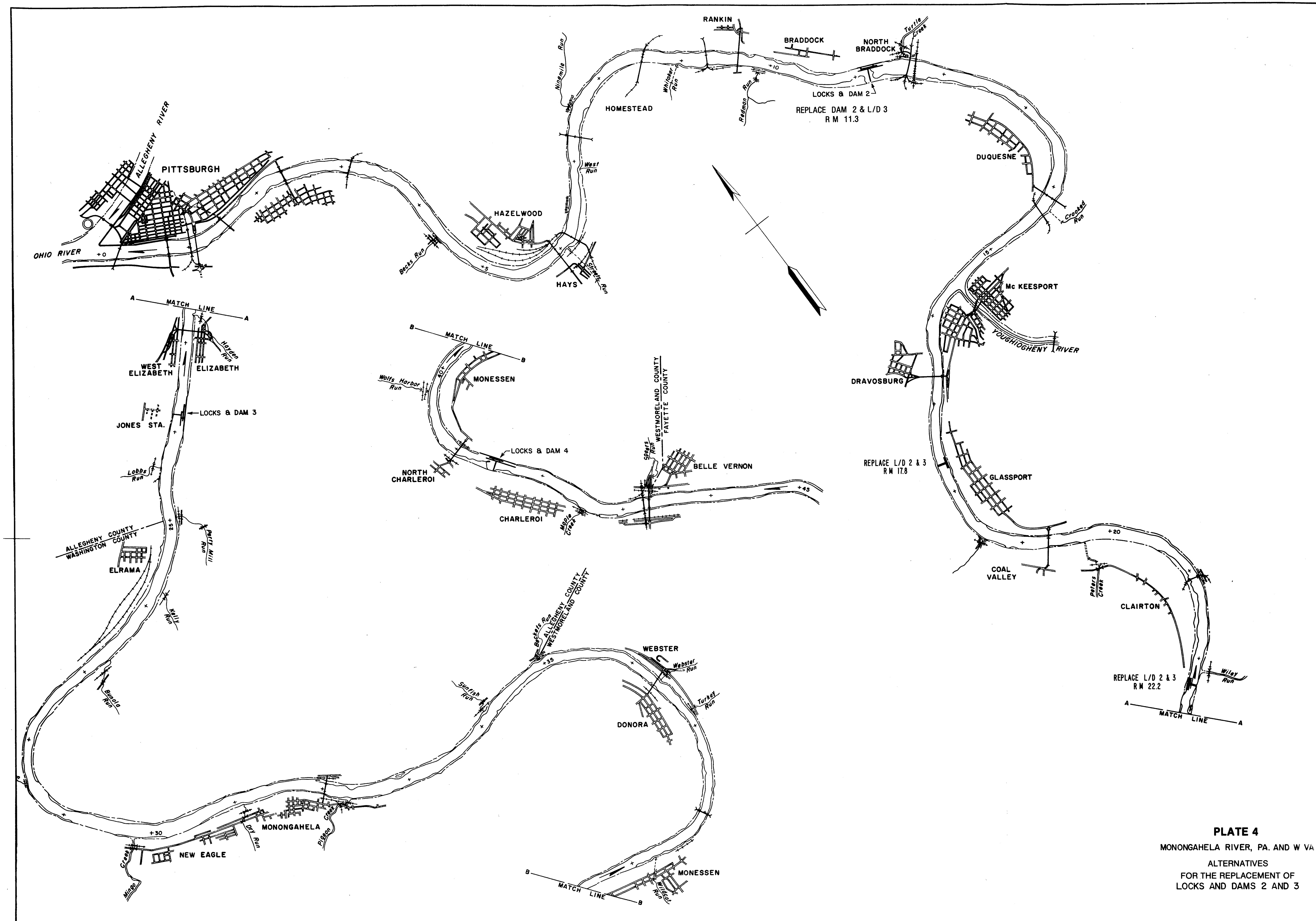


PLATE 4

MONONGAHELA RIVER, PA. AND W VA

ALTERNATIVES
FOR THE REPLACEMENT OF
LOCKS AND DAMS 2 AND 3

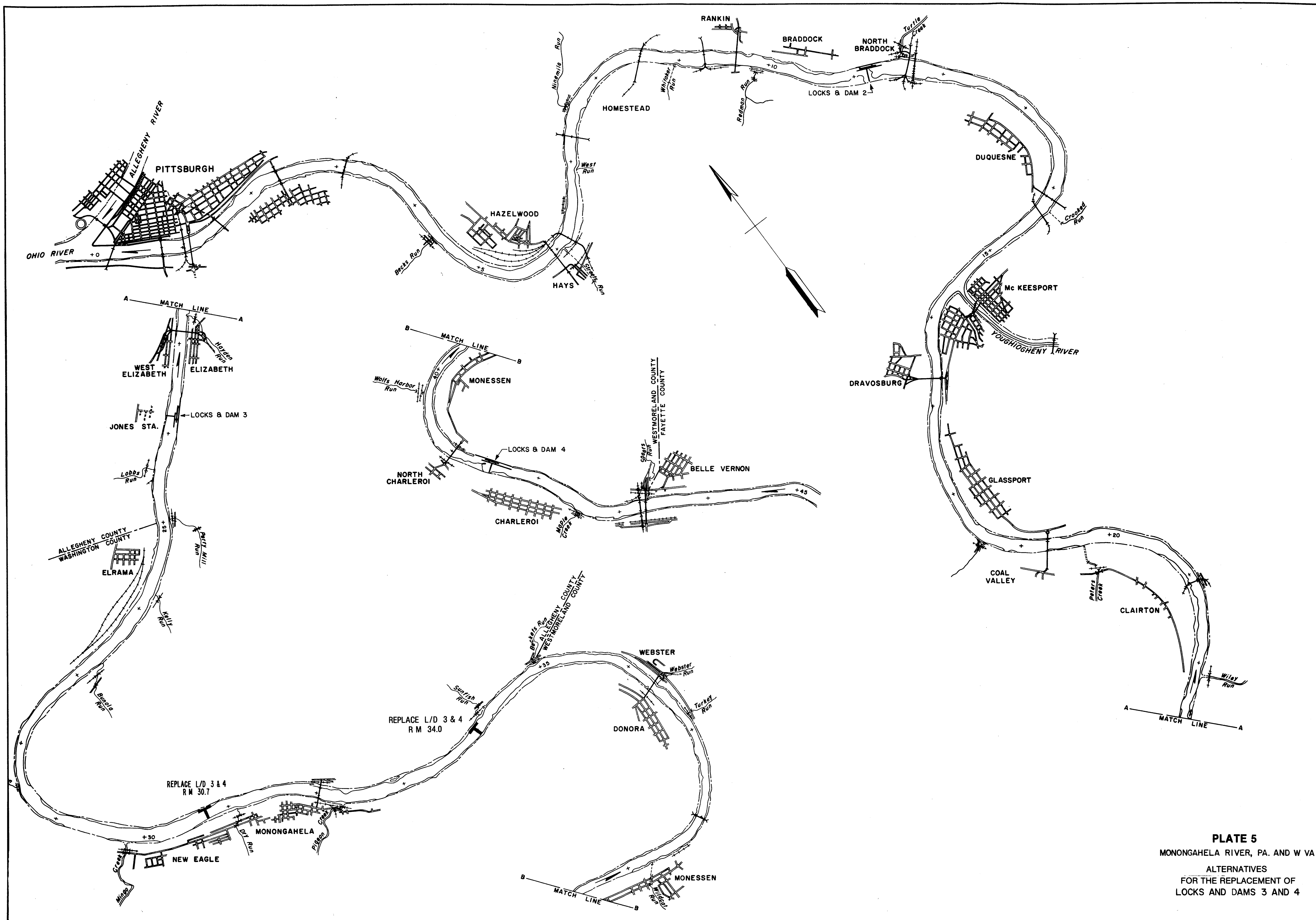


PLATE 5

MONONGAHELA RIVER, PA. AND W VA

ALTERNATIVES
FOR THE REPLACEMENT OF
LOCKS AND DAMS 3 AND 4

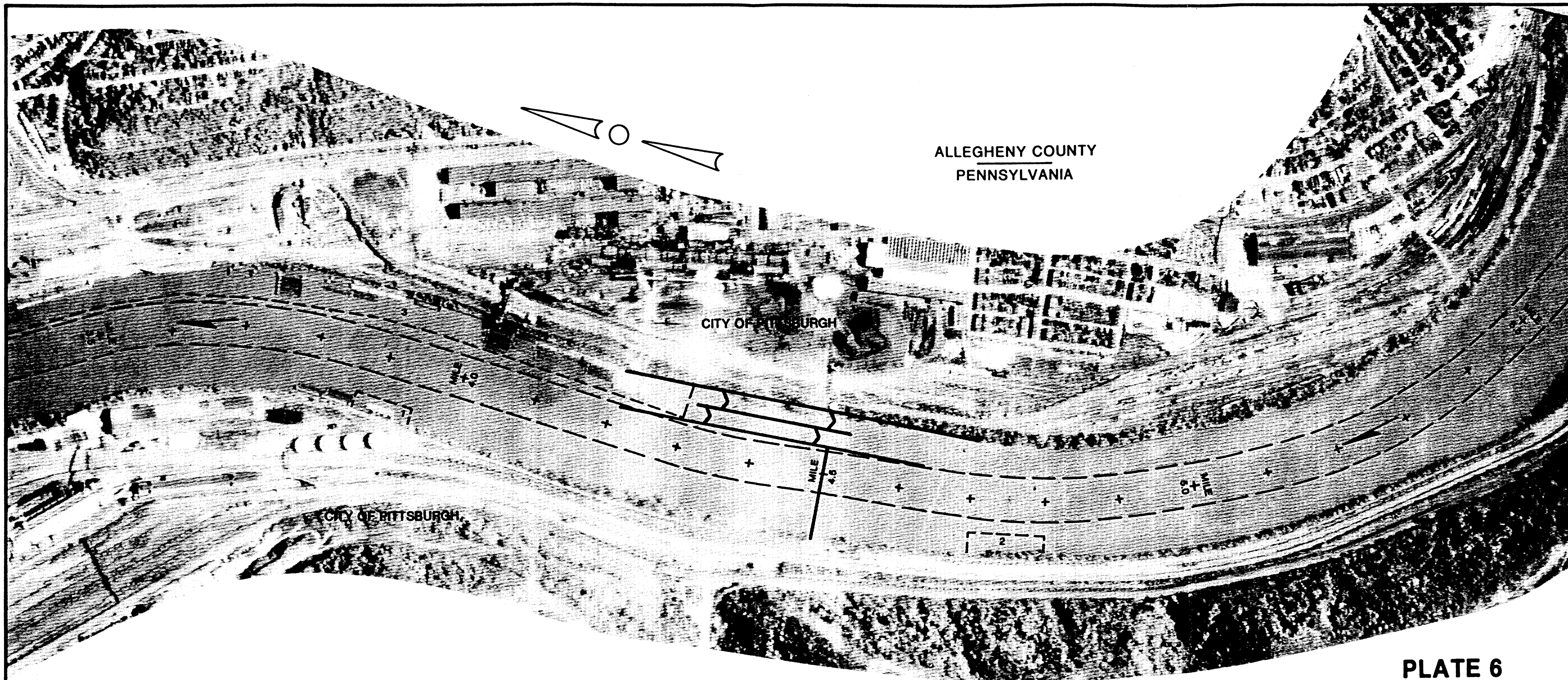


PLATE 6

MONONGAHELA RIVER

AREA SITE MAP

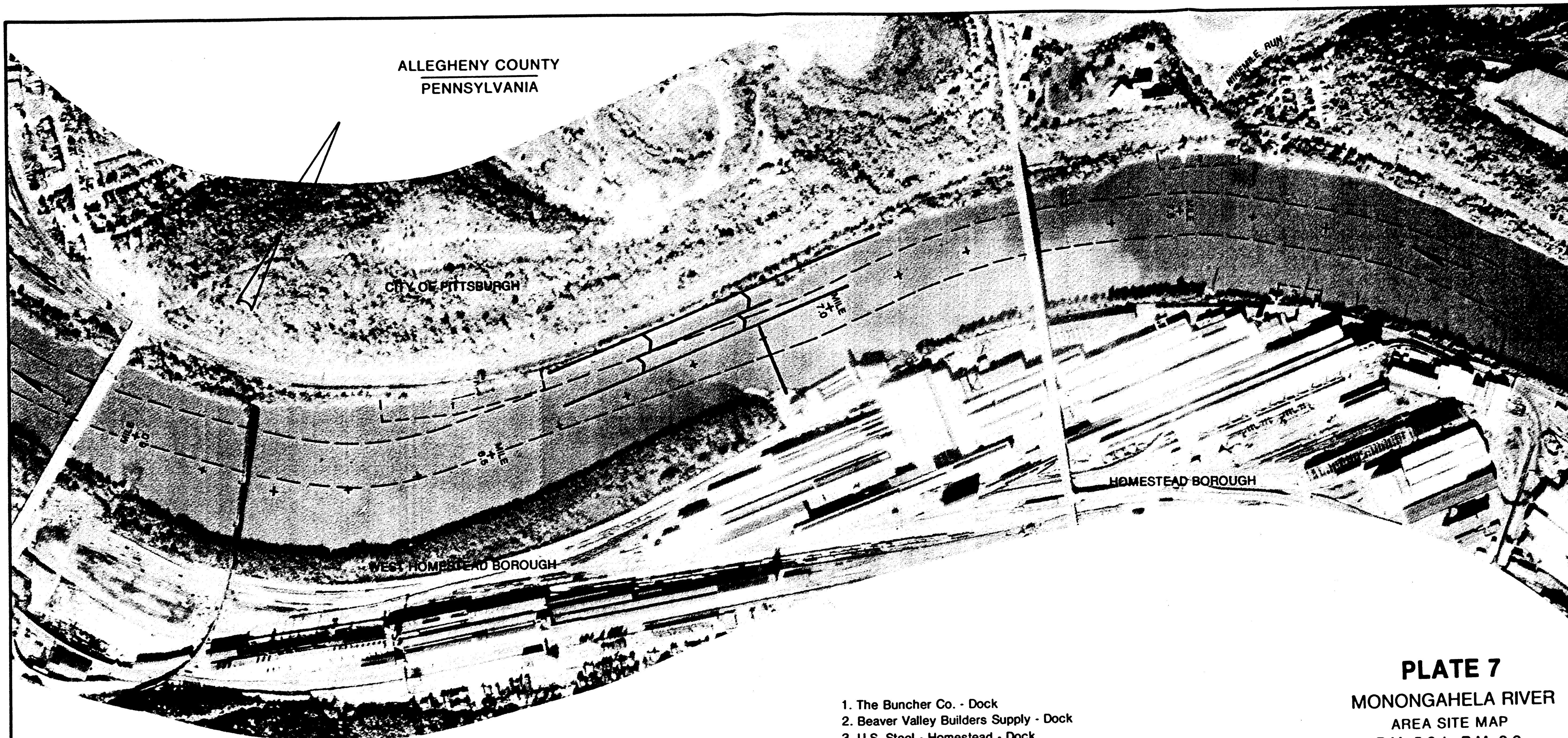
R.M. 3.4 to R.M. 5.5

500 0 500 1000

Approximate Scale

Date of Photography 23 October 1980

1. LTV Steel - Dock
2. Campbell Bargeline - Dock
3. LTV Steel - Dock

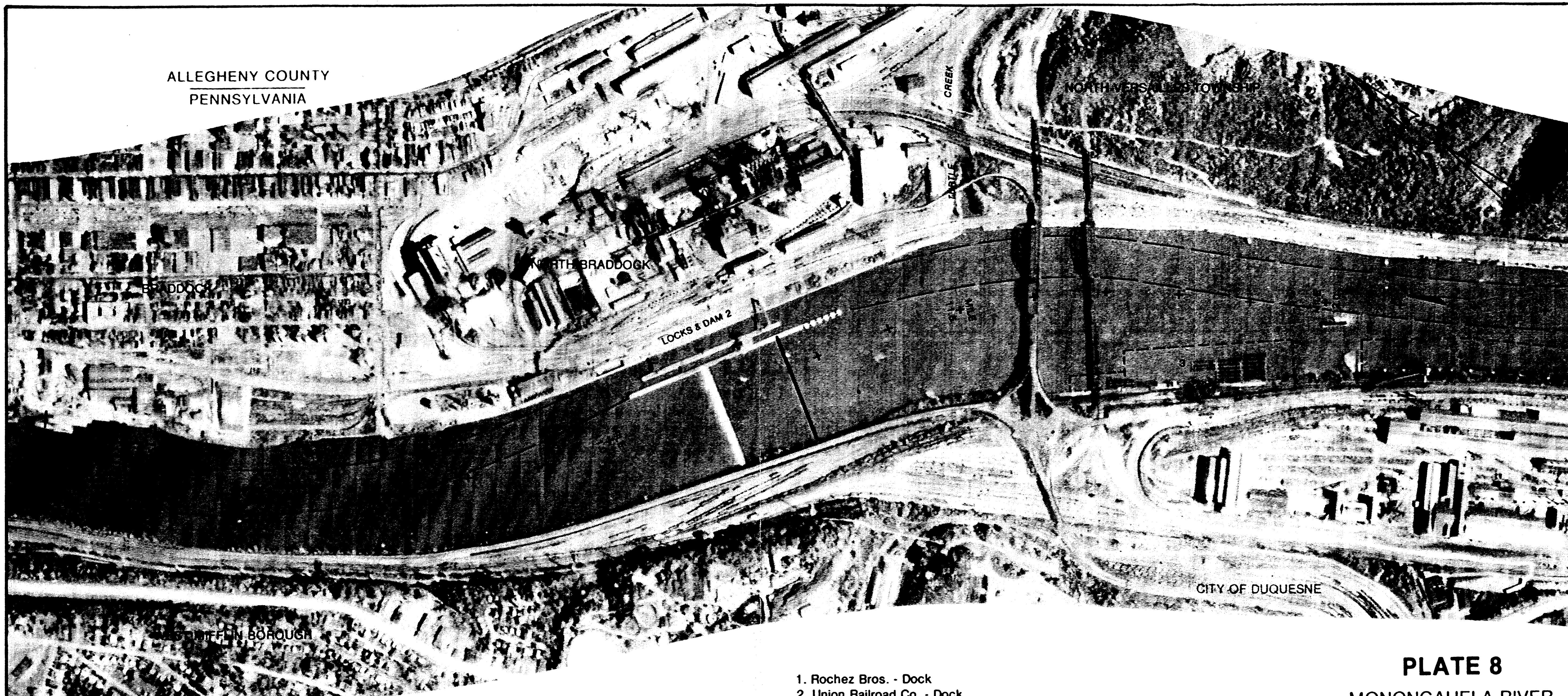


1. The Buncher Co. - Dock
2. Beaver Valley Builders Supply - Dock
3. U.S. Steel - Homestead - Dock

PLATE 7

MONONGAHELA RIVER
AREA SITE MAP
R.M. 5.9 to R.M. 8.0

Date of Photography 23 October 1980



1. Rochez Bros. - Dock
2. Union Railroad Co. - Dock
3. Union Railroad Co. - Dock
4. Union Railroad Co. - Dock

PLATE 8

MONONGAHELA RIVER

AREA SITE MAP

R.M. 10.2 to R.M. 12.3

500 0 500 1000

Approximate Scale

Date of Photography 23 October 1980

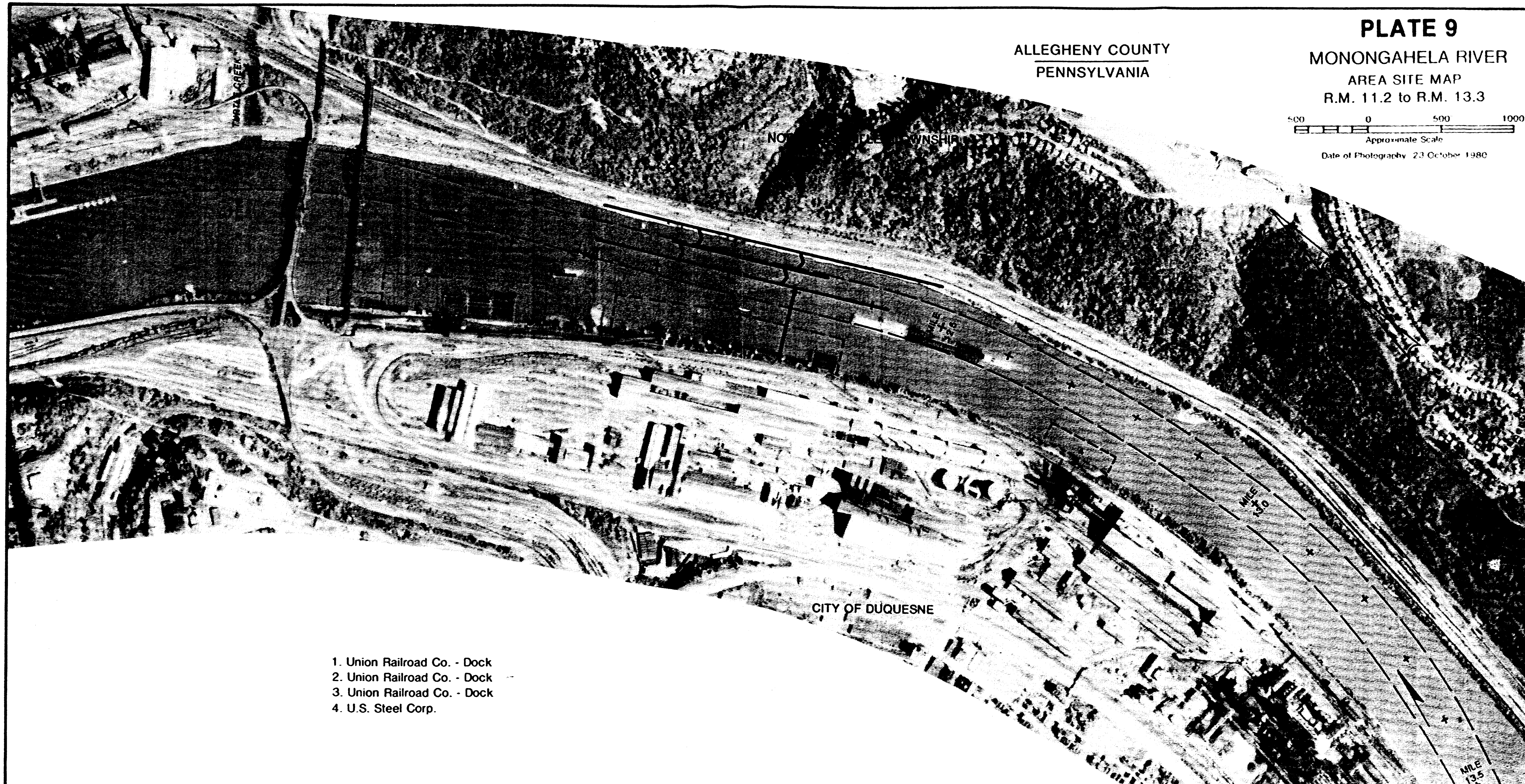
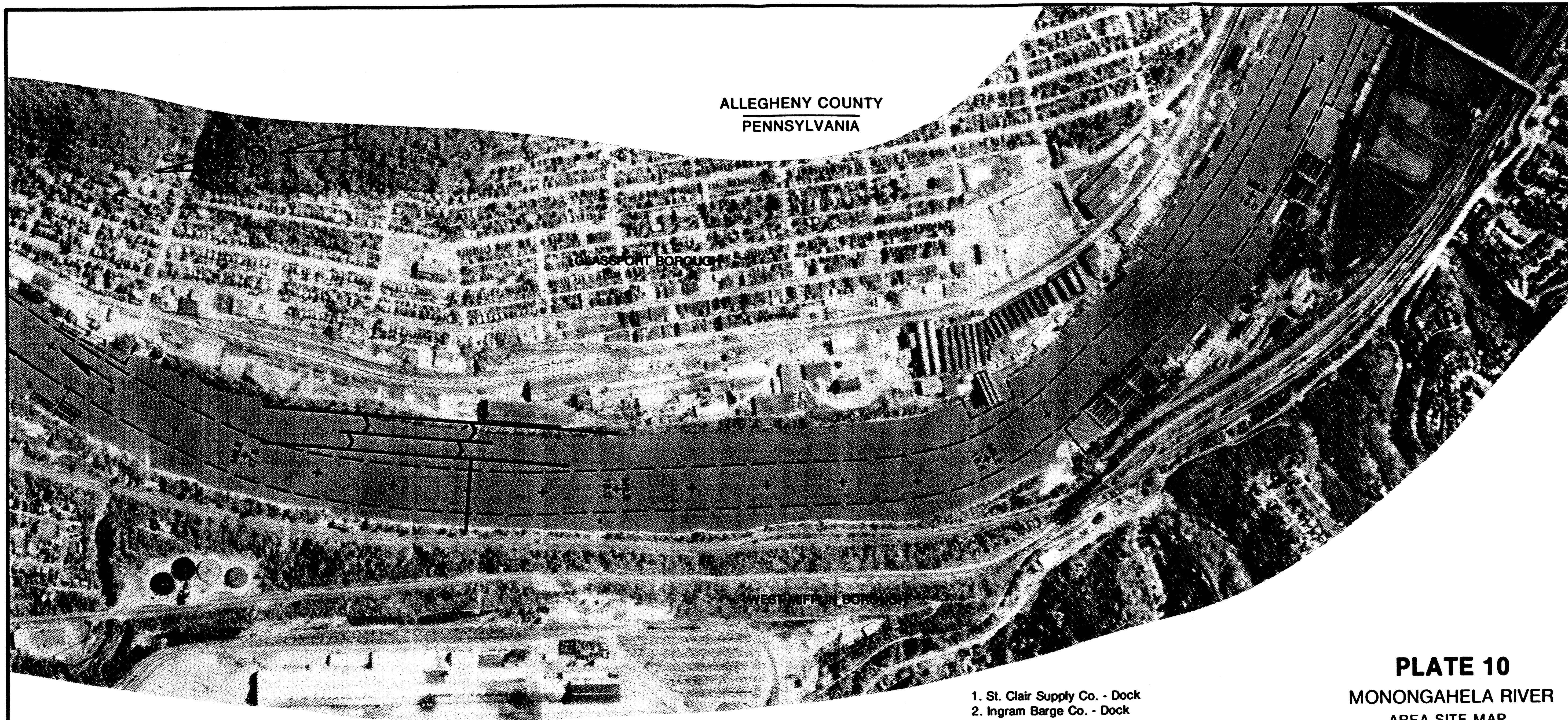


PLATE 9
MONONGAHELA RIVER
AREA SITE MAP
R.M. 11.2 to R.M. 13.3
ALLEGHENY COUNTY
PENNSYLVANIA
500 0 500 1000
Approximate Scale
Date of Photography 23 October 1980
CITY OF DUQUESNE
MILE 13.0
MILE 13.5
1. Union Railroad Co. - Dock
2. Union Railroad Co. - Dock
3. Union Railroad Co. - Dock
4. U.S. Steel Corp.



1. St. Clair Supply Co. - Dock
2. Ingram Barge Co. - Dock
3. Youngstown Steel - Dock
4. C & C Marine Maintenance - Dock
5. U.S Steel - Dock
6. Aristech Chemical Corp. - Dock
7. Glassport Trans. Center - Floating Dock

PLATE 10

MONONGAHELA RIVER

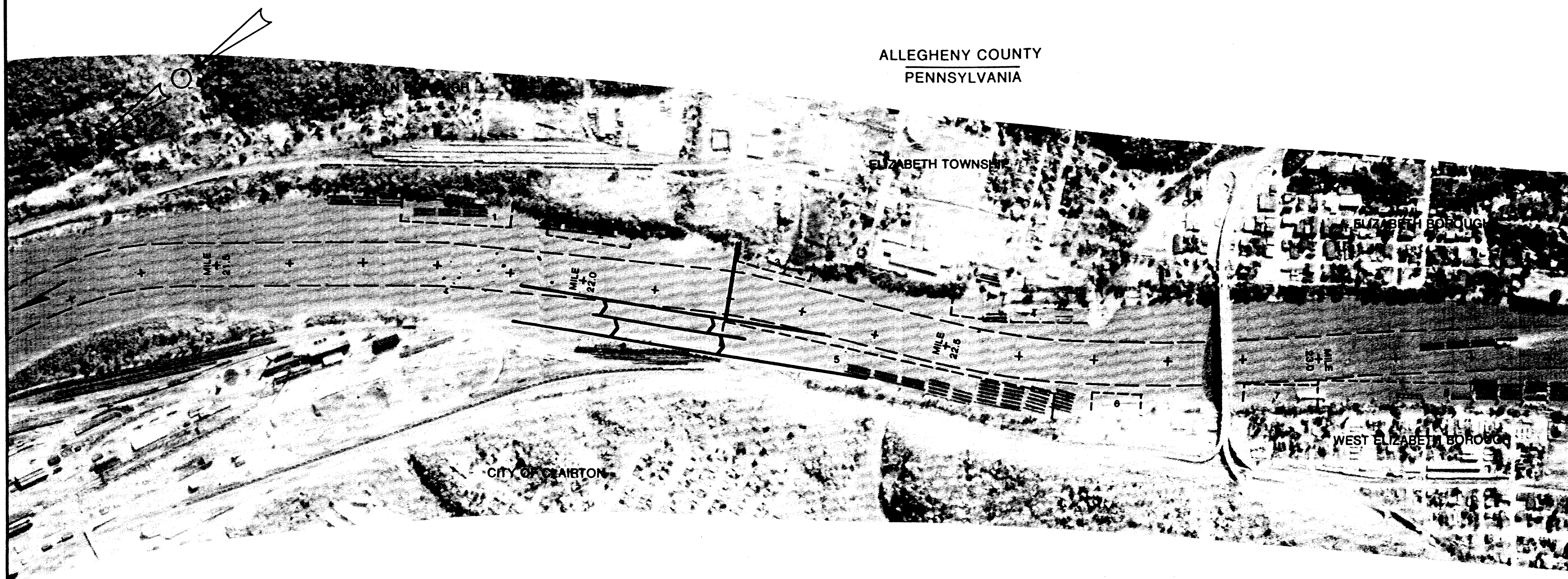
AREA SITE MAP

R.M. 16.8 to R.M. 18.9

500 0 500' 1000'

Approximate Scale

Date of Photography 23 October 1980



1. Mon. River Towing - Dock
2. Crounse Corp. - Mooring Buoys
3. Howell Bros. - Dock
4. Consolidation Coal Co. - Marine Ways
5. Consolidation Coal Co. - Dock
6. St. Clair Supply Co. - Dock
7. Consolidation Coal Co. - Dock
8. Consolidation Coal Co. - Dock

PLATE 11

MONONGAHELA RIVER

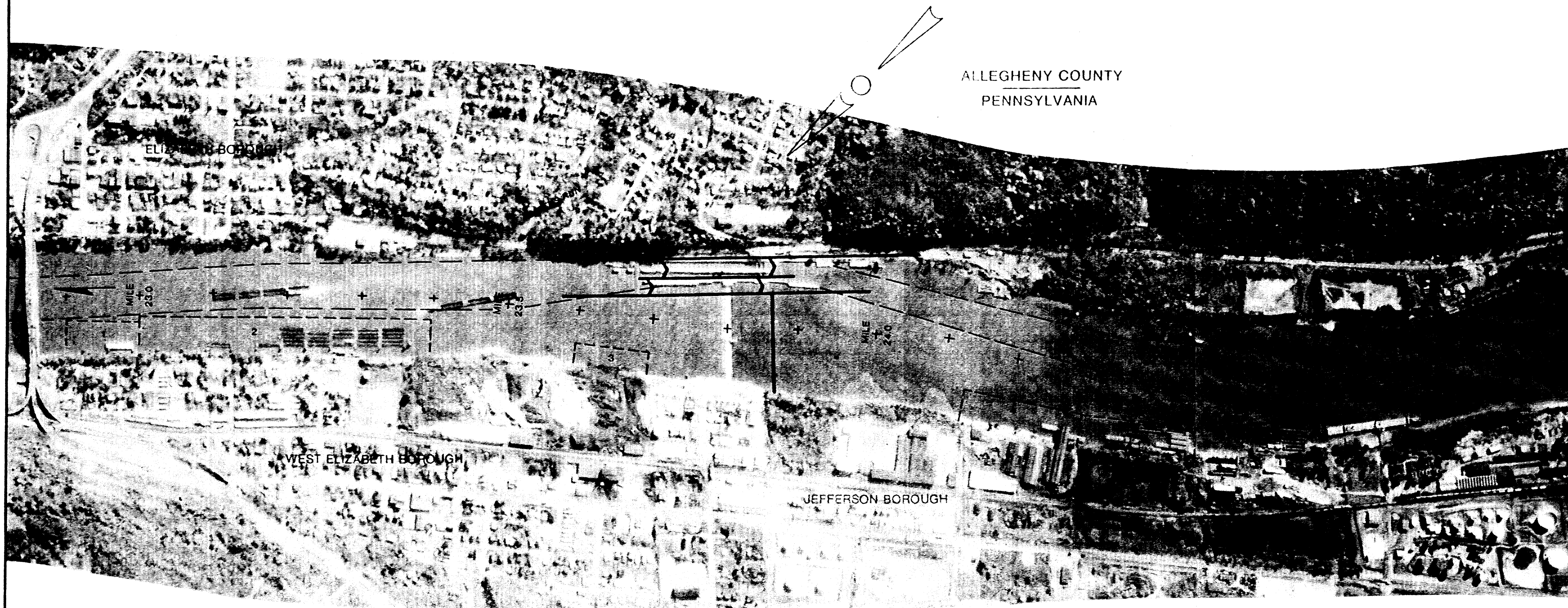
AREA SITE MAP

R.M. 21.2 to R.M. 23.3

500 0 500 1000

Approximate Scale

Date of Photography 23 October 1980



1. Consolidation Coal Co. - Dock
2. Consolidation Coal Co. - Dock
3. M.M. Schaeffer - Dock
4. Dillner Transfer & Storage - Dock
5. Guttman Realty Co. - Dock
6. Guttman Realty Co. - Dock
7. Ashland Oil Co. - Dock
8. Lock 3 Coal, Gas & Oil - Dock

PLATE 12

MONONGAHELA RIVER

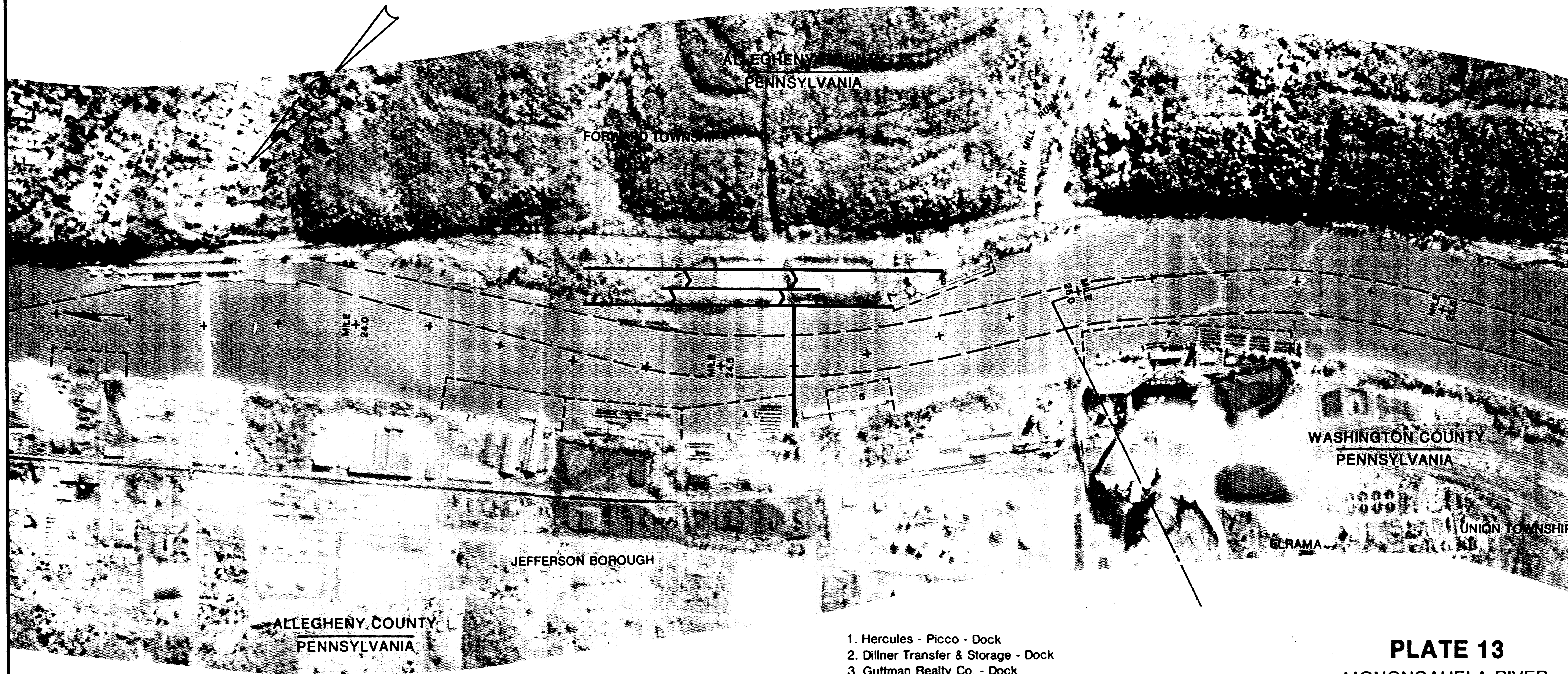
AREA SITE MAP

R.M. 22.8 to R.M. 24.9

500' 0 500' 1000'

Approximate Scale

Date of Photography 23 October 1980



1. Hercules - Picco - Dock
2. Dillner Transfer & Storage - Dock
3. Guttman Realty Co. - Dock
4. Guttman Realty Co. - Dock
5. Ashland Oil Co. - Dock
6. Lock 3 Coal, Gas & Oil - Dock
7. Duquesne Light Co. - Dock

PLATE 13

MONONGAHELA RIVER

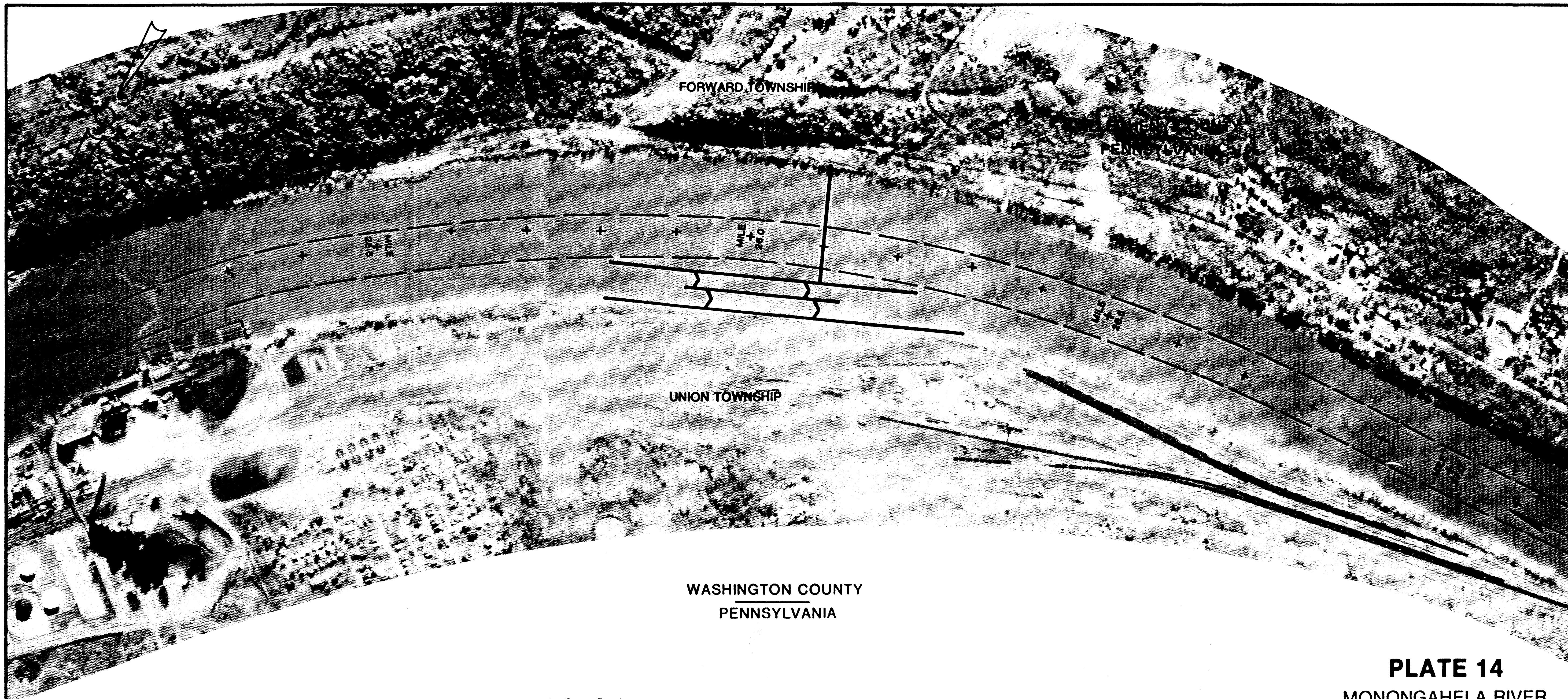
AREA SITE MAP

R.M. 23.6 to R.M. 25.7

500 0 500 1000

Approximate Scale

Date of Photography 23 October 1980



1. Duquesne Light Co. - Dock

PLATE 14

MONONGAHELA RIVER

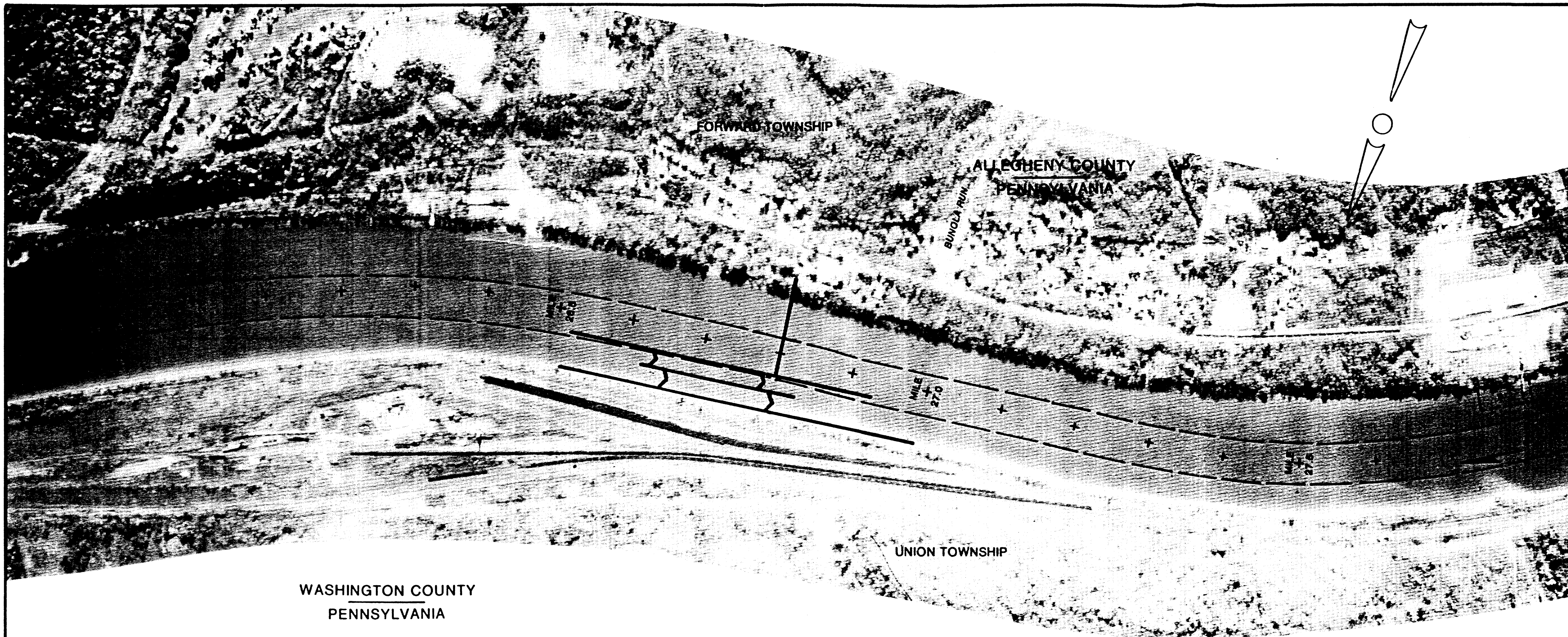
AREA SITE MAP

R.M. 25.0 to R.M. 27.1

500' 0 500' 1000'

Approximate Scale

Date of Photography 23 October 1980



1. Chemply Corp. - Dock

PLATE 15

MONONGAHELA RIVER

AREA SITE MAP

R.M. 25.8 to R.M. 27.9

500' 0 500' 1000'

Approximate Scale

Date of Photography 23 October 1980

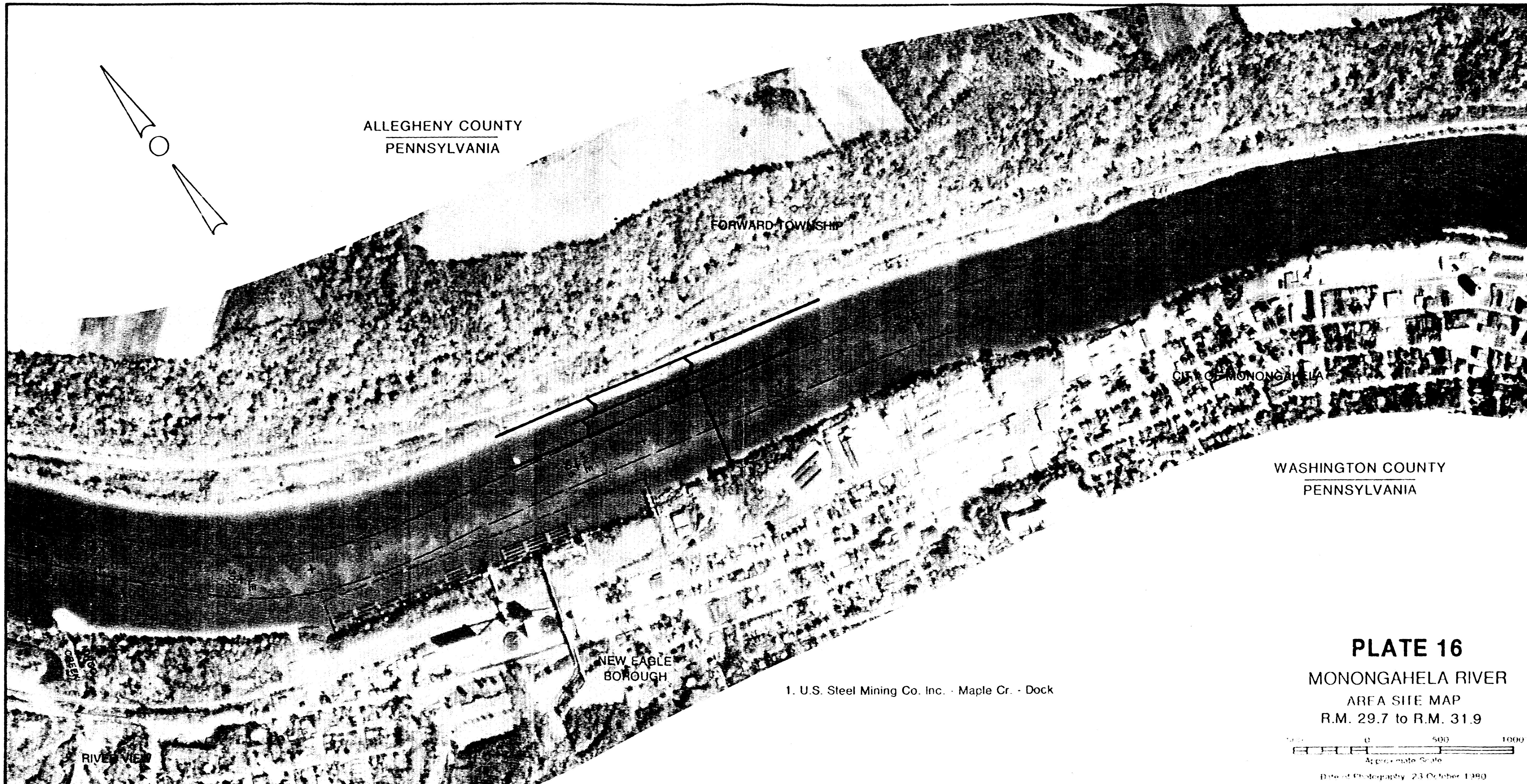
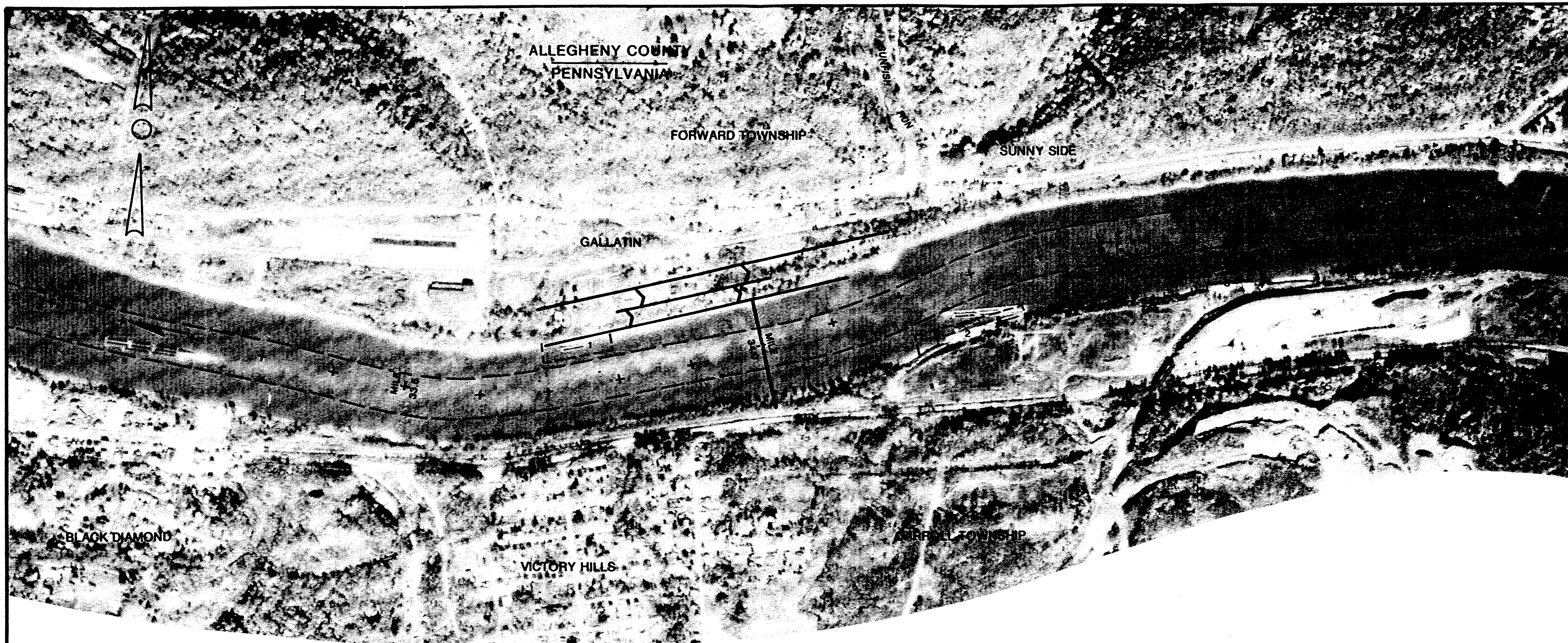


PLATE 16

MONONGAHELA RIVER

AREA SITE MAP

R.M. 29.7 to R.M. 31.9



WASHINGTON COUNTY
PENNSYLVANIA

1. Suchko Gas & Oil Co. - Dock
2. Inter - Carbon Coal Co. - Dock
3. Standard Terminals Inc. - Dock

PLATE 17

MONONGAHELA RIVER

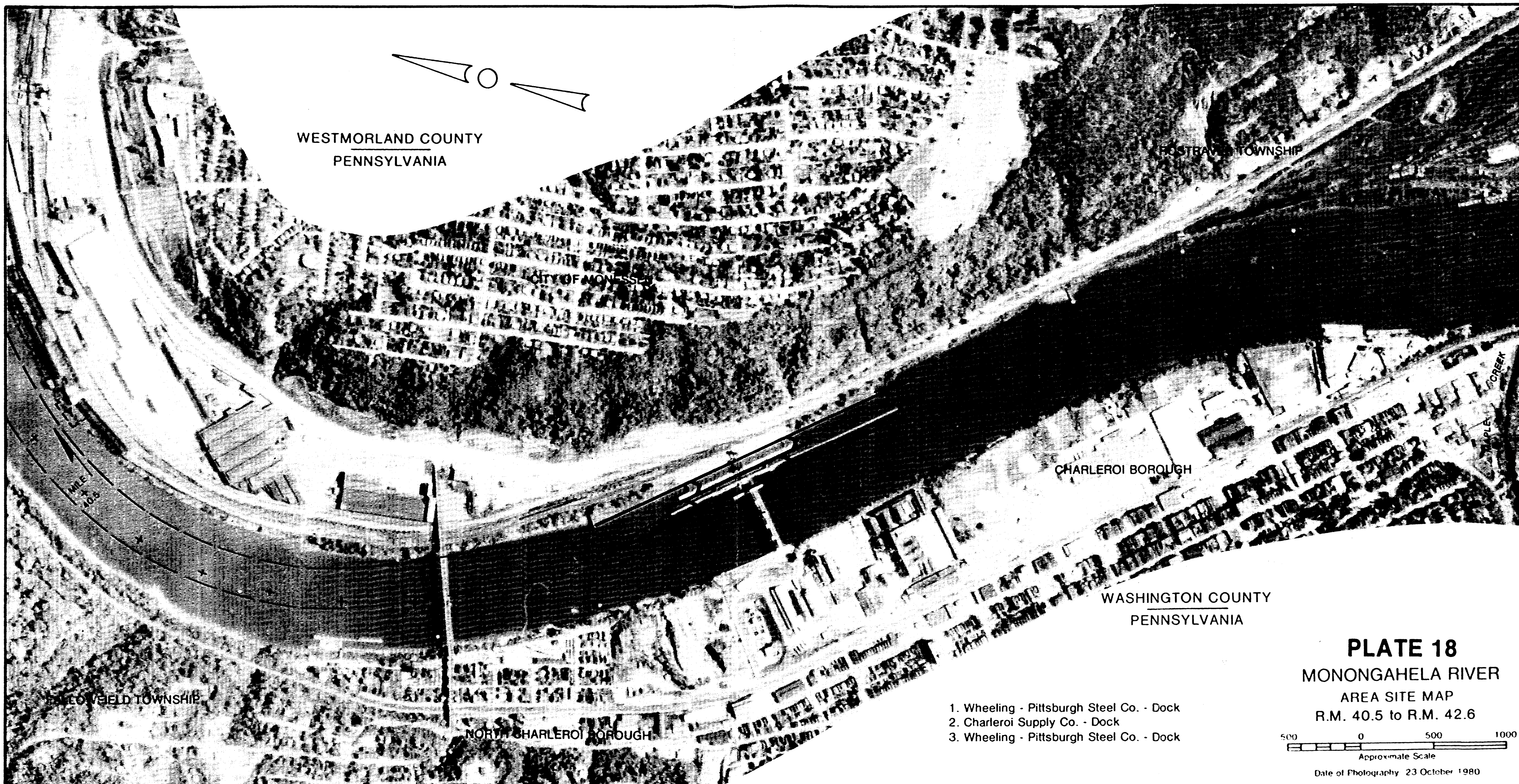
AREA SITE MAP

R.M. 33.0 to R.M. 35.1

500' 0 500' 1000'

Approximate Scale

Date of Photography 23 October 1980


WESTMORLAND COUNTY
PENNSYLVANIA
CITY OF MONESSEN
ROSTRAVER TOWNSHIP
CHARLEROI BOROUGH
WASHINGTON COUNTY
PENNSYLVANIA
NORTH CHARLEROI BOROUGH
MILE 40.5
CREEK
PLATE 18
MONONGAHELA RIVER
AREA SITE MAP
R.M. 40.5 to R.M. 42.6
1. Wheeling - Pittsburgh Steel Co. - Dock
2. Charleroi Supply Co. - Dock
3. Wheeling - Pittsburgh Steel Co. - Dock
500 0 500 1000
Approximate Scale
Date of Photography 23 October 1980

ATTACHMENT 5

ILLUSTRATIONS OF SEVEN PRELIMINARY PLANS

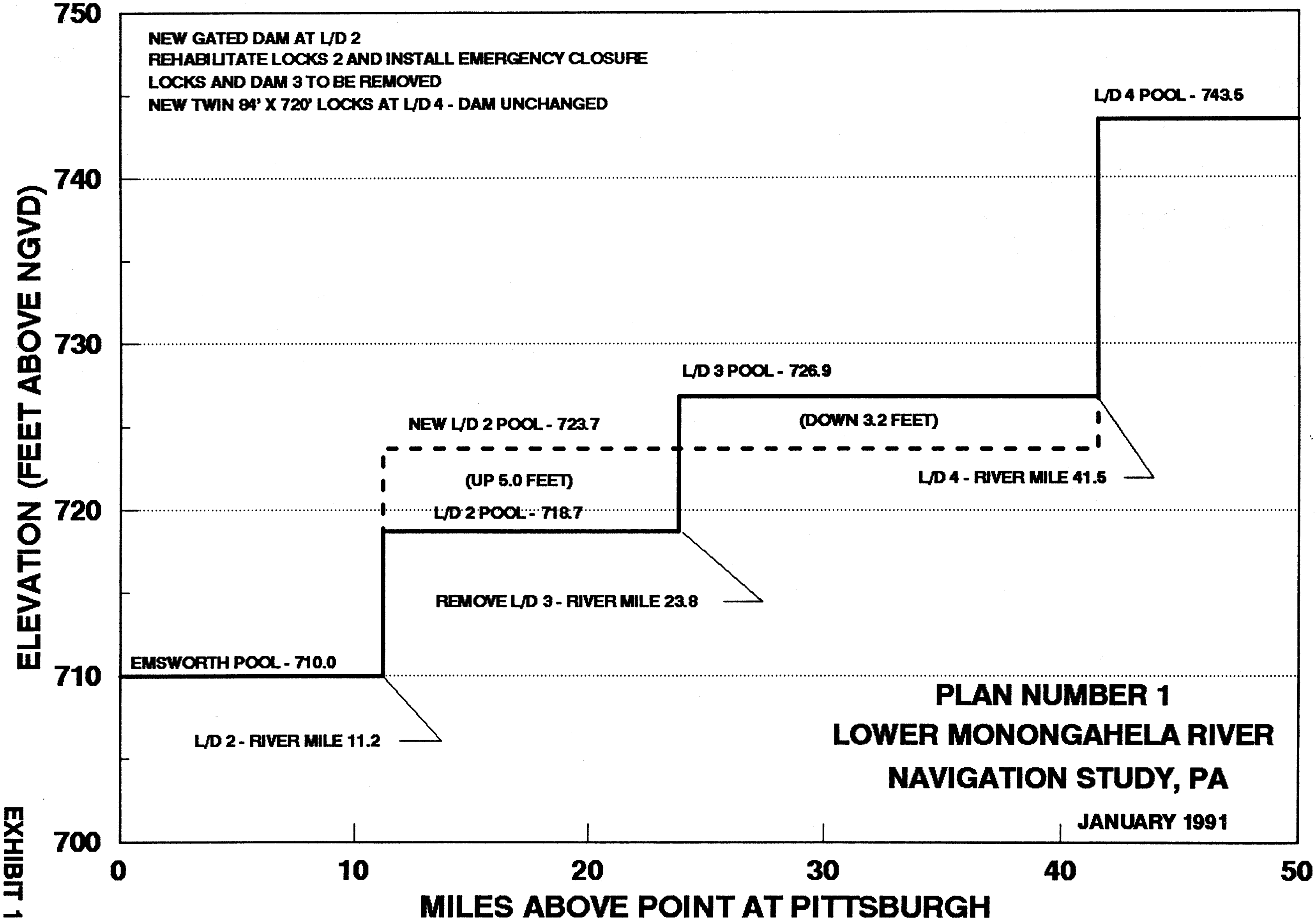

NEW GATED DAM AT L/D 2
REHABILITATE LOCKS 2 AND INSTALL EMERGENCY CLOSURE
LOCKS AND DAM 3 TO BE REMOVED
NEW TWIN 84' X 720' LOCKS AT L/D 4 - DAM UNCHANGED
L/D 4 POOL - 743.5
L/D 3 POOL - 726.9
NEW L/D 2 POOL - 723.7
(DOWN 3.2 FEET)
(UP 5.0 FEET)
L/D 4 - RIVER MILE 41.5
L/D 2 POOL - 718.7
REMOVE L/D 3 - RIVER MILE 23.8
EMSWORTH POOL - 710.0
L/D 2 - RIVER MILE 11.2
PLAN NUMBER 1
LOWER MONONGAHELA RIVER
NAVIGATION STUDY, PA
JANUARY 1991
ELEVATION (FEET ABOVE NGVD)
750
740
730
720
710
700
0
10
20
30
40
50
MILES ABOVE POINT AT PITTSBURGH

EXHIBIT 1

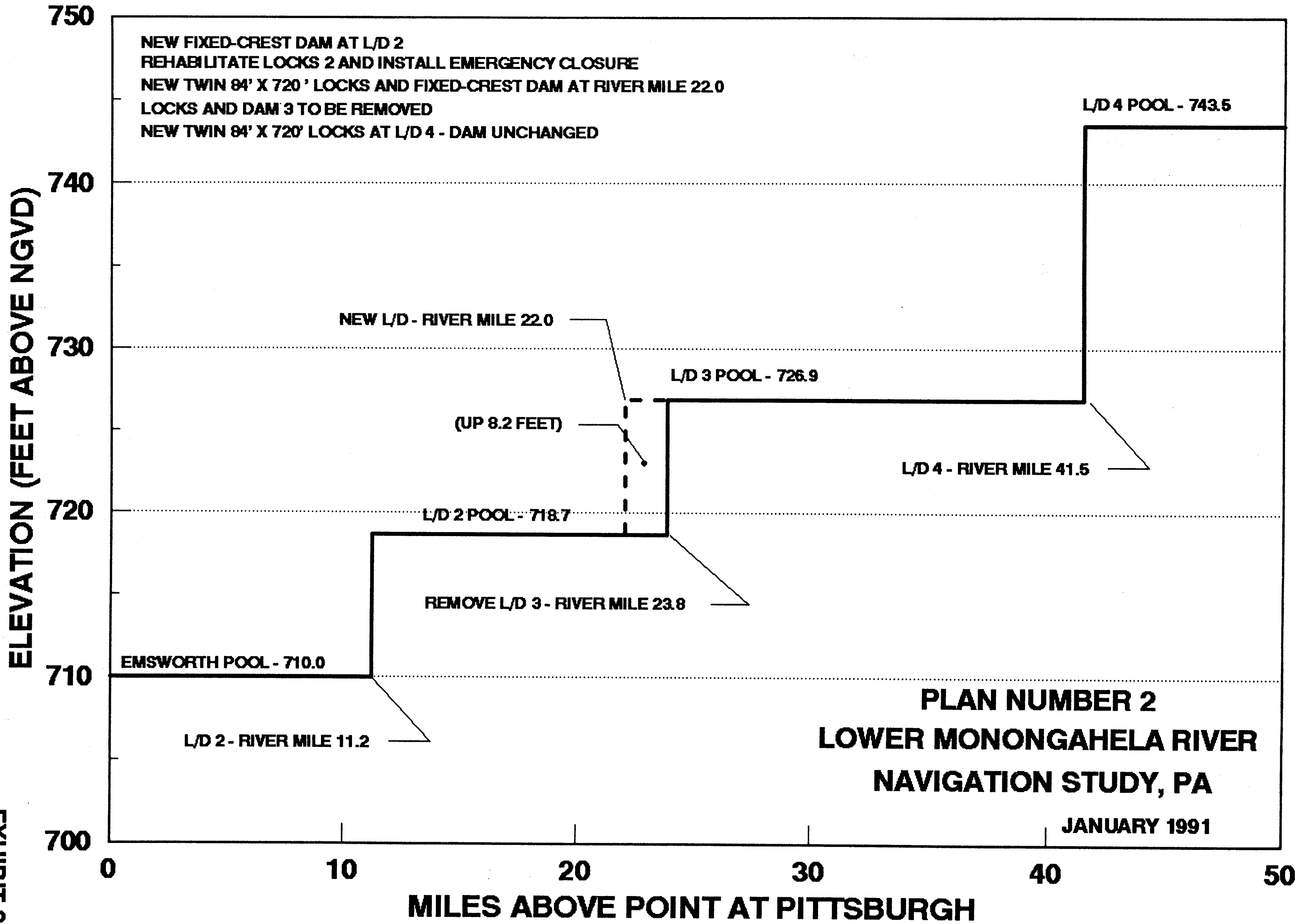

NEW FIXED-CREST DAM AT L/D 2
REHABILITATE LOCKS 2 AND INSTALL EMERGENCY CLOSURE
NEW TWIN 84' X 720 ' LOCKS AND FIXED-CREST DAM AT RIVER MILE 22.0
LOCKS AND DAM 3 TO BE REMOVED
NEW TWIN 84' X 720' LOCKS AT L/D 4 - DAM UNCHANGED
L/D 4 POOL - 743.5
NEW L/D - RIVER MILE 22.0
L/D 3 POOL - 726.9
(UP 8.2 FEET)
L/D 4 - RIVER MILE 41.5
L/D 2 POOL - 718.7
REMOVE L/D 3 - RIVER MILE 23.8
EMSWORTH POOL - 710.0
L/D 2 - RIVER MILE 11.2
PLAN NUMBER 2
LOWER MONONGAHELA RIVER
NAVIGATION STUDY, PA
JANUARY 1991
ELEVATION (FEET ABOVE NGVD)
750
740
730
720
710
700
0
10
20
30
40
50
MILES ABOVE POINT AT PITTSBURGH

EXHIBIT 2

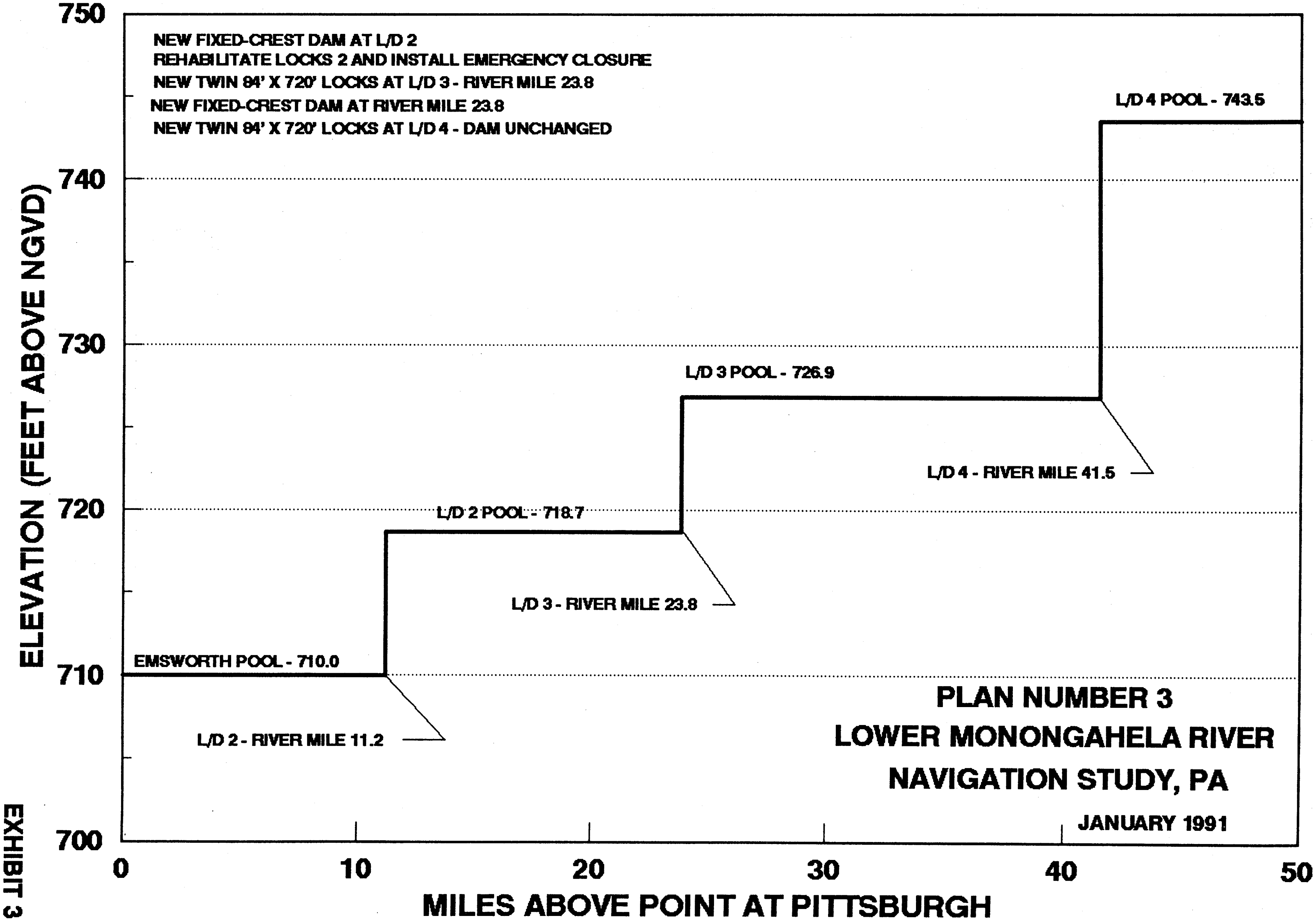
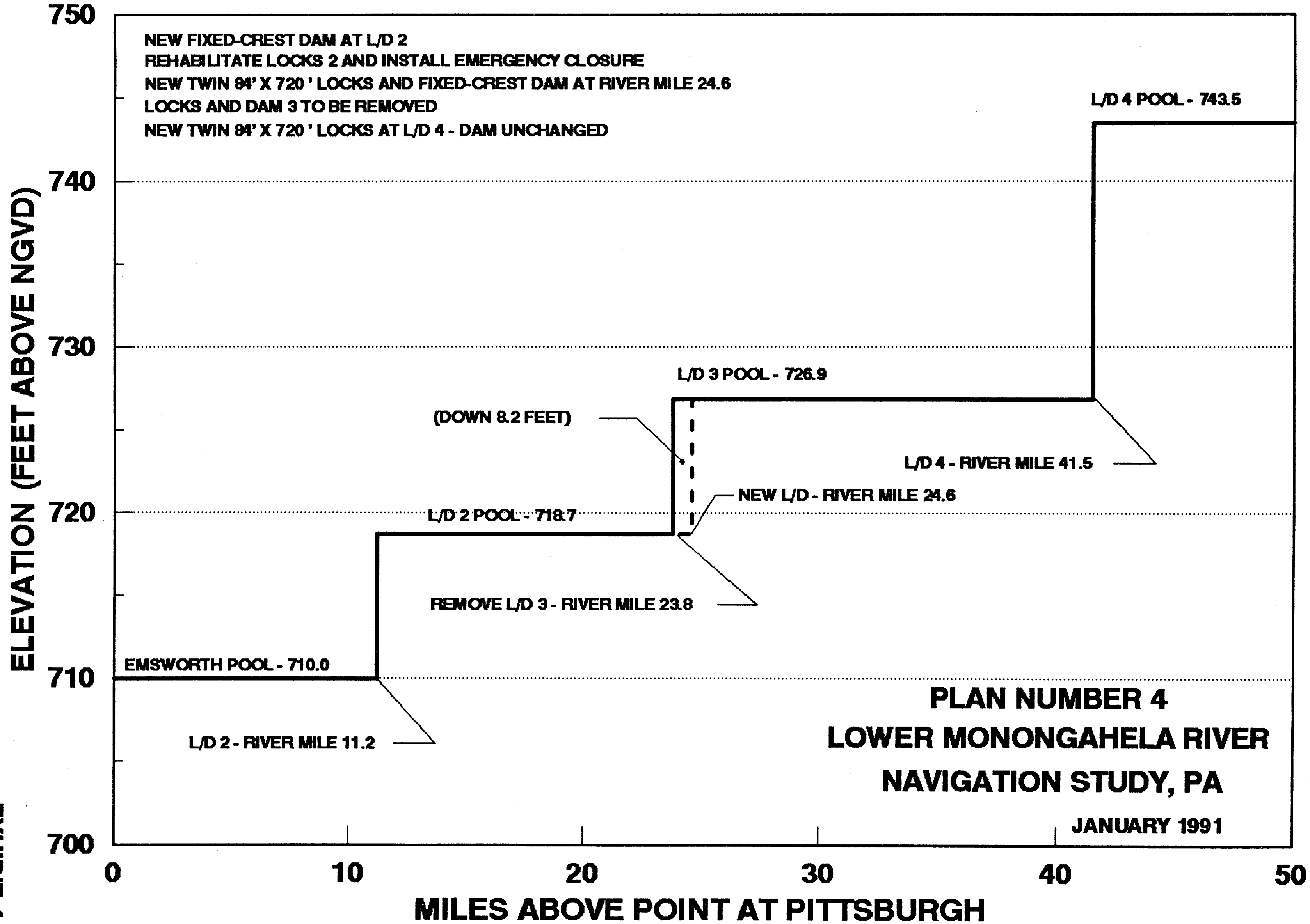
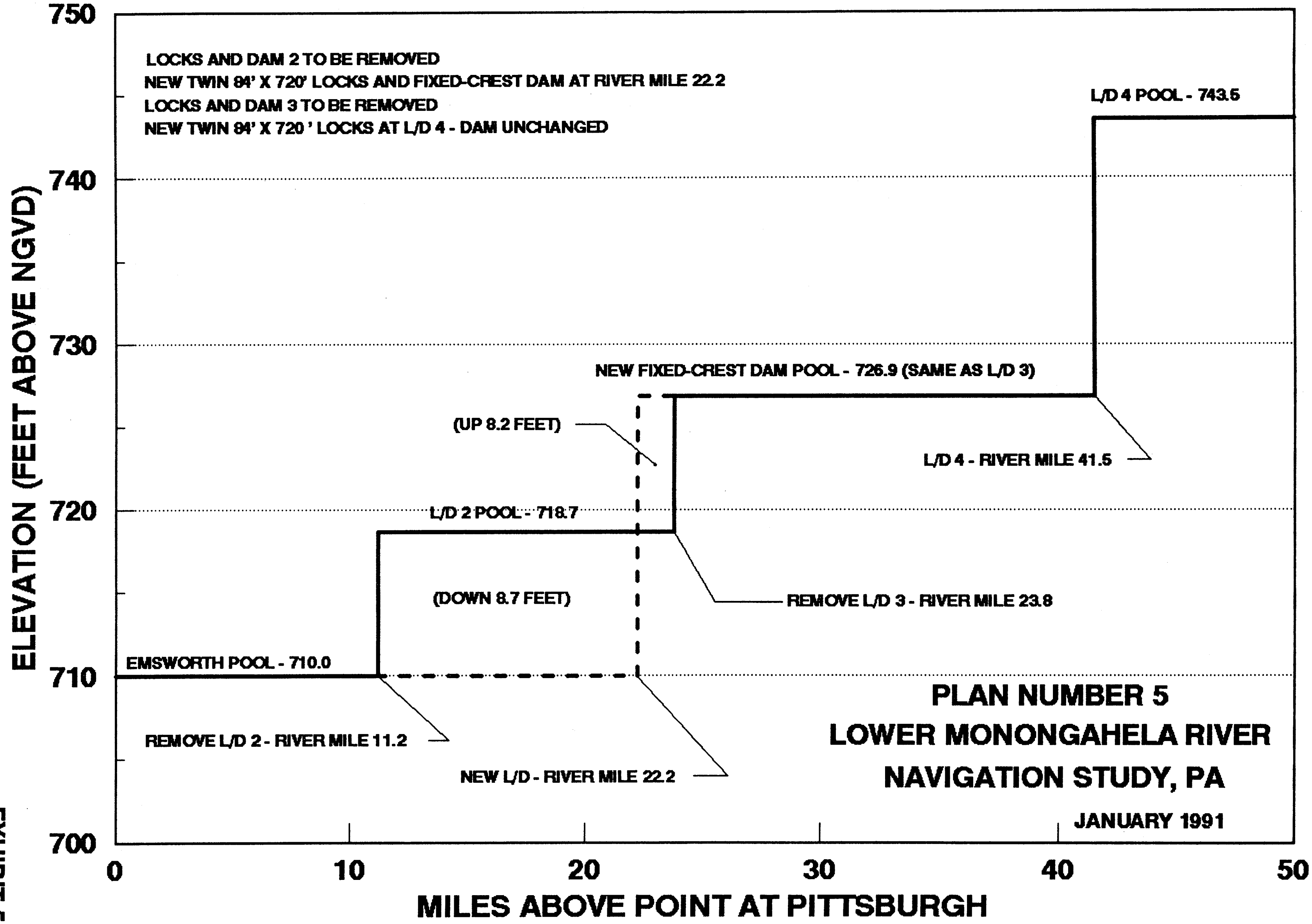

NEW FIXED-CREST DAM AT L/D 2
REHABILITATE LOCKS 2 AND INSTALL EMERGENCY CLOSURE
NEW TWIN 84' X 720' LOCKS AT L/D 3 - RIVER MILE 23.8
NEW FIXED-CREST DAM AT RIVER MILE 23.8
NEW TWIN 84' X 720' LOCKS AT L/D 4 - DAM UNCHANGED
L/D 4 POOL - 743.5
L/D 3 POOL - 726.9
L/D 4 - RIVER MILE 41.5
L/D 2 POOL - 718.7
L/D 3 - RIVER MILE 23.8
EMSWORTH POOL - 710.0
L/D 2 - RIVER MILE 11.2
PLAN NUMBER 3
LOWER MONONGAHELA RIVER
NAVIGATION STUDY, PA
JANUARY 1991
ELEVATION (FEET ABOVE NGVD)
750
740
730
720
710
700
0
10
20
30
40
50
MILES ABOVE POINT AT PITTSBURGH

EXHIBIT 3



NEW FIXED-CREST DAM AT L/D 2
REHABILITATE LOCKS 2 AND INSTALL EMERGENCY CLOSURE
NEW TWIN 84' X 720' LOCKS AND FIXED-CREST DAM AT RIVER MILE 24.6
LOCKS AND DAM 3 TO BE REMOVED
NEW TWIN 84' X 720' LOCKS AT L/D 4 - DAM UNCHANGED
L/D 4 POOL - 743.5
L/D 3 POOL - 726.9
(DOWN 8.2 FEET)
L/D 4 - RIVER MILE 41.5
NEW L/D - RIVER MILE 24.6
L/D 2 POOL - 718.7
REMOVE L/D 3 - RIVER MILE 23.8
EMSWORTH POOL - 710.0
L/D 2 - RIVER MILE 11.2
PLAN NUMBER 4
LOWER MONONGAHELA RIVER
NAVIGATION STUDY, PA
JANUARY 1991
750
740
730
720
710
700
ELEVATION (FEET ABOVE NGVD)
0
10
20
30
40
50
MILES ABOVE POINT AT PITTSBURGH

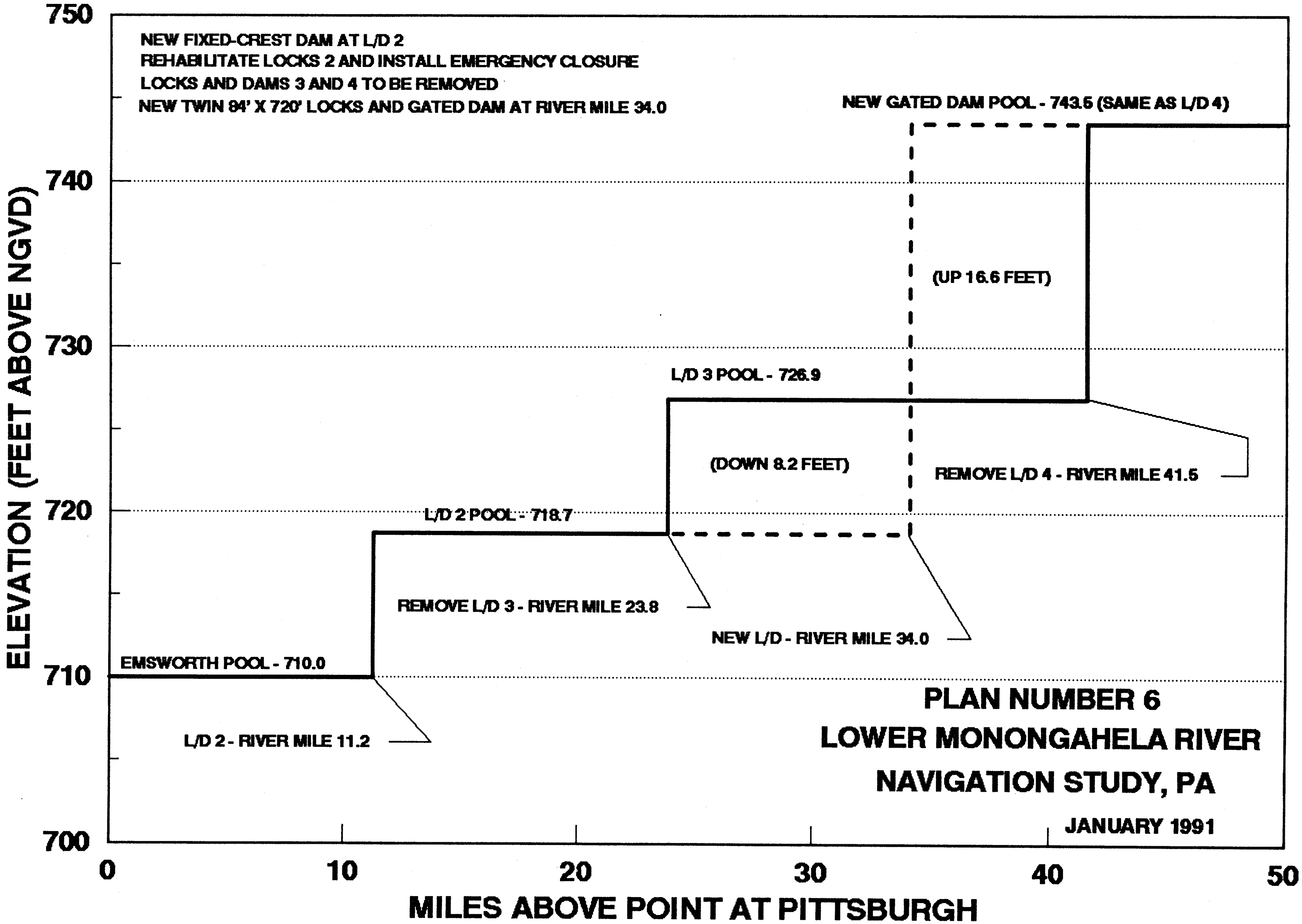
EXHIBIT 4



PLAN NUMBER 5
LOWER MONONGAHELA RIVER
NAVIGATION STUDY, PA

JANUARY 1991

EXHIBIT 5



NEW FIXED-CREST DAM AT L/D 2
REHABILITATE LOCKS 2 AND INSTALL EMERGENCY CLOSURE
LOCKS AND DAMS 3 AND 4 TO BE REMOVED
NEW TWIN 84' X 720' LOCKS AND GATED DAM AT RIVER MILE 34.0
NEW GATED DAM POOL - 743.5 (SAME AS L/D 4)
(UP 16.6 FEET)
L/D 3 POOL - 726.9
(DOWN 8.2 FEET)
REMOVE L/D 4 - RIVER MILE 41.5
L/D 2 POOL - 718.7
REMOVE L/D 3 - RIVER MILE 23.8
NEW L/D - RIVER MILE 34.0
EMSWORTH POOL - 710.0
L/D 2 - RIVER MILE 11.2
PLAN NUMBER 6
LOWER MONONGAHELA RIVER
NAVIGATION STUDY, PA
JANUARY 1991
ELEVATION (FEET ABOVE NGVD)
750
740
730
720
710
700
0
10
20
30
40
50
MILES ABOVE POINT AT PITTSBURGH

EXHIBIT 6

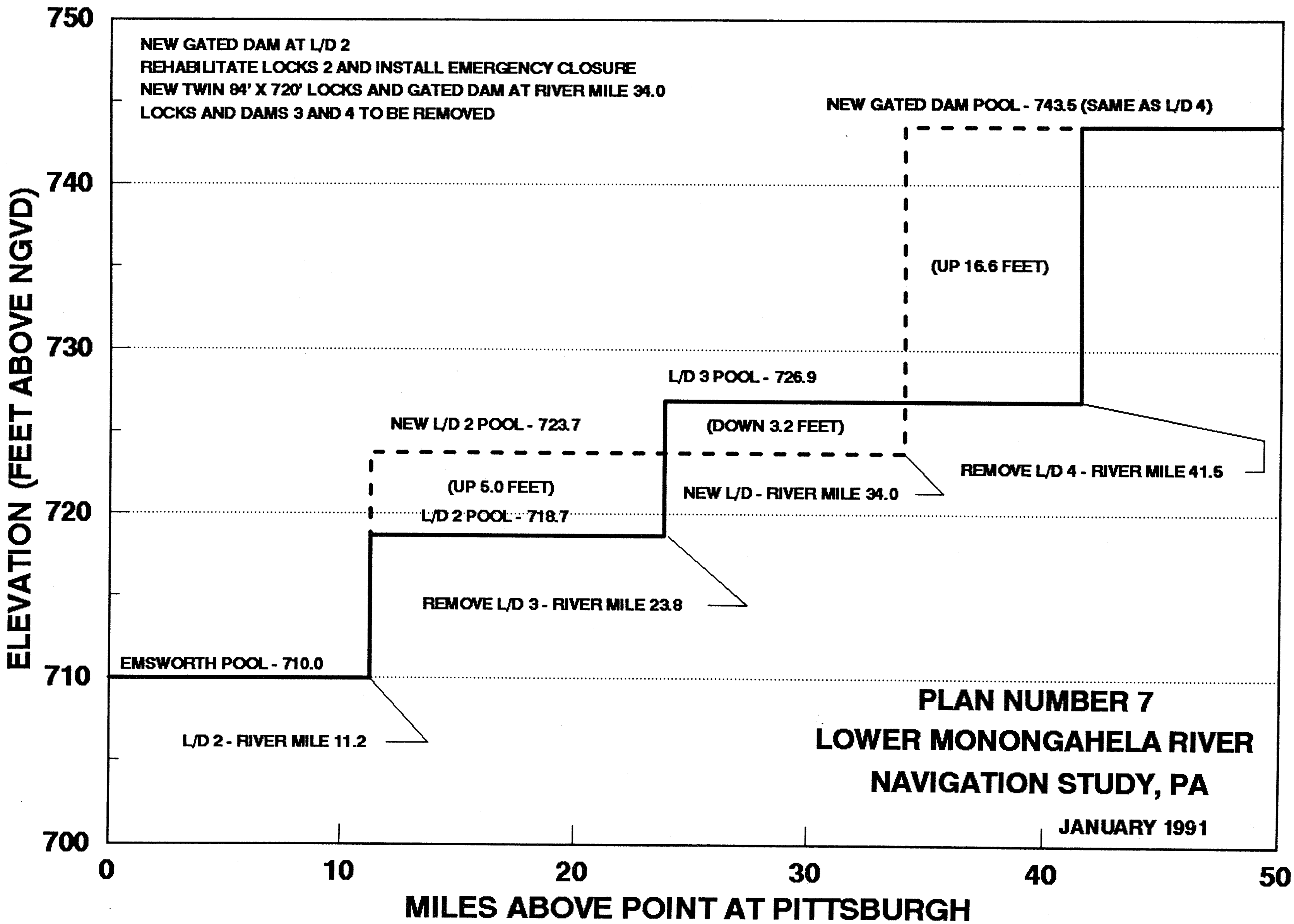

750
740
730
720
710
700
0
10
20
30
40
50
ELEVATION (FEET ABOVE NGVD)
MILES ABOVE POINT AT PITTSBURGH
NEW GATED DAM AT L/D 2
REHABILITATE LOCKS 2 AND INSTALL EMERGENCY CLOSURE
NEW TWIN 84' X 720' LOCKS AND GATED DAM AT RIVER MILE 34.0
LOCKS AND DAMS 3 AND 4 TO BE REMOVED
NEW GATED DAM POOL - 743.5 (SAME AS L/D 4)
(UP 16.6 FEET)
L/D 3 POOL - 726.9
NEW L/D 2 POOL - 723.7
(DOWN 3.2 FEET)
REMOVE L/D 4 - RIVER MILE 41.5
(UP 5.0 FEET)
NEW L/D - RIVER MILE 34.0
L/D 2 POOL - 718.7
REMOVE L/D 3 - RIVER MILE 23.8
EMSWORTH POOL - 710.0
L/D 2 - RIVER MILE 11.2
PLAN NUMBER 7
LOWER MONONGAHELA RIVER
NAVIGATION STUDY, PA
JANUARY 1991

EXHIBIT 7

ATTACHMENT 6

ECONOMIC COSTS INCLUDING INTEREST DURING CONSTRUCT

ATTACHMENT 6

ECONOMIC COSTS INCLUDING INTEREST DURING CONSTRUCT

1. GENERAL

Economic costs are expenditures adjusted to account for the time value of money: a dollar in the future is less valuable than a dollar at present. Therefore, a plan that defers expenditures has a lower economic cost than one that does not, even though the amounts of the expenditures are the same. The development of economic costs for the alternative plans are described in this section.

2. METHODOLOGY

Project costs were converted into economic costs using a discount rate of 8 3/4 % and construction schedules developed from data provided by Engineering Division and Programs Management. The present value of annual expenditures were calculated and totalled to obtain the economic cost. All years were in relation to the base year of 2002. All discounting was from the midpoint of the year of the expenditure.

3. COMPUTATION SHEETS

Data used in the calculations are listed in Table 1. The first column lists the years when expenditures are scheduled. The second column "Time" shows the difference in years of each year from the reference point: the base year 2002. "Factor" is the discount factor appropriate to each year which was computed using the formula:

factor = (1 + discount rate) ** time

The remaining columns list data for each of the eight plans. Each plan has three columns: 1) cost (expenditures) which is the unadjusted value of the expenditure; 2) adjustment (adj) which is the increase or decrease in the value of the expenditure when compared to its value in the base year; and present value (pv) which is the adjusted value of the expenditure.

The columns were totalled. The total of the "cost" column is the unadjusted cost estimate of the plan. The total of the "pv" column is the economic cost of the plan. The total of the "adj" column is the net difference between the other two. A negative "adj" total would indicates that most of the expenditures are scheduled after the base year while a positive "adj" indicates the opposite. Most projects require expenditures prior to the base year in order to realize the benefits of improvements and therefore the "adj" would be positive. Interest during construction (IDC) is typically designated as the sum of "adj" for expenditures prior to the base year.

As an example, the unadjusted cost estimate for the "without" plan was $739.3 million. The economic cost of the "without" plan is $582.1 million, which is considerably lower because a large portion of the expenditures are scheduled in the future and are therefore of low value in current dollars. The average annual cost is derived from the economic cost and is shown in the table: $51.7 million. IDC was designated as the difference between the present worth and the cost for expenditures scheduled prior the base year of 2002. IDC for the "without" plan is $107.9 million.

TABLE 1
COMPUTATION OF ECONOMIC COSTS INCLUDING IDC
(THOUSANDS OF OCTOBER 1991 DOLLARS; 8 3/4%)

			WITHOUT			PLAN 1			PLAN 4			PLAN 4 DEFERRED		
YEAR	TIME	FACTOR	COST	ADJ	PV	COST	ADJ	PV	COST	ADJ	PV	COST	ADJ	PV
1990			0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1991	10.50	1.41	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1992	9.50	1.22	1400.0	1706.0	3106.0	1400.0	1706.0	3106.0	1400.0	1706.0	3106.0	1400.0	1706.0	3106.0
1993	8.50	1.04	2240.0	2329.8	4569.8	2146.3	2232.3	4378.5	2240.0	2329.8	4569.8	2240.0	2329.8	4569.8
1994	7.50	0.88	2740.0	2400.1	5140.1	2646.3	2318.0	4964.2	2740.0	2400.1	5140.1	2740.0	2400.1	5140.1
1995	6.50	0.73	8618.3	6248.3	14866.5	6402.8	4642.0	11044.8	7018.3	5088.3	12106.5	7018.3	5088.3	12106.5
1996	5.50	0.59	9807.4	5749.2	15556.6	14444.5	8467.6	22912.1	7407.4	4342.3	11749.7	7407.4	4342.3	11749.7
1997	4.50	0.46	61199.1	28065.0	89264.1	33978.6	15582.1	49560.6	67976.5	31173.0	99149.5	60721.9	27846.1	88568.0
1998	3.50	0.34	68086.2	23232.9	91319.1	89326.3	30480.6	119806.8	101887.0	34766.6	136653.6	68594.7	23406.4	92001.0
1999	2.50	0.23	92421.7	21563.1	113984.8	138202.3	32244.3	170446.6	162167.1	37835.6	200002.7	102837.0	23993.2	126830.2
2000	1.50	0.13	107670.0	14436.5	122106.4	145469.8	19504.7	164974.5	162167.1	21743.4	183910.5	118085.3	15832.9	133918.3
2001	0.50	0.04	51519.7	2206.7	53726.4	139813.9	5988.6	145802.5	116851.9	5005.1	121856.9	72567.8	3108.3	75676.1
2002	-0.50	-0.04	15248.3	-626.3	14622.0	66272.0	-2722.0	63550.0	49448.2	-2031.0	47417.2	16960.7	-696.6	16264.0
2003	-1.50	-0.12	0.0	0.0	0.0	18536.2	-2191.5	16344.7	1712.3	-202.4	1509.9	1712.3	-202.4	1509.9
2004	-2.50	-0.19	0.0	0.0	0.0	18536.2	-3506.6	15029.6	1712.3	-323.9	1388.4	1712.3	-323.9	1388.4
2005	-3.50	-0.25	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2006	-4.50	-0.31	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2007	-5.50	-0.37	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2008	-6.50	-0.42	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2009	-7.50	-0.47	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2010	-8.50	-0.51	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2011	-9.50	-0.55	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2012	-10.50	-0.59	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2013	-11.50	-0.62	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2014	-12.50	-0.65	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2015	-13.50	-0.68	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2016	-14.50	-0.70	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2017	-15.50	-0.73	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2018	-16.50	-0.75	2500.0	-1873.6	626.4	2500.0	-1873.6	626.4	2500.0	-1873.6	626.4	2500.0	-1873.6	626.4
2019	-17.50	-0.77	30363.3	-23367.5	6995.8	18333.3	-14109.3	4224.1	18333.3	-14109.3	4224.1	18333.3	-14109.3	4224.1
2020	-18.50	-0.79	18333.3	-14449.1	3884.2	18333.3	-14449.1	3884.2	18333.3	-14449.1	3884.2	30363.3	-23930.4	6432.9
2021	-19.50	-0.81	51396.3	-41383.4	10012.9	18333.3	-14761.7	3571.7	18333.3	-14761.7	3571.7	49433.3	-39802.8	9630.5
2022	-20.50	-0.82	24400.2	-20029.1	4371.1	0.0	0.0	0.0	0.0	0.0	0.0	26037.7	-21373.3	4664.5
2023	-21.50	-0.84	48800.4	-40761.5	8038.9	0.0	0.0	0.0	0.0	0.0	0.0	52075.5	-43497.1	8578.4
2024	-22.50	-0.85	48800.4	-41408.3	7392.0	0.0	0.0	0.0	0.0	0.0	0.0	52075.5	-44187.3	7888.1
2025	-23.50	-0.86	48800.4	-42003.1	6797.3	0.0	0.0	0.0	0.0	0.0	0.0	52075.5	-44822.0	7253.5
2026	-24.50	-0.87	44936.0	-39180.6	5755.4	0.0	0.0	0.0	0.0	0.0	0.0	47938.2	-41798.2	6139.9
2027	-25.50	-0.88	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TOT:			739281.0	-157145.0	582136.0	734675.0	69552.3	804227.3	742228.0	98639.2	840867.2	794830.0	-166563.7	628266.3
PRE 2002:			405702.3	107937.6	513639.9	573830.7	123166.1	696996.8	631855.2	146390.2	778245.4	443612.3	110053.4	553665.7
PST 2002:			333578.6	-265082.5	68496.09	160844.3	-53613.7	107230.5	110372.8	-47751.0	62621.77	351217.6	-276617.0	74600.59
			474198.4	107937.6	582136.0	681061.2	123166.1	804227.3	694476.9	146390.2	840867.2	518212.9	110053.4	628266.3
AVE ANN:					51717.03			71447.65			74702.74			55815.25

TABLE 1
COMPUTATION OF ECONOMIC COSTS INCLUDING IDC
(THOUSANDS OF OCTOBER 1991 DOLLARS; 8 3/4%)

PLAN 2			PLAN 3			PLAN 5			PLAN 6			PLAN 7		
COST	ADJ	PV	COST	ADJ	PV	COST	ADJ	PV	COST	ADJ	PV	COST	ADJ	PV
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1400.0	1706.0	3106.0	1400.0	1706.0	3106.0	1400.0	1706.0	3106.0	1400.0	1706.0	3106.0	1400.0	1706.0	3106.0
2174.4	2261.5	4435.9	2240.0	2329.8	4569.8	2174.4	2261.5	4435.9	2258.8	2349.3	4608.0	2258.8	2349.3	4608.0
2674.4	2342.6	5017.0	2740.0	2400.1	5140.1	2674.4	2342.6	5017.0	2758.8	2416.5	5175.3	2758.8	2416.5	5175.3
45943.9	33309.6	79253.5	8618.3	6248.3	14866.5	45943.9	33309.6	79253.5	7454.4	5404.5	12858.9	7628.3	5530.6	13158.9
67705.7	39689.9	107395.6	9807.4	5749.2	15556.6	68738.9	40295.5	109034.5	119482.8	70042.1	189524.9	135829.0	79624.4	215453.4
72065.2	33048.0	105113.2	91386.4	41908.4	133294.9	72071.1	33050.7	105121.9	278112.6	127538.2	405650.8	317589.9	145641.9	463231.8
91493.5	31220.1	122713.6	124696.9	42550.0	167247.0	83308.1	28427.0	111735.1	285643.0	97469.2	383112.3	346252.6	118150.9	464403.4
135029.1	31504.0	166533.1	173656.5	40516.3	214172.8	136656.3	31883.6	168539.9	240686.6	56155.2	296841.8	297320.2	69368.6	366688.8
132839.3	17811.2	150650.4	173656.5	23284.0	196940.5	181269.3	24304.7	205574.0	167684.3	22483.2	190167.4	152114.2	20395.6	172509.8
99691.3	4270.0	103961.3	97347.7	4169.7	101517.4	166602.7	7136.0	173738.7	149652.4	6410.0	156062.4	124661.3	5339.6	130000.9
47997.5	-1971.4	46026.1	47735.8	-1960.7	45775.2	61726.5	-2535.3	59191.2	16712.5	-686.4	16026.1	19075.3	-783.5	18291.8
261.7	-30.9	230.7	0.0	0.0	0.0	13990.7	-1654.1	12336.6	16712.5	-1975.9	14736.6	19075.3	-2255.2	16820.1
261.7	-49.5	212.2	0.0	0.0	0.0	13990.7	-2646.7	11344.0	16712.5	-3161.6	13550.9	19075.3	-3608.6	15466.7
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2500.0	-1873.6	626.4	2500.0	-1873.6	626.4	2500.0	-1873.6	626.4	2500.0	-1873.6	626.4	2500.0	-1873.6	626.4
18333.3	-14109.3	4224.1	18333.3	-14109.3	4224.1	0.0	0.0	0.0	18333.3	-14109.3	4224.1	18333.3	-14109.3	4224.1
18333.3	-14449.1	3884.2	18333.3	-14449.1	3884.2	0.0	0.0	0.0	18333.3	-14449.1	3884.2	18333.3	-14449.1	3884.2
18333.3	-14761.7	3571.7	18333.3	-14761.7	3571.7	0.0	0.0	0.0	18333.3	-14761.7	3571.7	18333.3	-14761.7	3571.7
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
202.3	-176.4	25.9	202.3	-176.4	25.9	0.0	0.0	0.0	135.0	-117.7	17.3	135.0	-117.7	17.3
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
757240.0	149740.9	906980.9	790988.0	123530.9	914518.9	853047.0	196007.7	1049054.7	1362906.0	340839.0	1703745.0	1502674.0	398564.6	1901238.6
651016.8	197162.9	848179.7	685549.8	170861.7	856411.5	760839.2	204717.4	965556.5	1255133.5	391974.3	1647107.8	1387813.0	450523.3	1838336.3
106223.1	-47421.9	58801.21	105438.1	-47330.7	58107.40	92207.84	-8709.69	83498.1527	107772.5	-51135.3	56637.1743	114861	-51958.7	62902.2804
709818.0	197162.9	906980.9	743657.2	170861.7	914518.9	844337.3	204717.4	1049054.7	1311770.67	391974.3	1703745.0	1450715.28	450523.3	1901238.6
		80576.29			81245.97			93198.1494			151360.918			168906.277

4. SUMMARY

Table 2 summarizes the cost data for the alternative plans.

Table 2
Summary of Costs of Alternative Plans
(Millions of October 1991 Dollars; 8 3/4 %)

Plan	Cost	Present Worth	IDC	Remaining Worth	Annual Equivalent
"Without"	739.3	582.1	107.9	474.2	51.7
1	734.7	804.3	123.2	681.1	71.4
2	757.2	907.0	197.2	709.8	80.6
3	791.0	914.6	170.9	743.7	81.2
4	742.2	840.9	146.4	694.5	74.7
4 Defer	794.8	628.3	110.0	518.3	55.8
5	853.0	1,049.0	204.7	844.3	93.2
6	1,362.9	1,703.8	392.0	1,311.8	151.4
7	1,502.7	1,901.2	450.5	1,450.7	168.9

ATTACHMENT 7

OPERATIONS AND MAINTENANCE COSTS

O & M COSTS FOR
TWIN 84' X 720' LOCKS AND FIXED CREST DAM

The estimated annual cost of operation and maintenance, including extraordinary maintenance, of a proposed twin 84-foot X 720-foot Locks and a Fixed Crest dam is as follows:

(a) Operation: Personnel (crew of 13 plus two seasonal laborers), power, supplies and ordinary maintenance of operating machinery, buildings, tools and equipment	$680,000
(b) Channel maintenance	20,000
(c) Ordinary maintenance	80,000
(d) Supervision and administration	105,000
SUBTOTAL	$ 885,000

(e) Extraordinary maintenance: 1/

ITEM	ESTIMATED ITEM COST	PERIOD WORK TO BE REPEATED, YEARS	ESTIMATED AVERAGE ANNUAL COST
LOCKS:			
Repair one set of lock gates	$540,000	12	$ 26,900
Repair culvert valves	375,000	10	24,300
Unwater lock chambers, repair gate sills, valve operating machinery, etc.	800,000	5	132,900
Repair wiring & lighting	15,000	15	500
Repair piping	15,000	20	300
Repair floating mooring bitts	17,000	10	1,100
Repair walls & esplanade	20,000	20	400
Paint emergency bulkhead units (2)	55,000	15	1,900

ITEM	**ESTIMATED ITEM COST**	**PERIOD WORK TO BE REPEATED, YEARS**	**ESTIMATED AVERAGE ANNUAL COST**
Repair diesel standby generation plant	$ 6,000	15	$ 200
Repair emergency bulkhead handling equip	10,000	10	600
Channel dredging	50,000	15	1,700
SUBTOTAL:			**$ 190,800**

(f) **TOTAL ESTIMATE,** average annual cost for operation and maintenance **(ROUNDED)** **$ 1,100,000**

1/ Costs discounted to present worth and annualized over the life of the project at an 8-3/4 percent rate of interest.

O & M COSTS
FOR L&D 2

The estimated annual cost of operation and maintenance, including extra-ordinary maintenance, of the existing 110-foot X 720-foot and 56-foot X 720-foot Locks at L/D 2 and a new Fixed Crest dam is as follows:

(a) Operation: Personnel (crew of 13 plus two seasonal laborers), power, supplies and ordinary maintenance of operating machinery, buildings, tools and equipment	$680,000
(b) Channel maintenance	20,000
(c) Ordinary maintenance	80,000
(d) Supervision and administration	105,000
SUBTOTAL	**$ 885,000**

(e) Extraordinary maintenance: 1/

ITEM	**ESTIMATED ITEM COST**	**PERIOD WORK TO BE REPEATED, YEARS**		**ESTIMATED AVERAGE ANNUAL COST**
		Before Rehab	**After Rehab**	
LOCKS:				
Repair one set of lock gates	$540,000	10	12	$ 34,000
Repair culvert valves	375,000	8	10	29,500
Unwater lock chambers, repair gate sills, valve operating machinery, etc.	800,000	5	5	132,900
Repair wiring & lighting	15,000	13	15	500
Repair piping	15,000	18	20	300
Repair floating mooring bitts	17,000	8	10	1,300
Repair walls & esplanade	20,000	18	20	400
Paint emergency bulkhead units (2)	55,000	13	15	1,900
Repair diesel standby generation plant	$ 6,000	13	15	200

ITEM	ESTIMATED ITEM COST	PERIOD WORK TO BE REPEATED, YEARS		ESTIMATED AVERAGE ANNUAL COST
		Before Rehab	After Rehab	
Repair emergency bulk-head handling equip	10,000	8	10	$ 800
Channel dredging	50,000	15	15	1,700
SUBTOTAL:				$ 203,500

(f) **TOTAL ESTIMATE,** average annual cost for operation and maintenance **(ROUNDED)** $ 1,100,000

1/ Costs discounted to present worth and annualized over the life of the project at an 8-3/4 percent rate of interest.

O & M COSTS FOR
TWIN 84' X 720' LOCKS AND GATED DAM

The estimated annual cost of operation and maintenance, including extra-ordinary maintenance, of a proposed twin 84-foot X 720-foot Locks and Gated dam is as follows:

(a) Operation: Personnel (crew of 13 plus two seasonal laborers), power, supplies and ordinary maintenance of operating machinery, buildings, tools and equipment	$680,000
(b) Channel maintenance	20,000
(c) Ordinary maintenance	90,000
(d) Supervision and administration	105,000
SUBTOTAL	**$ 895,000**

(e) Extraordinary maintenance: 1/

ITEM	ESTIMATED ITEM COST	PERIOD WORK TO BE REPEATED, YEARS	ESTIMATED AVERAGE ANNUAL COST
LOCKS:			
Repair one set of lock gates	$540,000	12	$ 26,900
Repair culvert valves	375,000	10	24,300
Unwater lock chambers, repair gate sills, valve operating machinery, etc.	800,000	5	132,900
Repair wiring & lighting	15,000	15	500
Repair piping	15,000	20	300
Repair floating mooring bitts	17,000	10	1,100
Repair walls & esplanade	20,000	20	400
Paint emergency bulkhead units (2)	55,000	15	1,900
Repair diesel standby generation plant	6,000	15	200
Repair emergency bulk-head handling equip	10,000	10	600
Channel dredging	50,000	15	1,700
SUBTOTAL:			**$ 190,800**

ITEM	**ESTIMATED ITEM COST**	**PERIOD WORK TO BE REPEATED, YEARS**	**ESTIMATED AVERAGE ANNUAL COST**
GATED DAM:			
Paint crest gates (6) & emergency bulkhead units (2)	$150,000	10	$ 9,700
Repair seals, bearings & crest operating machinery	10,000	10	600
Wiring, lighting, etc.	5,000	10	300
Repair emergency bulkhead handling equip	10,000	10	600
Repair crest gates	700,000	30	4,900
SUBTOTAL:			**$ 16,100**

(f) **TOTAL ESTIMATE**, average annual cost for operation and maintenance **(ROUNDED)** **$ 1,100,000**

1/ Costs discounted to present worth and annualized over the life of the project at an 8-3/4 percent rate of interest.

O & M COSTS FOR

EXISTING LOCKS AND NEW GATED DAM AT L&D 2

The estimated annual cost of operation and maintenance, including extraordinary maintenance, of the existing 110-foot X 720-foot and 56-foot X 360-foot Locks at L/D 2 and a new Gated dam is as follows:

(a) Operation: Personnel (crew of 13 plus two seasonal laborers), power, supplies and ordinary maintenance of operating machinery, buildings, tools and equipment	$680,000
(b) Channel maintenance	20,000
(c) Ordinary maintenance	90,000
(d) Supervision and administration	105,000
SUBTOTAL	**$ 895,000**

(e) Extraordinary maintenance: 1/

ITEM	ESTIMATED ITEM COST	PERIOD WORK TO BE REPEATED, YEARS Before Rehab	After Rehab	ESTIMATED AVERAGE ANNUAL COST
LOCKS:				
Repair one set of lock gates	$540,000	10	12	$ 34,000
Repair culvert valves	375,000	8	10	29,500
Unwater lock chambers, repair gate sills, valve operating machinery, etc.	800,000	5	5	132,900
Repair wiring & lighting	15,000	13	15	500
Repair piping	15,000	18	20	300
Repair floating mooring bitts	17,000	8	10	1,300
Repair walls & esplanade	20,000	18	20	400
Paint emergency bulkhead units (2)	55,000	13	15	1,900
Repair diesel standby generation plant	6,000	13	15	200
Repair emergency bulk-head handling equip	10,000	8	10	800
Channel dredging	50,000	15	15	1,700
SUBTOTAL:				**$ 203,500**

ITEM	ESTIMATED ITEM COST	PERIOD WORK TO BE REPEATED, YEARS	ESTIMATED AVERAGE ANNUAL COST
GATED DAM:			
Paint crest gates (6) & emergency bulkhead units (2)	$150,000	10	$ 9,700
Repair seals, bearings & crest operating machinery	10,000	10	600
Wiring, lighting, etc.	5,000	10	300
Repair emergency bulkhead handling equip	10,000	10	600
Repair crest gates	700,000	30	4,900
SUBTOTAL:			**$ 16,100**

(f) **TOTAL ESTIMATE**, average annual cost for operation and maintenance **(ROUNDED)** **$ 1,100,000**

1/ Costs discounted to present worth and annualized over the life of the project at an 8-3/4 percent rate of interest.

O & M COSTS FOR
TWIN 84' X 720' LOCKS AND EXISTING GATED DAM AT L&D 4

The estimated annual cost of operation and maintenance, including extra-ordinary maintenance, of a proposed twin 84-foot X 720-foot Locks and existing Gated dam at L/D 4 is as follows:

(a) Operation: Personnel (crew of 13 plus two seasonal laborers), power, supplies and ordinary maintenance of operating machinery, buildings, tools and equipment	$680,000
(b) Channel maintenance	20,000
(c) Ordinary maintenance	90,000
(d) Supervision and administration	105,000
SUBTOTAL	**$ 895,000**

(e) Extraordinary maintenance: 1/

ITEM	ESTIMATED ITEM COST	PERIOD WORK TO BE REPEATED, YEARS	ESTIMATED AVERAGE ANNUAL COST
LOCKS:			
Repair one set of lock gates	$540,000	12	$ 26,900
Repair culvert valves	375,000	10	24,300
Unwater lock chambers, repair gate sills, valve operating machinery, etc.	800,000	5	132,900
Repair wiring & lighting	15,000	15	500
Repair piping	15,000	20	300
Repair floating mooring bitts	17,000	10	1,100
Repair walls & esplanade	20,000	20	400
Paint emergency bulkhead units (2)	55,000	15	1,900
Repair diesel standby generation plant	6,000	15	200
Repair emergency bulk-head handling equip	10,000	10	600
Channel dredging	50,000	15	1,700
SUBTOTAL:			**$ 190,800**

ITEM	**ESTIMATED ITEM COST**	**PERIOD WORK TO BE REPEATED, YEARS**	**ESTIMATED AVERAGE ANNUAL COST**
GATED DAM:			
Paint crest gates (5) & emergency bulkhead units (2)	$125,000	8	$11,400
Repair seals, bearings & crest operating machinery	10,000	8	900
Wiring, lighting, etc.	5,000	8	400
Repair emergency bulkhead handling equip	10,000	8	900
Repair crest gates	700,000	25	7,500
SUBTOTAL:			**$ 21,100**

(f) **TOTAL ESTIMATE**, average annual cost for operation and maintenance **(ROUNDED)** **$ 1,100,000**

1/ Costs discounted to present worth and annualized over the life of the project at an 8-3/4 percent rate of interest.

ATTACHMENT 8

POTENTIAL FLOOD DAMAGES

ATTACHMENT 8

POTENTIAL FLOOD DAMAGES

1. GENERAL

The dams at L&Ds 2 and 3 are considered to be in extremely poor condition and in need of replacement. The plans for correction of the problem are of four types: 1) replacement of both dams with fixed crest dams (type of dam currently at both projects) at or near the existing sites (W/O and Plans 2, 3, and 4); 2) replacement of 2 with a fixed crest dam at the existing site and elimination of the dam at 3 (Plan 6); 3) replacement of 2 with a gated dam and the elimination of 3 (Plans 1 & 7); 4) replacement with a fixed crest dam midway between the existing dams and elimination of both existing dams (Plan 5). All of the plans as well as the without project condition will require the construction and operation of a temporary cofferdam for a period of 3 years while a new permanent dam is under construction. During this time control of this stretch of river will be limited and the potential for flood damages higher. This section describes the analysis used to estimate potential flood damages during this construction period.

2. METHODOLOGY

The methodology used to estimate potential flood damages was the standard technique used in flood damage studies. Stage frequency curves were developed by H&H for the areas affected by the temporary change in pool. The curves depict the relationship between expected frequency of different water elevations and a particular geographic point. With the cofferdam, the expected pool elevations are higher than without it. The difference is the increase in potential flooding due to the effects of the cofferdam. Flood damages at each elevation were obtained from data compiled by the Pittsburgh District for the Monongahela River Basin. The gauges at L&D 2 and McKeesport were used as the geographic points of reference. Flood damages at each elevation were weighted by the expected frequency of different water levels to calculate expected damages. The flood damages were totalled to obtain expected annual flood damages. The difference between expected flood damages with and without the cofferdam are the annual potential damages attributable to the cofferdam.

3. FLOOD DAMAGE CURVES

Stage frequency curves were developed by H&H for the fixed crest and gated dam alternatives. Fixed crest dams increase pool levels and potential flooding impacts more than the gated dam. The curves for a gated dam include the affects for three phases: phase 1 when the first portion of the new dam is under construction and the river is controlled by the combination of the existing fixed crest dam and the section of cofferdam. Phase two is when several of the gates can be used while the remaining gates are under construction; and phase three is when additional gates are operational. With construction of a fixed crest dam, potential flood damages are greater because of the more limited control of the river provided by a fixed crest dam, particularly during periods of high flows. The only exception to this is Plan 5 where a fixed crest dam is constructed 10 miles upstream of the existing site and therefore the area affected by potential high water is less than with either type of dam at the exiting site.

4. FLOOD DAMAGES

Damages for selected points on the stage frequency curves were obtained from data available in "Damage Districts - Reservoirs Only" kept on file in the Pittsburgh District. The damages were converted into annual expected values using standard techniques and updated to Oct 1990 price levels. The results are summarized in Table 1.

Table 1
Potential Flood Damages
(Thousands of October 1991 Dollars; 8 3/4%)

Plan	Amount
Without	993.6
Plan 1	510.3
Plan 2	993.6
Plan 3	993.6
Plan 4	993.6
Plan 5	899.1
Plan 6	510.3
Plan 7	899.1

5. SUMMARY OF FLOOD DAMAGE COSTS

Total potential annual damages due to construction are nearly $1 million for the "without" project condition and Plan 2, 3, and 4. Potential damages are slightly less for Plan 7 ($0.9 million) and nearly one-half for Plan 1 and 6 ($0.5 million).

ATTACHMENT 9

ADVANCE REPLACEMENT BENEFITS

ATTACHMENT 9

ADVANCE REPLACEMENT BENEFITS

1. GENERAL

The preliminary array of alternatives for the Lower Monongahela River navigation system consisted of seven replacement plans and the without project condition. Six of the seven replacement plans result in changes in navigation pools which, in turn, require the adjustment of shoreside facilities. Adjustment costs are included as project costs and are described in the COST APPENDIX. The benefit of adjusting a shoreside facility is an expected life longer than the remaining life of the existing facilities. The computation of benefits attributable to the replacement of shoreside facilities are described in this section.

2. DESCRIPTION OF ADVANCE REPLACEMENT BENEFITS

Advance replacement benefits are the savings in future investments due to upfront replacement during construction of the navigation project. Since all facilities must eventually be replaced, the true effect of changing pool levels is to possibly accelerate the scheduled replacement date. The closer to the original replacement date is the early replacement date, the closer are the advance replacement benefits to the costs. If the required replacement date is the same as the original replacement date, the advance replacement benefits will equal the costs and the net affect on the economics of the project are zero. The further in the future are the originally scheduled replacement dates, the smaller are the advanced replacement benefits as compared to the costs and, therefore, the more adverse are shoreside adjustments on the economics of the project.

An illustration and interpretation of the computation of advance replacement benefits is as follows. First, a change in pool lowers the clearance of a bridge below the required limit, necessitating the replacement of the bridge. The bridge was originally scheduled to be replaced in the year 2010 but the change in pool requires that it be replaced with a higher bridge in the year 2000. The cost of replacement is $50 million and is included as a project cost. Replacement in 2000 means that the bridge does not have to be replaced in 2010 as originally scheduled and this is counted as a future savings or advance replacement benefit of the project. The advance replacement benefit is measured as the present worth of the originally scheduled investment of $50 million and is $21 million. The economic cost of requiring early replacement is $29 million, or the difference between the cost of replacement ($50 million) and the advance replacement benefit ($21 million).

In certain cases, a change in pool may require higher expenditures than without a pool change. In our example, the cost of the bridge may be $60 million in the year 2000 rather than $50 million in the year 2010 because of the need for a higher bridge. The additional $10 million represents an economic and financial cost with no corresponding advance replacement benefit. In our example, the replacement cost is $60 million, the advance replacement benefits is $21 million, and the economic cost is $39 million.

The entire cycle of planned rehabilitation / replacement expenditures could be affected because of the need to adjust to changes in pool elevations. However, only the initial step in the cycle was considered since the actual life of most shoreside facilities is 50 years or greater, which is also the project life for navigation facilities. Moreover, the uncertainty surrounding future timing and cost for replacing shoreside facilities beyond the initial step was considered greater than any subsequent refinements to the cost and benefit numbers.

3. **METHODOLOGY USED IN CALCULATIONS**

The first step was to compile a list of facilities that could be affected by the replacement alternatives. For each facility, the following data were obtained: its age and expected life; replacement cost; and what, if any, of the replacement plans would require its adjustment. The data were used to calculate the present worth and the average annual equivalent costs of the originally scheduled investments. The percent of replacement costs that are attributable to the pool change were estimated and used to adjust downward the average annual equivalent costs. The results were the average annual equivalent costs of the original amount of the investment or, alternatively, the advance replacement benefits attributable to early replacement of the facilities.

4. SHORESIDE FACILITIES

The average expected life of each type of facility is listed in Table 1, along with their average age in the year 2002 and average remaining life. Storm sewers have the longest average remaining life and water intakes the shortest. In general, the shoreside facilities have long expected lives, are already relatively old, but most still have long average remaining lives before they require replacement.

Table 1
Average Age and Expected Life of Shoreside Facilities
(Years)

Facility	Expected Life	Age in 2002	Remaining Life	Rank by Remain Life
Bridges	120	71	49	2
Roads	30	15	15	6
Storm Sewers	100	50	50	1
Municipal Facil	70	45	35	4
Submarine Crossings	100	60	40	3
Commercial Facil	50	33	17	5
Water Intakes	50	49	1	7
Private Facil	50	35	15	6

The number of facilities of each type affected under each alternative are listed in Table 2. Plan 7 would affect the greatest number of facilities, followed by 1, 6, 5, 2, 4, and 3. No facilities are affected by the "without" alternative.

Table 2
Number of Facilities Affected by Alternative Plans

	Plan							
Facilities	W/O	1	2	3	4	5	6	7
Bridges								
Highway	0	0	0	0	0	0	1	1
Railroad	0	1	1	0	0	1	0	1
Roadway Section								
Highway	0	0	3	0	0	3	8	8
Railroad	0	0	0	0	0	0	1	1
Major Storm Sewers	0	24	2	0	0	2	21	45
Municipal Facilities	0	17	2	0	0	5	13	19
Submarine Crossings	0	12	0	0	2	13	8	8
Commercial Facilities	0	36	3	0	4	19	21	36
Water Intakes	0	4	0	0	0	2	3	4
Private Facilities	0	18	2	0	0	5	13	18
Total	0	109	12	0	6	49	88	139

5. RELOCATION COSTS

The construction component of relocation costs for each of the alternatives are listed in Table 3. The components of relocation costs that are not included are the cost of Programming, Engineering, and Design (PED) work and Supervision and Administration (S&A) during construction. Plans 6 and 7 have relocation costs that exceed one-half billion dollars, Plans 1 and 5 of $146 and $110 million dollars respectively, and the other plans of $11 million or less.

Table 3
Relocation Costs
(Millions of October 1991 Dollars)

Facilities	Plan W/O	Plan 1	Plan 2	Plan 3	Plan 4	Plan 5	Plan 6	Plan 7
Bridges								
Highway	0	0	0	0	0	0	52	52
Railroad	0	25	*	0	0	1	0	25
Roadway Sections								
Highway	0	1	0	0	0	1	3	3
Railroad	0	0	0	0	0	0	1	1
Major Storm Sewers	0	38	2	0	0	2	282	330
Municipal Facilities	0	14	6	0	0	14	80	93
Submarine Crossings	0	15	0	0	7	15	13	13
Commercial Facilities	0	44	2	0	3	9	50	46
Water Intakes	0	23	0	0	0	60	23	23
Private Facilities	0	3	*	0	0	*	11	3
Total	0	159	11	0	10	102	515	589

Note: * indicates less than $500 thousand.

The present worth of relocation costs are summarized in Table 4. They are based on the estimated cost and the expected life of each facility after the year 2002. The total present worth is the preliminary advanced replacement benefits prior to adjustment downward for the additional costs due to pool changes. The preliminary advanced replacement benefits are equivalent to 10 - 30 percent of the relocation costs, depending on the plan. Since it was assumed that half of the relocation costs are attributable to the pool change and therefore do not yield any benefits, the actual advance relocation benefits are 5 - 15 percent of relocation costs.

Table 4
Present Worth of Relocations
(Millions of October 1991 Dollars; 8 3/4%)

	Plan							
Facilities	W/O	1	2	3	4	5	6	7
Bridges	0	0	0	0	0	0	15.6	19.6
Roads	0	*	0	0	0	*	*	*
Storm Sewers	0	.2	*	0	0	*	4.2	5.9
Municipal Facil	0	.6	.1	0	0	.3	5.5	6.4
Submarine Cross	0	.7	0	0	.1	.1	.4	.4
Commercial Fac	0	16.7	.5	0	.9	2.0	26.5	16.8
Water Intakes	0	22.4	0	0	0	23.9	23.6	22.5
Private Facilities	0	.4	*	0	0	*	1.2	.5
Total	0	44.9	.6	0	1.0	26.3	77.1	71.1

Note: * indicates less than $100 thousand.

6. ADVANCED REPLACEMENT BENEFITS

The preliminary advance replacement benefits were reduced by fifty percent to reflect the added costs of adjusting to a new navigation pool. The results were converted into annual equivalent values using standard discounting techniques and are listed in Table 5. Plan 6 provides average annual benefits for advanced replacements of $3.6 million, followed by $3.2 for Plan 7, $2 million for Plan 1, $1.2 million for Plan 5, and $100 thousand or less for the other alternatives.

Table 5
Advanced Replacement Benefits
(Millions of October 1991 Dollars; 8 3/4%)

	Plan							
Facilities	W/O	1	2	3	4	5	6	7
Bridges	0	.2	0	0	0	0	.7	.9
Roads	0	*	0	0	0	*	*	*
Storm Sewers	0	*	*	0	0	*	.1	.1
Municipal Facil	0	*	*	0	0	*	.4	.3
Submarine Cross	0	*	0	0	*	*	*	*
Commercial Fac	0	.7	*	0	*	*	1.2	.8
Water Intakes	0	1.0	0	0	0	1.1	1.0	1.0
Private Facilities	0	*	0	0	0	*	*	*
Total	0	2.0	*	0	*	1.1	3.5	3.1

Note: * indicates less than $100 thousand.

LOWER MONONGAHELA RIVER
NAVIGATION SYSTEM STUDY

APPENDIX

STRUCTURAL CONDITION

U.S. Army Engineering District, Pittsburgh
Corps of Engineers
Pittsburgh, Pennsylvania

MONONGAHELA RIVER NAVIGATION SYSTEM
PENNSYLVANIA
LOCKS AND DAMS 2, 3 AND 4

APPENDIX

STRUCTURAL CONDITION

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TABLES

1. LOCKS AND DAM 2

a. General

Locks and Dam 2 were originally constructed from 1904-1906 and placed into operation on 15 August 1905. The existing locks, consisting of double chambers, replaced the original locks in July 1951 (riverward chamber) and November 1953 (landward chamber). The land chamber is 110 feet wide and 720 feet long and the river chamber is 56 feet wide and 360 feet long. The walls are concrete gravity sections with the middle and river walls founded on concrete box caissons and the Land wall founded on rock. The lower guide wall is on steel bearing piles and the upper guide and both guard walls are on steel sheet pile diaphragm cells. The upper guard wall extension is constructed of circular steel sheet pile cells. Top of wall elevation is 730.5 feet. Bulkhead facilities are provided so that the riverward lock can be used as a floodway during periods of high water.

The existing dam is part of the original construction. The dam is a fixed crest weir with crest at elevation 718.7. It is 748 feet long and terminates at an abutment on the left bank. The dam is an unreinforced concrete section founded on wood piles. No records exist defining the type and size of bearing piles. It is speculated that the piles are 12 inch diameter oak, which is consistent with normal practice at the time. The apron is supported on stone filled timber cribs. The bottom of the concrete on the dam is at elevation 703.7, and the bottom of the cribs is at elevation 691.2. The dam was shortened and midstream pier removed during the lock reconstruction (1949-1953). Scour protection stone was placed downstream of the apron in 1987.

A summary of major maintenance subsequent to the installation of the new locks is contained in TABLE 1.

TABLE 1
MONONGAHELA RIVER LOCKS AND DAM 2
SUMMARY OF MAJOR MAINTENANCE

Year(s)	Repairs
1954	Guard fence.
1954	Raised foundation for emergency dam gates.
1957	Installed gate lifting connectors on gates in land chamber.
1957	Cleaned and painted the floodway bulkheads and appurtenances.
1958	Repaired upper land chamber gate.
1958	Repaired gates,valves, gate latching device, etc. (unwatered river chamber)

TABLE 1
MONONGAHELA RIVER LOCKS AND DAM 2
SUMMARY OF MAJOR MAINTENANCE
(Continued)

Year(s)	Repairs
1958	Installed gate latching devices. (unwatered river chamber)
1959	Removed, repaired, and replaced lower land chamber gates.
1961	Repaired land chamber valves.
1962	Repaired land wall valves.
1962	Repaired oil gear pump in powerhouse.
1963	Installed gate mitering device on land chamber gates.
1963 & 1964	Repaired upper guard cell fender timbers.
1964	Repaired land chamber gates.
1965	Repaired land wall electrical signal lights damaged in accident.
1965	Repaired guard cells damaged in accident
1965	Repaired land chamber gate sills, gates, machinery, etc. (unwatered land chamber
1966	Repaired seals on emergency dam bulkheads.
1966	Repaired gate latching device.
1966	Installed rubber seals on floodway bulkheads and replaced emergency dam needles.
1967	Installed filling and emptying valve interlock controls.
1967	Installed gate mitering devices.
1969	Repaired gates, valves and sills in auxiliary chamber.
1969	Revised lock sewage system.
1969	Repaired floodway bulkhead fillers.
1969	Installed additional control stations for hydraulic oil pumps.
1970	Installed small boat signal system.
1971	Installed of gate mitering devices.
1973	Repaired gate anchorage.
1974	Repaired 110' gate.
1974	Repaired gate damaged in accident.
1977	Repaired upper gate.
1979	Repaired lower gate.
1979	Revised lock gate anchorage.
1980	Repaired filling and emptying valves
1980	Repaired sector arm and gudgeon pin in gate.
1981	Repaired middle wall filling valve.
1982	Repaired middle wall emptying valve.
1982	Replaced wire rope and repaired wheels on floodway bulkhead.
1983	Repaired middle wall emptying valve.

TABLE 1
MONONGAHELA RIVER LOCKS AND DAM 2
SUMMARY OF MAJOR MAINTENANCE
(Continued)

Year(s)	Repairs
1983	Replaced wheels & hoisting cables in floodway bulkhead.
1983	Dredged chamber and approaches.
1984	Repaired and installed gate.
1984	Repaired bulkhead.
1984	Repaired river wall filling valve.
1984	Replaced standby generator.
1985	Repaired and installed gate.
1986	Repaired river wall emptying valve.
1986	Repaired 110' gate.
1987	Unwatered river chamber.
1987	Repaired erosion in downstream face of the dam.
1987	Repaired land wall gate.
1987	Installed bulkhead brakes.
1987	Provided erosion control below dam.
1987	Repaired guard wall.
1988	Repaired 110' gate and fabricate new gates.
1989	Adjusted floodway bulkhead cables.
1990	Fabricated valve bulkhead.
1990	Repaired land wall emptying valve.
1990	Dredged chambers and approaches

b. **Present Structural Condition**

i. Locks 2

A condition survey was conducted at Locks 2 by the Waterways Experiment Station (WES) and a report forwarded in March 1988. The following conclusions are taken directly from that report (paragraph numbers from report).

100. The concrete at Locks and Dam No. 2 making up the lock walls, the guide walls, and guard walls is in fair to good condition. All of the concrete is air entrained which has protected the concrete from any major thaw damage. Some surface scaling is evident in most of the concrete, but the original surface is generally recognizable.

101. Dissolutioning of the limestone coarse aggregate is evident throughout the entire lock structure. The aggregate is partially dissolved thus weakening the support of the thin surface mortar which has eventually eroded away causing the concrete to have an exposed aggregate appearance. The phenomenon is widespread but is confined to the surface of the concrete and has not caused any deep penetrating damage to the concrete.

102. During the construction of the lock, the majority of the concrete was a 4-bag mixture using 3-in. maximum size coarse aggregate and then topped with a 5-bag mixture using 1 1/2 in. maximum size coarse aggregate. Both concretes were found to be in good condition, and interface between the two concretes was generally intact.

103. The steel armor has protected the guide walls, the guard walls, and the lock walls from abrasion due to the river traffic. The concrete associated with the armoring is in good condition.

104. Some "D" cracking was present along the monolith joints, but the cracks appeared healed. Hairline cracks were also common along the steel-edged plates along the river wall and the guard walls. These hairline cracks do not appear to be active.

105. Popouts are common on some of the surfaces. This indicates that some of the aggregate used in the construction was low-durability aggregate. Popouts are surface features and will not affect the internal integrity of the concrete.

106. Vertical cracking was present on the top of the guide walls at periodic intervals and was not associated with any apparent chemical reaction and did not appear to be active. The cracks may have been due to original shrinkage of the concrete.

107. Some vertical monolith joints have spalled. Borings made adjacent to these areas have indicated that the depth of deterioration is confined to the visible spalled concrete. No damage due to the interior cracking was evident in the cores examined from these areas.

108. Some minor repairs have been made in the gate machinery area. The repaired concrete is generally in good condition. Some cracking of the concrete was noted in the vicinity of some of the opening winches. The concrete from borings adjacent to these areas indicates that the concrete is intact and in good condition.

109. The near surface concrete shows only minor surface deficiency. While at the present these surface defects are not currently a maintenance problem, as normal weathering progresses, the concrete surface will continue to deteriorate as it has in the past, which is essentially none at all. Vertical and horizontal core showed no signs of deterioration. Due to this fact, along with the fact that the exterior concrete has not deteriorated since construction, a rate of deterioration was not calculated for Lock and Dam No. 2. The concrete should remain in serviceable condition for a period extending on the order of 50 years.

110. The shale recovered from the lock wall foundation did not contain weak zones such as clay seams, therefore, intact specimens were tested in direct shear parallel to bedding. Two groups of shale were identified and tested separately. For the analysis of the direct shear strength parameters, the groups were combined due to similarities in the shear stress versus shear deformation curves and similarity of other key rock properties. The peak shear strength parameters are phi:peak = 47.5 degrees and c = 6.4 psi. The residual strength values are phi:residual = 25.8 degrees and c = 1.32 psi.

This WES Condition Survey indicates that the locks are in fair to good condition. There are presently only surface deficiencies that are not a maintenance problem. Furthermore, the stability of the lock walls has been checked and found to be well within the criteria for all cases in both sliding and overturning.

ii. Dam 2

The available data on the dam and dam foundation consists of information gleaned from diver inspections. Soundings in 1973 indicated that a scour hole downstream of the dam appeared to extend below the foundation elevation of the cribs. In 1978, uneven flow over the dam was reported and again the scour was mentioned as a possible problem. In 1983, divers reported many serious observances. There were several areas where timbers were missing from the cribbing, and several holes were noted under the apron, with one extending all the way to the downstream face of the dam. In addition, the divers reported strong currents coming out of two of these holes, suggesting the existence of through channels under the dam. Uneven flow over the dam has been reported in all periodic inspections since 1978, with possible causes listed as: settlement, uneven apron elevations, concrete deterioration, erosion and/or impact damage.

c. **Structural/Foundation Deficiencies**

i. Locks 2

As indicated by the WES Condition Survey, locks 2 are in relatively good shape. However, there are numerous deficiencies that will need addressed during the analysis period. The present surface condition of the concrete is in need of repair, as there is minor cracking at the recesses and severe spalling at some of the monolith joints within the chambers. Dissolutioning of the limestone coarse aggregate is evident throughout the entire lock structure. The aggregate has partially dissolved thus weakening the support of the thin surface mortar which has gradually eroded away causing the concrete to have an exposed aggregate appearance. This phenomenon is widespread but confined to the surface. The miter gates, anchorages and operating machinery are showing signs of age as are the butterfly valves, as well as the valve operating machinery. Both piers supporting the existing floodway bulkhead contain large vertical cracks. Furthermore, this bulkhead is difficult to operate and unreliable due to inherent deficiencies in design which causes misalignment of bulkheads. This poses potential safety problems during misalignment corrections and encroaches on valuable timely placement.

ii. Dam 2

The major deficiencies associated with the dam are the possibility of through channels under the dam and the voids exposing the timbers in the foundation. Through channels beneath the dam would constitute a serious threat to the dam stability. When fill is missing from under the dam or apron, lateral pile support is removed. The stability analyses of the dam, assuming full lateral pile support, indicates that the piles are overloaded laterally. The allowable load is 6,000 pounds per pile (lb/pile), whereas the load experienced by the piles at Dam 2 is 14,000 lb/pile. Furthermore, these analyses show that the piles are overloaded even more in both tension and compression for design loads when loss of supporting fill is assumed. The pile loads are even more critical due to the questionable lateral support of the piles. These concerns led the District to complete interim scour protection downstream of the dam in 1987; however, there was no provision for repairing voids in the foundation of the dam. The scour protection was placed within the O&M program and repairing the voids would have been far too costly and relatively ineffective in terms of increasing the reliability of the dam. (See Paragraph 2.b.(3) of the PLAN FORMULATION APPENDIX). However, this limited work effort was considered as an acceptable interim solution until comprehensive improvements could be made.

2. LOCKS AND DAM 3

a. General

Locks and Dam 3 was constructed in the period 1905-1907 and consists of double lock chambers with the land chamber measuring 56 feet wide by 720 feet long and the river chamber measuring 56 feet wide by 360 feet long. Top of wall elevation is 736.0 and 737.0. The river wall was extended in 1978 in order to provide a temporary river chamber, 56 wide by 720 feet long. This temporary chamber extension was left in place and is usable today. Since, however, the land chamber emptying valves discharge into the area of the river chamber extension, the use of two large chambers simultaneously is not possible. The original facility has been operated and maintained since May 1907.

All lock walls, except the upper guard wall extension and the extended lower river wall, are concrete gravity type founded on rock. The upper guard wall and lower river wall extensions are a series of six circular steel sheet pile cells with connecting arcs. The sheet piles were driven to rock, filled with sand and gravel, and capped with concrete, with the exception of the first upstream cell which is totally concrete filled.

Major modifications were made to the lock structure during 1923 and 1924 which included lengthening the land chamber to 720 feet and revising its filling and emptying system. In 1926 the upper guard and guide walls were extended. The upper guard wall extension consisted of a concrete cap supported on a rock filled crib. The upper guide wall monoliths were founded on rock.

Based on a 1976 Condition Survey and Structural Investigation conducted by the Waterways Experiment Station (WES) which outlined very serious deficiencies in many of the essential components of the project, a major rehabilitation of the locks was performed from 1977-1980. This included replacing the upper guard wall extension, anchoring unstable walls, renovating gate and valve operating machinery, refacing and resurfacing lock walls, changing the operating system from air to hydraulic, and renewing the electrical system.

The original dam provided a gated structure founded on timber piles with the crest of the concrete section at elevation 723.9 and the gate providing a pool elevation of 726.7. As in the case of Dam 2 the type and size of piles is not known and assumed to be 12 inch diameter oak consistent with normal practice at that time. In 1919 after the desired effect of the gated dam was not achieved, the gates were removed and a concrete section was added to the original concrete to create a fixed crest dam with the crest at elevation 726.9. The length of the dam from the river wall to the abutment is 688 feet with an 18 foot pier located about midstream. The abutment is a concrete gravity structure on timber piles. The top is at elevation 736.0 and the length is 223.3 feet.

A SUMMARY of the major maintenance at this facility is included in TABLE 2.

TABLE 2
MONONGAHELA RIVER LOCKS AND DAM 3
SUMMARY OF MAJOR MAINTENANCE

Year(s)	Repairs
1919	Filled lock gate recesses.
1930	Repaired land lock.
1931	Repaired river chamber.
1932	Repaired unwater river chamber.
1932	Replaced turbine and valve stems.
1935	Placed stone protection.
1935	Refaced lock walls.
1936	Replaced lower lock gates. (unwatered river chamber)
1936	Repaired land chamber, valves, lock walls and miter sills. (unwatered land chamber)
1936	Repaired foundation of river wall powerhouse.
1937	Constructed dike and fill below abutment.
1938	Repaired emptying valves in land chamber.
1938	Placed riprap stone and derrick stone below abutment.
1939	Repaired apron of dam.
1939	Repaired valves and sills. (unwatered river chamber)
1940	Repaired river wall.
1940	Repaired miter sills. (unwatered land chamber)
1943	Repaired powerhouse wall.
1943	Replaced upper lock gates in river chamber.
1944	Repaired miter sills, quoin seals and valves. (unwatered river chamber)
1944	Repaired valves and miscellaneous equipment. (unwatered land chamber)
1946	Repaired lower guide wall.
1949	Replaced gates in land chamber.
1949	Repaired valves and sills (unwatered river chamber)
1950	Repaired water turbine.
1951	Repaired gate anchorage and gate operating machinery.
1951	Repaired upper middle wall gate.
1952	Refaced land chamber by guniting.
1952	Removed upper lock gates and install reconditioned lock gates.
1952	Repaired top of river wall.
1952	Repaired miter sills. (unwatered land chamber)
1952	Reconstructed land wall powerhouse.

TABLE 2
MONONGAHELA RIVER LOCKS AND DAM 3
SUMMARY OF MAJOR MAINTENANCE
(Continued)

Year(s)	Repairs
1954	Reface upper guard wall and river chamber lock walls by gunite.
1955	Repaired valves, gates, etc. (unwatered land chamber)
1955	Repaired valves, sills, gates, etc. (unwatered river chamber.
1957	Spot refaced river face of river wall. (unwatered river chamber)
1958	Repaired top of middle wall.
1958	Replaced turbine with compressor and remove turbine and river wall turbine house.
1958	Replaced upper land chamber gates.
1959	Replaced gates in lower end of land chamber.
1960	Repaired valves, sills, etc. (unwatered river chamber)
1960	Installed steel coffer beam recess fillers in both chambers.
1960	Repaired lock and guide walls.
1960	Replaced lower river chamber gates.
1961	Repair valves, sills, etc. (unwatered land chamber)
1963	Repaired lower guide wall.
1963	Installed land wall filling valve "flumeway bulkhead beam."
1964	Repair emptying and filling valves, gates, sills, etc. (unwatered land chamber)
1965	Repaired upper land chamber gate.
1965	Repaired to upper middle wall anchorage (emergency).
1965	Replaced upper river chamber gates.
1966	Repaired gates, sills, valves and machinery. (unwatered river chamber)
1966	Repaired upper guide wall.
1966	Replaced mooring pier.
1969	Install filling and emptying valve interlocks controls.
1970	Replaced upper gates large chamber.
1970	Repaired upper gate anchorages, land chamber.
1971	Replaced lower gate, large chamber.
1975	Repaired valves, sills, etc. (river chamber unwatered)
1976	Repair gate in river chamber.
1976	Repair gate in land chamber
1977	Repair sills in river chamber.
1977 - 1980	Rehabilitation of locks.

TABLE 2
MONONGAHELA RIVER LOCKS AND DAM 3
SUMMARY OF MAJOR MAINTENANCE
(Continued)

Year(s)	Repairs
1980	Repair gates in river chamber.
1981 & 1982	Fabricated new gates.
1982 & 1983	Dredged pool.
1985 & 1986	Rehabilitated mooring cells.
1986	Installed new lock gates.
1985 - 1987	Made electrical repairs.
1987	Renovated and installed lock gates.
1988	Unwatered river chamber.
1988	Sealed cracks on top surface of all lock walls.
1988	Sealed cracks and joints on concrete caps of upper guard and river wall extension cells.
1988	Installed new gates.
1988 & 1989	Removed lower guide cells.
1989	Repaired valves and gate sills (unwatered river chamber)
1989	Repaired concrete below needle beam recesses
1989 & 1990	Fabricated new gates. in monoliths L46B and M26.
1990	Repaired gate and sector gear.
1990	Dredged chambers and approaches.

b. **Present Structural Condition**

i. Locks 3

A condition survey of the locks was conducted at Locks 3 by the Waterways Experiment Station (WES) and a report forwarded in February 1988. The summary taken directly from that report are as follows: (Paragraph numbers from report)

Exterior Concrete Conditions

62. The concrete placed in 1978-1980, on horizontal surfaces, was in good condition as evidenced by few concrete deficiencies and slight weathering. A few areas were deteriorated; however, these were localized areas where thin surface overlays had debonded and where original concrete existed. An area of delamination exists near the service building on the land wall where Sikatop 121 topping was placed, and 30 percent has delaminated or is visibly cracked.

63. Cracks in the overlay concrete were routed and sealed with a gray-colored substance. Top surface cracks appear to be temperature cracks as they are regular and do not tend to go into the section any further than the thickness of the overlays.

64. The concrete used to reface the lock walls is in good condition. Some isolated defects in the walls were noted; however, the majority of these existed prior to the rehabilitation and were not repaired. They do not appear to have been sources of accelerated deterioration as the deterioration has remained localized. The worst deficiency observed in the newer concrete on the chamber wall is medium scaling and local failures of the overlay in the middle wall face of the river chamber.

65. Cracks in the gate machinery recesses are mostly reflection cracks from the original concrete. Oil can be seen outlining some of these cracks at the surface. Cracking in the refaced and resurfaced areas tends to be minor and not a source of major deterioration.

66. The riverside of the river wall, the lower guide wall, all existing gate recesses, and selected areas on the upper guide wall and middle wall were treated with a thin layer of shotcrete. It was reported in the 1981 Periodic Inspection Report that shotcrete in areas subjected to tow abrasion and impact was unsatisfactory. In June 1982, it was reported that the failure of the shotcrete overlay appeared to be progressing. In July 1985, it was reported that additional failures of the shotcrete repairs were occurring. In December 1987, and inspection at Lock 3 by WES staff revealed that the shotcrete applied during the 1978-80 rehabilitation had indeed deteriorated to a point where it was questionable whether it was serving any purpose other than to cover the underlying concrete. It was never intended to protect the underlying concrete. In many small areas it has delaminated or fallen off.

67. Deterioration continues to be significant in the non-rehabilitated original concrete. A depth of three feet was measured in one void in the river wall.

Interior Concrete Condition

68. Poor quality concrete exists in the outer 2 to 6 feet of the lock and guide wall that is now covered up by the resurfacing and refacing done during the 1978-1980 major rehabilitation. Open lift joints and structural cracks still exist in the walls that were not intended to be repaired during this rehabilitation.

69. Weathered breaks, open lift joints, and cracks in the concrete continue to allow percolating and flowing water to leach the concrete, which contributes to on-going deterioration of the interior concrete.

70. In-place pulse velocity measurements made in the early 1970's indicate poor quality concrete in monoliths of the river and middle lock walls. Three such sections are within the gate block monoliths. Velocities as low as 8,720 ft/sec were measured over path lengths of up to 24 ft. Velocities below 12,000 ft per sec are considered to represent poor concrete which can contain either cracks, small voids, segregation, or all three defects. Granted, many other monoliths had velocities indicating good quality concrete; however, these low velocities contribute to the overall picture of poor quality concrete in high stress zones such as gate block monoliths.

71. Compressive strengths of honeycomb concrete are at best 50 percent of the 2,500-psi strength considered acceptable for gravity structures using present day standards. When low strength cores were broken in the testing machine, sand, gravel, and sand and gravel were observed falling from the center of the cores. Low strengths of the honeycomb concrete (1,150 and 1,450 psi, or less) can be assigned to all honeycomb lenses throughout the guide and lock walls

72. Honeycomb lenses were encountered 56 times in 12 of 13 vertical borings. Over half of these borings were drilled in gate block monoliths. The percentage of honeycomb per height of monoliths ranged from 4.0 to 27.5 percent, with the average for the 12 monoliths being 13 percent. About 30 percent of the honeycomb lenses were 1 to 2 ft in height. The lenses occurred from top to bottom in the monoliths, with the majority being in the middle and bottom.

73. One 2-ft-high cave-in zone was described in the core log of boring M-5 about 2.5 ft above the concrete-foundation contact. It could only occur because loose aggregate was adjacent to the boring. It is assumed that the 2 ft height was the maximum height and not a dimension along the slant of the aggregate pile that was placed instead of concrete. The base of the aggregate pile is thought to be about 6 ft. Aggregate particles recovered from this zone had no paste or cementitious material on them.

74. The 31 cavities on the exterior of the guide and lock walls were originally honeycomb lenses that were deteriorated by freezing and thawing action and acid water attack, and abrasion and gouged by ice and barge impact. These features support the existence of honeycombing throughout the guide and lock walls.

75. To obtain a sense about the poor quality concrete at Locks and Dam No. 3, a comparison of six defects that can indicate concrete quality was made between Locks and Dam No. 2 and 3; No. 2 is also on the Monongahela River. Low compressive strengths at No. 3 are about 50 percent of present day standard for gravity structures; at No. 2, the lowest strength is about 50 percent greater. concrete core recovery at No. 3 was 85 percent, while at No. 2 it was 99.9 percent. The occurrences of honeycomb and weathered core breaks at No. 3 were about 500 percent more than at No. 2. Open and weathered lift joints occurred 11 times at No. 3 and zero times at No. 2.

76. The authors' major concern is that one or several of the concrete defects could connect up with a structural crack propagating through a monolith, as a result of a boat or barge impact, and contribute to a failure of a monolith that could result in closure of a chamber of loss of pool. Projected concrete condition

77. Freezing and thawing of the older nonair-entrained concrete is the major deteriorating mechanism likely to degrade the concrete at the locks during the next 25 years.

78. A vertical rate of deterioration for a period of 68 years (1906 to 1974) was calculated for the lock walls; a maximum of 1.06 in. per year is the worst case for exposed original concrete. A rate of deterioration for the concrete in the overflow dam could not be determined.

79. Where air-entrained concrete overlays existing, the overlay will serve to greatly reduce ingress of surface water. However, the original concrete will become critically saturated by capillary rise, and freezing-and-thawing action will continue in the nonair-entrained concrete, probably at a somewhat reduced rate than the historical calculated rate. A horizontal rate of deterioration, 0.90 in. per year, was calculated using results of an evaluation of concrete quality at Locks and Dam 3 and Dashields Locks and Dam. A ratio of horizontal to vertical rate of deterioration calculated at Dashields was applied to a vertical rate of deterioration calculated for Locks and Dam 3 to obtain the 0.90-in.-per-year rate.

80. Where the original concrete is exposed on vertical faces of the lock walls, i.e., not refaced or refaced with shotcrete during the 1978-80 major rehabilitation, and where the shotcrete has delaminated or dropped off the wall, the worst case damage of an additional 32 in. is estimated by the year 2010

81. The sections of the walls refaced with the high quality air-entrained concrete should be serviceable at least until the year 2010 if high quality concrete exists behind the refacings. There is so much poor quality concrete in the lock and guide walls that one cannot tell where good or poor quality concrete exists without core drilling. Local high stress areas will require repairs as deficiencies, such as cracks and spalls, are formed from the action of freezing and thawing cycles in the older nonair-entrained concrete.

In summary, the WES Condition Survey indicates that the locks are in very poor condition which is masked by the rehabilitation conducted in 1977-80. Any one of the defects at Locks 3 would not necessarily be cause for concern. There are, however, so many problems at Locks 3 that there now exists a potential for a failure resulting in at the very least closure of the river and loss of pool.

ii. Dam 3

The structural and foundation conditions at Dam 3 are nearly a repeat of those at Dam 2; however, there have been no reports to date of flow under the dam. Most of the data concerning the dam is based on diver inspections and visual observations of surface flow patterns. The most recent inspection highlights the most serious of these concerns. Divers have reported missing timbers from the cribbing, voids under the apron, and many large cracks and concrete breakouts. Scour is also a problem downstream of the dam. The District also believes that fill may be missing from under the dam foundation, which is especially dangerous since the piles rely on the fill for lateral support. However, even under ideal conditions i.e., full lateral support with no missing fill, the piles are overloaded by current standards, both axially and laterally when ice/impact loads are considered. For example, the allowable vs. actual maximum pile loadings for this structure are 60,000 lb/pile vs. 68,000 lb/pile compression, 6,000 lb/pile vs. 13,000 lb/pile lateral and 0 lb/pile (no tension pile loads are allowed in this type of structural design) vs. 23,000 lb/pile tension. Furthermore, the abutment piling is extremely overloaded, 60,000 lb/pile allowable vs. 139,000 lb/pile actual maximum compression, 0 lb/pile allowable vs. 47,000 lb/pile actual maximum tension and 6,000 lb/pile allowable vs. 13,000 lb/pile actual maximum lateral load. Therefore, none of these maximum loads meet current criteria.

There are also concerns about the condition of the dam abutment. Furthermore, the abutment piling is extremely overloaded, 60,000 lb/pile allowable vs. 139,000 lb/pile actual maximum compression, 0 lb/pile vs. 47,000 lb/pile actual maximum tension and 6,000 lb/pile vs. 13,000 lb/pile actual maximum lateral load.

c. **Structural/Foundation Deficiencies**

i. Locks 3

The concrete in the lock walls is in the advanced stages of deterioration, however, much of this is not visible from the normal vantage points. During the 1978 rehab, most of the lock wall vertical and horizontal faces were refaced or resurfaced. Generally a 1 ft. thick cap was placed above pool level, mainly to restore the surface to a serviceable condition and to provide protection to the underlying deteriorated concrete. When viewed from the top of the lock walls, the concrete looks reasonably good, but this is misleading. The overlay covered many problems, it did not cure them. Concrete deterioration has progressed anywhere from two to six feet into the structure. The refacing provided during the major rehabilitation has been effective by allowing safe and reliable operation during the past ten years. However, the WES findings highlight the fact that this rehabilitation has masked numerous critical deficiencies in the original concrete and foundation.

The rehabilitation also sought to stabilize many wall sections with the use of rock anchors. However, the stability of the walls was so poor that to attempt to stabilize them in accordance with present day standards by this rehabilitation was deemed inappropriate, if not impossible. Therefore, reduced design criteria were adopted that would still provide a reasonable factor of safety. These reduced criteria were based on obtaining 70 percent active base along with maintaining a 1.3 resisting to overturning moment ratio, and providing a factor of safety against sliding of 1.5. The anchor system consisted of 1 1/4 inch high strength steel bars, grouted into rock, with a nominal load applied to the bar for the land wall (40,000 lbs) and 60 percent of ultimate (112,500 lbs) for the middle and river walls, with subsequent grouting of the stressing length. Anchor loads were designed based on ultimate capacity of the bars. Two grout systems were used for the anchor installation. One system consisted of cement grout for both the bond length and the stressing length, while an alternate system allowed use of polyester resin grout. The contractor opted for using polyester resin grout in the bond length and cement grout in the stressing zone. This method was used for the river and middle wall anchors, but due to problems with installation the District directed the contractor to use only cement grout for the land wall anchors.

Several areas not repaired during the rehabilitation are noted as being in particularly poor condition. The land wall filling flume has several areas where the deteriorated concrete has been eroded away leaving gouges 1 to 1 1/2 feet deep. The retaining wall on the right side of the filling flume is an area of concern, since the loads it supports are very high and the wall is thin and unreinforced. The middle wall gallery also has deteriorated and eroded concrete along the bottom of the wall and at the monolith joints. The lower reach of the middle wall, from Station 4+79.7B to Station 8+76.0B, was placed in the wet by dumping concrete into wooden forms during the 1920-1923 modification of the large chamber. The foundation contact for this section is very poor, and it is estimated that 10 to 20 percent of the total concrete is honeycombed and/or affected by segregation. There are many large structural cracks in the supporting beams for the land wall operations building, supporting beams which were modified in 1923 when the land chamber was lengthened. These areas are not protected from adverse conditions and will continue to deteriorate in the future.

Age, intense traffic demand, harsh environment and initial construction features, such as lack of wall armor and reinforcing, poor concrete placement techniques and lack of air-entrainment, have combined to take their toll on locks 3. The results and findings of the WES Condition Surveys and the District investigations have shown that this nearly 90-year old project will soon be at the end of its useful life.

ii. Dam 3

Except for the absence of through channels under the dam, the deficiencies with Dam 3 are a repeat of those for Dam 2. The voids under the dam, missing timbers from the cribbing, and numerous cracks and concrete breakouts pose serious threats to this dams ability to resist loads such as those due to ice and impact. In addition, the supporting piles under the abutment are overloaded, which leads the District to the conclusion that the abutment is highly susceptible to failure.

3. LOCKS AND DAM 4

a. **General**

Locks and Dam 4 was originally constructed from 1931-1932, and placed into operation on 14 August 1932. The locks consist of double chambers. The main lock chamber, located on the landward side, is 56 feet wide and 720 feet long and the auxiliary lock chamber is 56 feet wide and 360 feet long. The elevation of the top of lock walls is 749.0 feet. Lock walls are founded on 12 inch diameter oak timber bearing piles within parallel steel sheet pile enclosures.

In 1934 the upper guard wall was extended by adding 13 monoliths, approximately 500 feet. These monoliths are supported on rock filled timber cribbing. During the reconstruction of Dam 4, 1967-1969, a new river wall section, with its foundation on rock, was constructed using seven monoliths for a total length of 224 feet, top width of 32 feet and top elevation of 751.0. This new wall section is 43 feet riverward of the existing river wall and will be used for future reconstruction of the locks. The existing lock walls of both chambers were strengthened by the addition of concrete struts across the bottom of the lock chambers and support cells were constructed behind the existing river wall below the dam to accommodate the 6 feet raise in pool. In 1969, the repairs to the top of the lock walls were completed. The work consisted of completing the recapping of the land wall, middle wall, river wall, and portions of the upper guard wall. In 1984, a sidewalk was constructed beside the top of the upper guide wall.

The original dam was a fixed crest dam on timber bearing piles which was reconstructed in 1967 to provide a gated crest. The upper pool was raised 6 feet at this time. The crest of the original dam was removed and the remaining structure now serves as the apron and stilling basin for the gated dam. The overall length of the dam is 535 feet. This includes a fixed weir uncontrolled spillway 43 feet long with a crest elevation of 742.5 feet and the 32 foot wide future river wall section. The controlled spillway consists of five gated sections. Each section is 84 feet long with a fixed sill at elevation 724.0. The gate sills and the abutment training wall are founded on steel bearing piles, while the dam piers and abutment are founded on rock. The six piers support a five-span, pre-stressed concrete service bridge which in turn carries the bulkhead hoist and auxiliary crane used to place the emergency bulkhead units.

A summary of the major maintenance at this facility are listed in TABLE 3.

TABLE 3
MONONGAHELA RIVER LOCKS AND DAM 4
SUMMARY OF MAJOR MAINTENANCE

Year(s)	Repairs
1932	Placed stone protection at abutment.
1935	Replaced valves, repaired sills. (river chamber unwatered)
1935	Repaired sills. (land chamber unwatered)
1936	Repaired valves.
1938	Repaired valves, placed stone protection at river wall and abutment.
1939	Repaired gates and sills. (land chamber unwatered)
1939	Placed fill and drainage at abutment.
1940, 1941 & 1942	Repaired and replaced filling and emptying valves.

TABLE 3
MONONGAHELA RIVER LOCKS AND DAM 4
SUMMARY OF MAJOR MAINTENANCE
(Continued)

Year(s)	Repairs
1941	Replaced deteriorated concrete in abutment.
1942	Repaired concrete in the land wall.
1944	Repaired oil lines, gates, sill. (river chamber unwatered)
1945	Repaired valves, sill, seals, etc. (land chamber unwatered)
1946	Repaired oil lines, gates, valves (river chamber unwatered)
1949	Repaired valves and gates. (land chamber unwatered)
1950	Repaired gates and valves.
1954	Replaced valves.
1956 & 1957	Replaced gates.
1958	Replaced valves and gates. (land chamber unwatered)
1959	Repaired valves. (river chamber unwatered
1961, 1962, 1963	Repaired valves.
1965	Repair gates.
1966	Repaired concrete in the upper guard wall.
1967	Repaired concrete in the land and middle walls and repaired gates.
1967	Repaired gate.
1968	Repaired valve blade.
1969	Repaired piling in spur dike.
1969	Repaired deteriorated concrete in land and middle walls.
1971	Repaired valves.
1972, 1973 & 1976	Repaired gates.
1977 & 1978	Repaired valves.
1978	Repaired gates.
1979	Placed stone protection at upper guard wall.
1980	Repaired gates.
1981	Repaired gate seals and sector arm.
1982	Repaired middle wall emptying valve.
1982 & 1983	Painted tainter gates.
1983	Repaired lock wall concrete and river wall filling valve.
1984	Repaired, fabricated and installed gates.
1985	Painted tainter gates, fabricated lock gates.
1985	Unwatered both chambers.
1986	Renovated railway crossing.
1986	Fabricated lock gates.
1986	Constructed access road.
1986	Made miscellaneous repairs and clean up after November 1985 flood.
1987	Painted tainter gates and bridge on dam.
1987	Replaced stone along upper guard wall.

TABLE 3
MONONGAHELA RIVER LOCKS AND DAM 4
SUMMARY OF MAJOR MAINTENANCE
(Continued)

Year(s)	Repairs
1987	Installed lock gates.
1988 & 1989	Installed tow haulage units.
1988 & 1989	Repaired land wall emptying valve.
1989	Renovated lock gates, valve blade, gate machinery and anchorages.
1989	Erect security fence.
1990	Repaired gate machinery and land wall filling valve.
1990	Renovated and installed lock gates.
1990	Dredged chambers and approaches.
1990	Replaced upstream small chamber gates.
1990	Repaired gate anchorage and machinery.

b. **Present Structural Condition**

i. Locks 4

A condition survey was conducted at Locks 4 by the Waterways Experiment Station (WES) and a report forwarded in March 1988. The conclusions below are taken directly from the report: (Paragraph numbers are from report)

> 162. The process causing the greatest amount of deterioration of the concrete is freezing and thawing action. This process will continue at accelerated rates in the older nonair-entrained concrete if adequate repairs or replacement of the damaged concrete are not carried out.
>
> 163. During the dewatering of the chambers for repair of miter gates, the lock walls below low pool elevations were observed to have an architectural concrete appearance. Throughout time, acid water in the river had removed fines for a depth of about 1 in. from the concrete leaving the large aggregates exposed. Concrete observed in the filling and emptying culverts had a similar appearance.
>
> 164. The newer air-entrained concrete used in the overlays and in the construction of the future lock wall has light to moderated scaling and locally reflective cracking as observed in segments of the upper guard and middle lock walls. In general the overlay concrete is in good condition.
>
> 165. Local zones of core recovered from the future lock wall displayed a crack pattern when drying out after having been wetted. The concrete is intact and appears sound. The cracking is primarily around large aggregates and could be attributed to dirty aggregate being used in the concrete.

166. The concrete on and near the top surfaces of the guide, guard, and lock walls is generally in fair to poor condition. Concrete damage is considered extensive covering greater than 50 percent of these surfaces. Concrete defects include a few areas of light to medium scaling, severe to very severe scaling, areas of random cracking and transverse and longitudinal cracking. The middle lock wall has a longitudinal crack nearly the full length of the wall that connects to the longitudinal crack in the ceiling of the gallery in that wall.

167. Concrete from the upper sections of the lock walls was of variable quality. Deterioration varied from surface scaling to incipient cracks at 6.5 ft depths. Although concrete damage exists at depths of 6.5 ft, only the near surface concrete (to 2 ft depths) should be given repair considerations. Approximately 30 percent of the cores contain surface damage, approximately 50 percent contain damage of 1 to 2 ft depth and 20 percent contain damage greater than 2 ft. The low quality concrete is present as either rubble, broken pieces less than 3 in. in size, or cracked pieces 3 to 12-in. thick. White reaction products on the hand size pieces indicate the rubble was formed in place.

168. The vertical surfaces of the guide, guard, and lock walls above upper and lower pool elevations are generally in poor condition. Damage is extensive covering about 80 percent of these surfaces, however near surface damage is limited. Generally, the deterioration has penetrated to about 0.5 ft with a maximum of 1.4 ft in the middle wall. The lock wall faces are very severely scaled, some construction joints are very severely scaled and spalled, monolith joints are spalled up to several feet wide, vertical and diagonal cracks and pattern cracking are common. The majority of the concrete within the straight armor sections is in fair to poor condition; the armored sections within the lock chambers are in the worst condition.

169. Concrete in the miter gate recesses is in fair to poor condition. Horizontal and vertical borings were not drilled in the gate recesses adjacent to gate anchorage locations because of the concern of weakening the thinner sections, therefore, the condition of the internal concrete in these zones is unknown.

170. The concrete in the galleries exhibited some spalling and scaling but the primary deficiencies were cracks (fine, vertical, transverse, and longitudinal), efflorescence, leakage at monolith joints and construction joints and freeze-thaw damage at all ladder and shaft openings.

171. The concrete in the culverts and in the lock walls below the lower pool elevation has been eroded due to abrasion erosion and acid water attack. Generally the matrix with fine aggregate has been removed, however, the exposed concrete appears sound. Leakage from vertical cracks and monolith joints (one making 20 gal per min in the river wall) are common defects in the three culverts. Slight vertical displacement of monoliths were observed in the culverts of the middle and river walls. Vertical displacements were noted at monolith joints M-12/M-13, M-15/M-16, M-17/M-18, M-22/M-23, and R-33/R-34. Erosion of the culvert floors has removed concrete up to 15 in. deep in several areas.

172. Locations where noticeable relative displacement has occurred are: middle of L-44, between L-59 and the first monolith of the wing wall; M-6 and M-7, M-10 and M-11, R-45 and R-46, R-49 and R-50; and a series of the upper guard wall monoliths that indicate tilting (R-1 thru R-15).

173. The ability of the near-surface concrete to perform satisfactorily under anticipated conditions of future service is questionable, especially on horizontal surfaces. The continued deterioration will further reduce the quality of the concrete surfaces.

174. Concrete below damaged zones is in good condition. the compressive strength is generally well above 5,000 psi; the lowest strength obtained was for overlay concrete (3,810 psi). The average strength of 40 cores is 6,930 psi with a standard deviation of 1,370 psi. Indications are that the internal concrete should remain in serviceable condition for a period extending on the order of 50 years.

175. Previous patching in some areas has been inadequate since the older concrete beneath has deteriorated despite the repair. In some cases, deterioration has been aggravated by the repair by allowing infiltration of water into the older concrete through surface defects.

176. The river sediments recovered from beneath the small and large chamber concrete floor slabs consist of silty sands and gravels, gravel, clayey gravels, gravelly silty sand, indurated clays and clayey shale. About 26 ft of these materials were recovered before encountering clayey shales. The foundation material beneath the future lock wall consists of clayey red and gray shales and siltstone. No appreciable lithologic differences exists nor are any structural features apparent between the three borings.

177. The shale recovered from the bedrock did not contain naturally occurring weak zones, therefore, intact shale specimens were tested for shear strength parameters. Four groups of shale were identified and tested separately. The lower strength parameters for the three mod-hard shale groupings are phi = 53 degrees and c = 5.8 tsf (80.6 psi). The residual strength values are phi = 15.5 degrees and c = 0 tsf (0 psi). The hard gray shale has a peak strength of phi = 69 degrees and c = 8 tsf (111 psi); and residual strength of phi = 25.9 degrees and c = 0 tsf (0 psi).

The WES Condition Survey indicates that the locks are in fair to poor condition. The freeze thaw cycle will continue to contribute to further deterioration due to older non air-entrained concrete. There are many cracks, scaling spalling, efflorescence and leakage at the monolith joints. Locks 4 is showing signs of its age and the aging process will continue to deteriorate Locks 4 in the future.

ii. Dam 4

The existing gated dam is in good condition both structurally and mechanically.

c. **Structural/Foundation Deficiencies**

i. Locks 4

There are several aspects of this structure considered to be problem areas: age, concrete condition, construction techniques employed in the project's development and pile loadings. The lock walls are thin unreinforced concrete sections founded on 12" diameter wood piles. They are considerably spalled and eroded with concrete deterioration penetrating several feet and projections are for this to continue. The process causing the greatest amount of deterioration of the concrete is freeze thaw action. This process will continue at an accelerated rate in the older non-air entrained concrete. There is severe scaling and abrasion damage on chamber wall faces and monolith joints are severely spalled. Throughout the history of the project, acidic river water has removed fines for a depth of about 1" from the concrete, leaving the large aggregates exposed. These conditions are exacerbated by the lack of adequate wall armor and reinforcing. There is extensive leakage into the middle and river wall galleries. There has been relative movement between the monoliths in the middle wall, noted both in the pipe gallery and the culvert. Most of the lock wall monoliths contain cracks which are structural in nature and some of which may be working. The ceiling and floor of the galleries have longitudinal cracks as well as occasional transverse cracks. The presence of cracks is made more serious by the absence of reinforcing steel in these relatively thin sections. The many cracks, thin sections and lack of reinforcing would require any rehabilitation to include a major rebuilding of the pipe galleries.

The upper guard wall is founded on stone filled cribbing and is leaning toward the land chamber. The lower guide wall is also leaning riverward due to the loads imparted by the backfill behind the guide wall.

Another area of concern involves the piling beneath the lock walls. They were intended to be end bearing on rock, but it is not known if the piles were driven to rock. This uncertainty combined with the age of the piles reduces the reliability of these piles to adequately resist normal loads. Furthermore, stability analyses indicate that some piles are in tension (no tension is allowed for this type of structural design) and that a majority of piles are loaded very near the allowable compression load (60,000 lbs/pile) and lateral load (6,000 lbs/pile). The loads on the piles were increased when the new dam was built in 1967 and the upper pool was raised. It was recognized at that time that the loads were approaching the maximum allowed, but the plan then was that it would be a temporary condition.

In addition, the pile cap for these walls is also considered a potential problem area. The cap is a 4 foot thick unreinforced concrete beam at the base of the wall monoliths. With the high pile loads that are transferred to it, this cap is subject to tensile loads that could propagate cracks throughout the monolith. Under normal, current design, the cap would be designed with steel reinforcement to resist such tension.

ii. Dam 4

The only problem areas that will need addressed are the scouring of the derrick stone protection below the stilling basin to various depths over its entire length and the poor condition of the concrete baffles. These deficiencies may be caused by a higher than optimum elevation of the apron, a part of the original structure that was incorporated into the reconstructed dam.