Chapter 7

Electric Power on the Delaware

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I. INTRODUCTION

The electric utilities that serve the Delaware Valley and neighboring regions once included in their vision of the future a 1,300-megawatt pumped-storage facility that would depend on the Tocks Island reservoir as a lower pool, and a 33,000-megawatt network of steam-electric generating plants that would evaporate tremendous amounts of cooling water from the Delaware River. Without the Tocks Island Dam, pumped storage will probably not be built, and, under the present policies of the Delaware River Basin Commission (DRBC), neither will most of the downstream power plants—at least at the sites the utilities originally suggested. Not surprisingly, electric power looms as a significant issue in the debate over constructing the dam.

The power companies speak in threatening terms about the consequences of the demand for electricity outgrowing their generating capacity. They predict that rationing of electricity, reduced industrial growth, and severe unemployment will result if their schedule for constructing new power facilities is not met. The DRBC, which is responsible for planning and managing the region's water resources, has tied the fate of many of the utilities' power plants to the Tocks Island project. The Commission staff projections assert that, without the Tocks Island project, the Delaware's flow is not adequate to meet the future water demands of the power plants, as well as those of industries and cities in the region, and that unless the Tocks Island Dam is built, even the water supply for plants now under construction may be in jeopardy by 1980. They conclude that the utilities would either have to bolster the flow with their own offstream dams and reservoirs or shut down during the late summer periods of low flow.

The projections of the utilities and the DRBC are supported by detailed quantitative studies, which thwart casual criticism. However, like all projections, theirs embody crucial assumptions, which are open to question. Both the utilities and the DRBC have perceived their responsibilities entirely in terms of assuring an adequate supply. The utilities are the energy providers; the DRBC, in spite of a mandate that would permit a broad role in regional planning, perceives itself primarily as a water provider. Neither considers any attempt to *control* demand as within its prerogatives. Thus, the projections of both the DRBC and the utilities are based on the conventional model of indefinite exponential growth. If energy conservation becomes an effective national policy, then, of course, all such projections may need fundamental revision.

Moreover, as the utilities are primarily concerned with minimizing the dollar cost of providing the power, they generally postulate the lowest cost means of cooling. At some additional cost, the utilities could adopt less water consumptive means of cooling. When such options are assumed in a forecast, the projections of water consumption associated with a given projection of energy consumption are reduced substantially.

This essay reviews the analyses of demands for energy and water in the Delaware River Basin and the strategies for meeting these demands developed by the utilities and the DRBC. Section II describes the forecasting of new electric generating capacity. Section III explains why growth in electric power consumption need not necessarily require growth in fresh water consumption to the same extent. Sections IV and V discuss how the Tocks Island Dam decision is linked to electric power supply: at stake are the expansion of downstream generating capacity (section IV) and the expansion of pumped storage (section V).

II. THE EXPANSION OF ELECTRIC GENERATING FACILITIES

Demand Projections by the Utilities

The total service area of the nine power companies which operate in the Delaware Valley includes all of New Jersey and Delaware, most of Pennsylvania and parts of Maryland and New York (see Fig. 7–1). The population of this region, approximately 50 million people, is serviced (1974) by more than 30,000 megawatts of electric

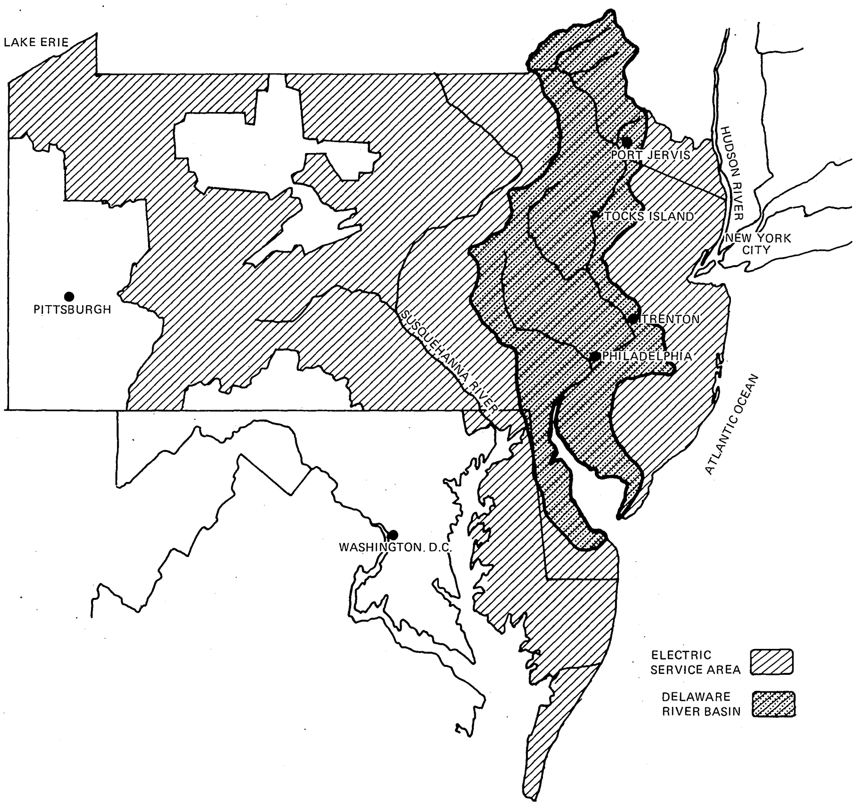

Figure 7-1. Total Electric Service Area
The electric service area supplied by the electric companies which presently own and operate, or propose to install, major generating facilities within the Delaware River Basin.

power plant capacity. (1,000 megawatts is a typical size for the major fossil fuel fired and nuclear power plants under construction today; earlier power plants tend to be much smaller.) This installed capacity exceeds by about 20 percent the "peak demand," which occurs during the afternoon of a hot summer weekday.[a]

It is this peak demand that is the subject of the demand projections performed by the electric utilities, for they must have the power plants built and functioning (or must be able to borrow the power) when the peak demand occurs, and they must allow for

[a]This is true all over the eastern seaboard; annual peaks still tend to occur in winter in some inland areas (central Pennsylvania is an example) where winter is more severe and summer air conditioning is not as widely adopted.

inevitable breakdowns and repairs. Peak electric demand is also the appropriate subject of attention of the water professionals (rather than, for example, demand averaged over the year, which is typically about half as large) for a different reason: the yearly peak occurs in the summer, when the river flow is lowest and the allocation of scarce water resources is most rigorously constrained.

The electric utilities have not ordinarily made public their plans for the construction of power plants until the time when permissions and approvals had to be sought, rarely more than ten years before the plant would be producing electric power. On the other hand, those responsible for the planning of water allocations, in a basin for which a dam with a 50-year or 100-year "project life" is slated, are driven to consider more distant horizons. The Delaware River Basin Commission, faced with requests for approvals of power plants, one at a time, demanded in 1971 that the Basin's utilities prepare a fifteen-year, Basinwide plan for power plant construction.[1] The result was a 1971 Master Siting Study,[2] and, approximately two and one-half years later, a 1974 Master Siting Study,[3] a modest but significant revision of the earlier study. These two documents are the subject of brief discussion in the remainder of this section, and again in section IV.

The Master Siting Studies take the reader through a three-step argument. First, peak demand is projected for the entire service area of Figure 7–1, an area four times larger than the area of the Delaware River Basin. Second, the additional capacity required to meet this demand year by year is displayed. Third, the particular power plants that the utilities wish to construct to meet that demand, and the scheduled times of completion, are itemized. As will be seen, in the two Master Siting Studies this third step was confined to plants in the Delaware River Basin.

In Figure 7–2, graphs from MSS-74 for the first two steps in the argument are reproduced. The projection of peak demand is a smooth curve, representing exponential growth from 27.2 megawatts in 1974 to 67.1 megawatts in 1988, an average rate of growth of 6.66 percent per year, corresponding to a doubling time of 10.8 years.[b] The projection of installed capacity is a bumpy curve, reflecting the large size of the individual power plants that are planned.

Relative to MSS-71, the projected rate of exponential growth of peak demand in MSS-74 is about one percentage point per year *less*.

[b]Close inspection of Figure 7–2 suggests that the rate of exponential growth is somewhat higher than this average in the first few years of the period and somewhat lower in the last few years.

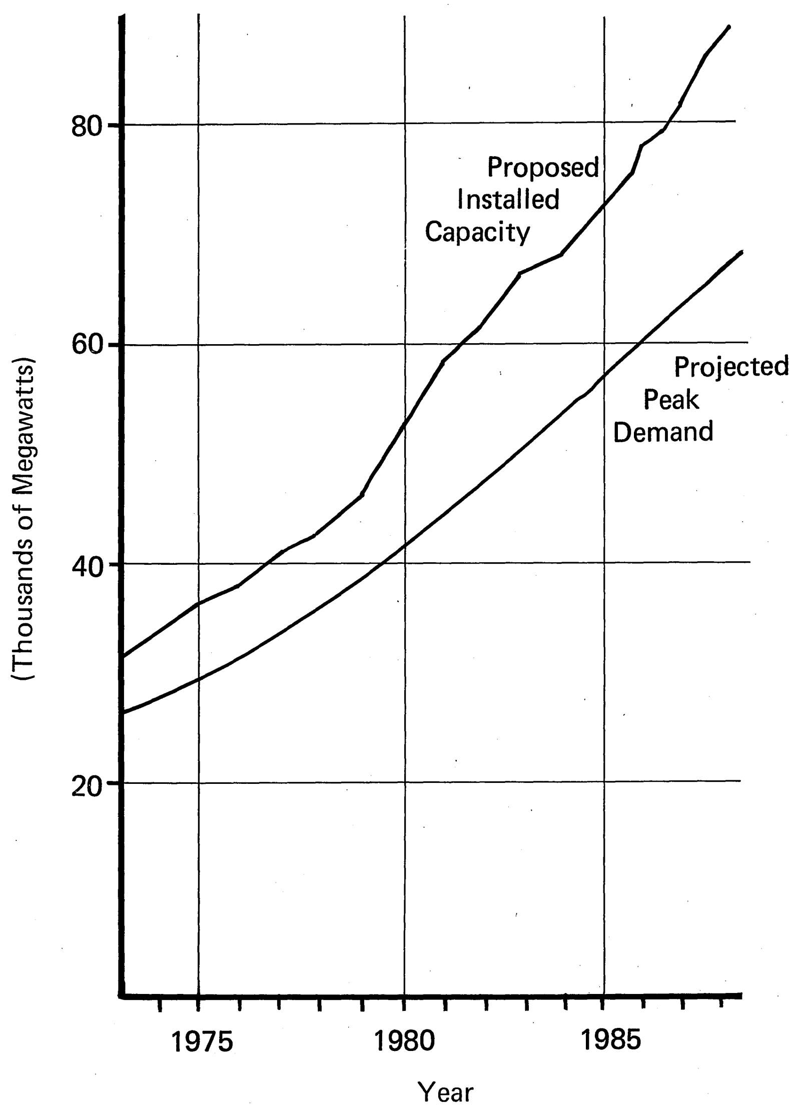

Figure 7-2. Projected Peak Electric Demand and Proposed Installed Capacity for the Service Area of Figure 7-1, May 1974
Source: MSS-74, Figure No. 1.

A clue to the reasoning behind this downward revision of growth rate is to be found in the few new sentences found in the "Growth and Capacity" sections of MSS-74. (The two reports are identical for pages at a time.) In MSS-74, but not in MSS-71, one finds:

> Existing programs by utilities to conserve basic resources used in the operation of their systems, and programs to promote conservation of energy among their customers are becoming effective, changing to some extent the historical pattern. Long-range forecasts of needed electric generation will take into account this change in use. These companies have recognized the need for conservation of basic energy resources and also recognize their obligation to plan for the future demands for electricity so that the needs of the public for electrical energy can be met.[4]

For two and one-half sentences, the concept of energy conservation gets an airing.

The word "conservation" did not appear at all in MSS-71. And, as Figure 7–2 shows, at the time of MSS-74 the utilities' planners still clung to the vision of indefinite exponential growth, which had been confirmed as a method of projection for several consecutive decades; "conservation" merely stretched out the predicted growth over time—and not by very much, at that.

B. Other Views of Future Demand

A considerable body of opinion is developing at this time which holds that the next fifteen years are likely to witness considerably less growth in the consumption of electric power than is projected in either MSS-71 or MSS-74. The critical variable is the change in the price of electricity: after years of falling prices (representing, in particular, technological innovation and economies of scale), the price of electricity has been rising recently (due to the rising costs of fuel, capital, and labor). Virtually all those willing to predict expect prices to continue rising for some time. The connection between rising prices and falling consumption is quantified through studies of "the elasticity of demand." (The elasticity of demand is approximately the percent change in demand divided by the percent change in price.) Estimations of elasticities require the statistical treatment of data and are notoriously difficult. During the long period when prices were falling at nearly a constant rate, and were expected to continue to do so, studies of elasticity were superfluous. It is when price trends change that elasticities become crucial to the projection business.

To show the significance of price elasticity, we borrow on the results of a widely cited study by Chapman, Tyrrell, and Mount,[5] who fit an algebraic model to data on energy prices, electricity consumption, and per capita regional income for eight regions of the country over the years 1945–1970. When they inserted into their model the 1970 Federal Power Commission projections[6] for the growth in national annual electric power consumption, they concluded that implicit in the FPC projections is an assumption that the price of electricity, in constant dollars, will *fall* continuously (dropping by 24 percent from 1970 to 1980 and by 39 percent from 1970 to 1990). Inserting into their model the FPC's predictions of gradually *rising* prices (19 percent from 1970 to 2000) presented in the 1970 National Power Survey, and holding all other factors constant, they find a much slower rate of growth than the FPC's own projection in the same survey: consumption is down 22 percent in 1980 and 47 percent in 1990 relative to the FPC projections. Finally, inserting more rapidly rising prices (a doubling of the price of electricity between 1970 and 2000), and holding all other factors constant, they find a still slower growth rate: down 32 percent in 1980 and 63 percent in 1990, again relative to the FPC projections.

The projections of growth of regional peak demand in MSS-71 are contemporaneous with the projections of total national consumption in the FPC's 1970 National Power Survey, and a close inspection shows ten-year doubling to be characteristic of both. How rising prices might reduce the growth projected in MSS-71 is shown in Figure 7–3, where the "correction factors" derived in CTM are used to "correct" the 1980 and 1990 peak demand values found in MSS-71. The demand projections are dramatically reduced.

Two other recent studies of future energy supply and demand, one by the Ford Foundation[7] and one by the Federal Energy Agency,[8] have confirmed the likelihood of rising prices and reduced demand. These reports go further in arguing that reductions in rates of growth and energy consumption (including electricity consumption) need not have deleterious effects on the national economy. The Ford Foundation report calls particular attention to the ways in which the deployment of energy conserving technology will stimulate the economy. Time will tell.

C. The Location of New Capacity

The projection of new capacity in the Service Area of Figure 7–1 was not revised downward anywhere near as much as the projection of peak demand, between MSS-71 and MSS-74. As a result (as can be

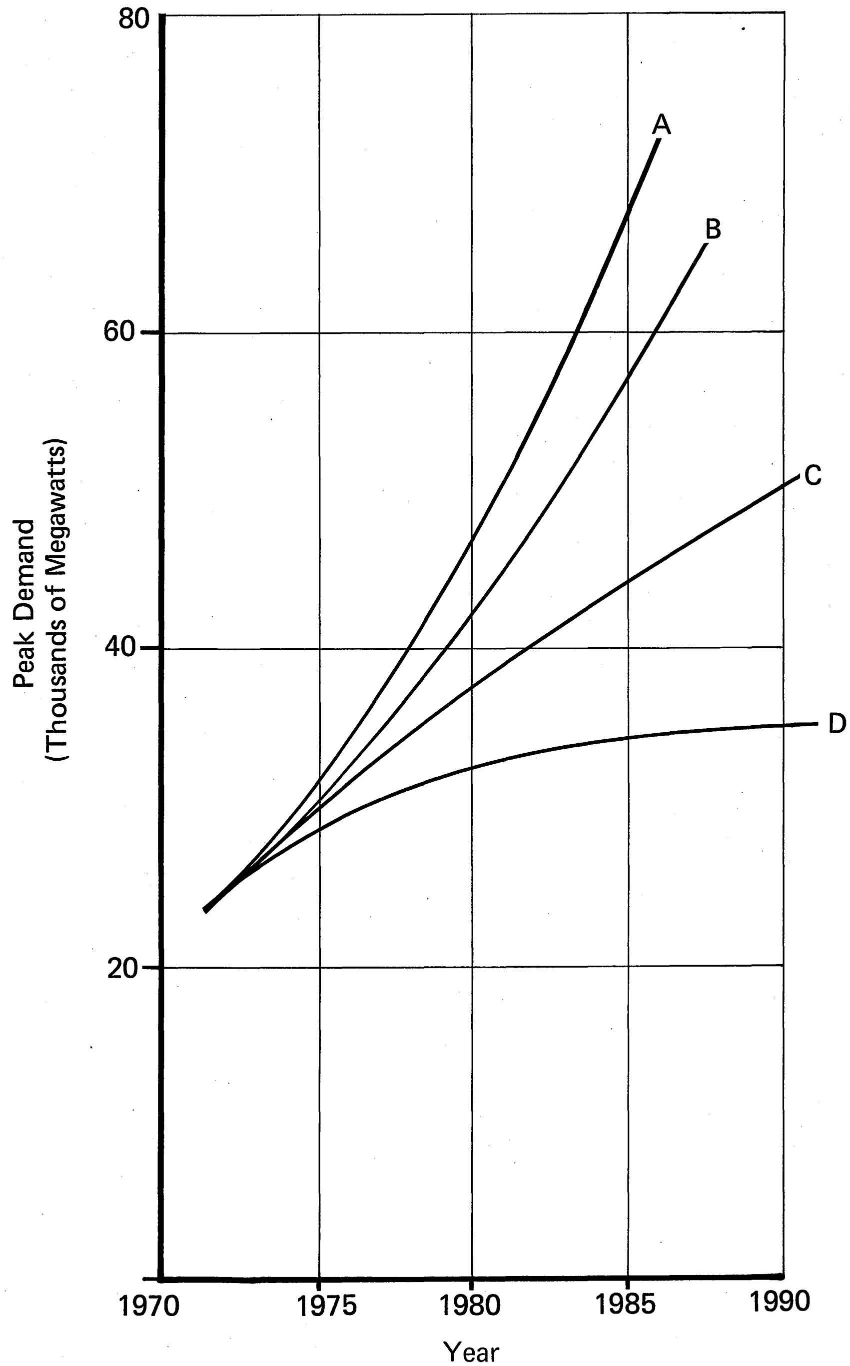
80
60
40
20
Peak Demand
(Thousands of Megawatts)
A
B
C
D
1970
1975
1980
1985
1990
Year

Table 7-1. Comparison of the 1971 and 1974 Master Siting Studies. (All figures are in thousands of megawatts.)

	MSS-71 (1971 to 1986)		*MSS-74 (1973 to 1988)*	
Capacity installed at start of study period				
Total service area	27.2		33.5	
Delaware River Basin	6.3		6.8	
(percent in Basin)		(23.2%)		(20.3%)
Capacity added in next fifteen years				
Total service area	59.7		54.2	
Delaware River Basin	34.4		22.5	
(percent in Basin)		(57.6%)		(41.5%)
Total capacity installed at end of study period				
Total service area	86.9		87.7	
Delaware River Basin	40.7		29.3	
(percent in Basin)		(46.8%)		(33.4%)

seen in Figure 7–2), MSS-74 calls for a 30 percent reserve capacity in 1988, compared to 20 percent reserve in 1973 (MSS-71 had kept the reserve under 25 percent throughout.) Apparently, the authors of the Master Siting Studies were more prepared to revise the rate of growth of demand than to revise the rate of growth of capacity to meet that demand. However, as Table 7–1 shows, 12,000 megawatts of new power plant capacity were shifted out of the Delaware River Basin.

The geographical distribution of the new power plants in the Service Area of Figure 7–1 was altered between MSS-71 and MSS-74 in two ways. Not only was a smaller fraction of the new power plants assigned to the Delaware River Basin, but also, within the Delaware River Basin, there was much more of a cutback in fresh water power plants than in salt water power plants. Figures 7—4 and 7—5 show

Figure 7-3. Published and Modified Projections for Peak Electricity Demand for the Service Area of Figure 7-1.

A. 1971 Master Siting Study. Published curve.

B. 1974 Master Siting Study. Published curve.

C. Modification of curve A, using "correction factors" for 1980 (2.38/3.05 = 0.78) and 1990 (3.01/5.66 = 0.53) calculated in CTM for electricity prices rising 19 percent by the year 2000. See Table 3 in CTM.

D. Modification of curve A, using "correction factors" for 1980 (2.07/3.05 = 0.68) and 1990 (2.11/5.66 = 0.37) calculated in CTM for electricity prices doubling by the year 2000. See Table 3 in CTM.

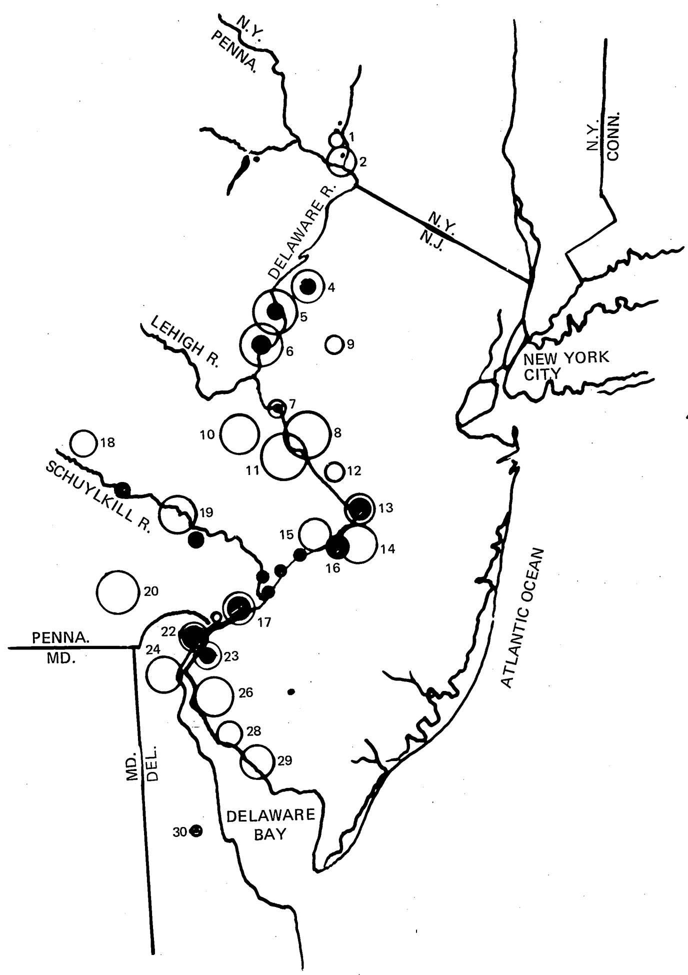

Figure 7–4. Power Plants, 1971 Master Siting Study

Existing plants in 1971

Proposed plants to 1986

Areas of circles are proportional to plant capacities. Numbers identify plants. See Table 7-2.

the power plants currently in place in the Basin, slated for construction in MSS-71, and slated for construction in MSS-74. Table 7—2 gives the schedule of construction of all of the principal plants discussed in the two Master Siting Studies.

A simple explanation for both these alterations is that the uncertainty about the date of completion of the Tocks Island Dam

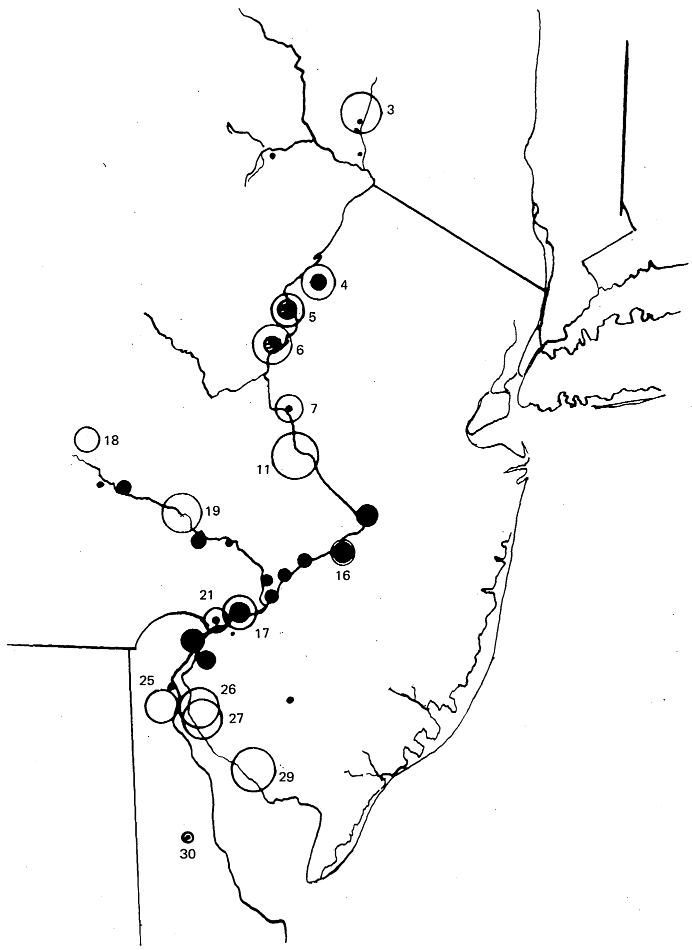

Figure 7-5. Power Plants, 1974 Master Siting Study

- Existing plants in 1974
- Proposed plants to 1988

Areas of circles are proportional to plant capacities. Numbers identify plants. See Table 7-2.

led the utilities to postpone several of the large power plants scheduled for the region between the dam site and Trenton, where water for cooling would be in short supply without the dam, and to advance the planned time of construction of those power plants elsewhere in their territories that had no equivalent pressures upon them. A closely related explanation is that the utilities came to

Table 7-2. Schedule of Construction of Major Generating Plants
N nuclear; F fossil; CC combined cycle; PS pumped storage.

	Generating Plant	*1971 Master Siting Study* Capacity (mw)	Avg. Water Use (cfs)[a]	Year in Operation[b]	*1974 Master Siting Study* Capacity (mw)	Avg. Water Use (cfs)[a]	Year in Operation[b]
A.	*Above Trenton*						
1	Lumberland (Metauque), PS	300	c	80,81	—	—	—
2	Lumberland (Delaware), F	1200	20.4	82,85	—	—	—
3	Lumberland (Cliff), N	—	—	—	2400	70.0	86,88
4	Kittatinny, PS	1300	c	76,79	1300	c	82
5	Portland, N	2400	56.0	81,83	1120	28.0	84
6	Martins Creek, F	2400	41.1	75,77,81	1600	27.4	75,77
7	Gilbert, CC	320	2.0	73,74	926	16.0	76,80
8	Frenchtown, N	3000	73.2	83,84	—	—	—
9	North Jersey, CC	316	2.0	85	—	—	—
10	Lower Lehigh, N	2240	50.0	83,85	—	—	—
11	Upper Delaware River, N	3000	80.0	83,85	3000	80.0	86,88
12	Thuerk, CC	316	2.0	80	—	—	—
	Totals	16792	326.7		10346	221.4	
B.	*Trenton to Wilmington*						
13	Mercer, F	400	1.6	85	—	—	—
14	Newbold Island, N	2200	54.2	78,79	relocated to Hope Creek		
15	Croydon, F	1500	28.0	86	—	—	—
16	Burlington, CC	40	0.1[d]	73	40	0.1[d]	74
17	Eddystone, F	800	4.6	74,75	800	4.6	74,75
18	Berne, N	1200	28.0	85	800	14.0	86
19	Limerick, N	2100	54.0	76,77	2110	54.0	80,81
20	Mid-County, N	2320	e	79,81	—	—	—
21	Chester, F	—	—	—	600	8.8	78
	Totals	10570	170.4		4350	81.4	

Table 7-2 continued

C.		*Below Wilmington*						
	22	Edge Moor, F	400	3.2	73		installed	
	23	Deep Water, F	700	3.2	78,81	—	—	—
	24	Red Lion, N	1600	23.8	79,82	relocated to Summit		
	25	Summit, N	—	—	—	1540	19.8	80,82
	26	Salem, N	2205	28.0	75	2205	28.0	76,77
	27	Hope Creek, N	—	—	—	2200	53.2	81,82
	28	Bayside, F	900	4.1	84,86	—	—	—
	29	Delaware Bay, N	1500	19.1	86	2300	30.6	85,86
	30	Dover, F	110	f	74	110	f	74
		Totals	7415	81.4[g]		8355	131.6[g]	

[a]See Figure 7-6 (p. 280) for a graphic representation of the cumulative average consumptive water use for the power plants proposed in both siting studies.

[b]Some power plants have two or three separate units, expected to go into operation in different years.

[c]Pumped-storage plant (see section V).

[d]Air cooled capacity of 528 mw also to be added.

[e]Mid-County was to import cooling water from the Susquehanna River Basin.

[f]Uses municipal water, which was not included (!).

[g]As discussed in section III, only a portion of the water consumed in the saline reaches of the River needs to be replenished with fresh water.

perceive that even with the Tocks Island Dam in place the competition for water in that reach of the Delaware was likely to be formidable, and the Delaware River Basin Commission was likely to impose a tough set of regulations on the utilities. The types of constraints the DRBC is able to put on power plant operations, among them requirements for the maintenance of stand-by supplies of cooling water, are discussed in some detail in the next section.

There remains the question of where new power plants *should* be located. Is the "fair share" of the Basin relative to the whole service area to be found by calculating its share of the electric power consumption (presumably, approximately the same as its share of the population, which is 40 percent), or by its share of environmental carrying capacity (measured crudely by its share of the area, which is 27 percent), or how? There has been a continuing thrust by the electric utilities to generate their power requirements within their own service areas. As transmission costs have dropped relative to production costs, however, two trends can be discerned: (1) the tying together of more and more generating capacity via regional grids,[c] thus freeing a utility from the necessity of building all its capacity within its territory; and (2) the creation of consortia to develop special generation sites, such as sites near coal mines, sites in the ocean, and (as discussed in section IV below) sites amenable to pumped storage.

Alternatives to power development on the Delaware include floating nuclear power plants in the Atlantic, generating stations in the Susquehanna River Basin, and plants in western Pennsylvania. Each alternative possesses its own set of economic, political, and environmental trade-offs that need to be evaluated before adopting policies for the Delaware River Basin. Care needs to be taken to assure that policies designed to limit exploitation of the Delaware do not impose even greater damages elsewhere. Miles of high voltage transmission lines to tie out-of-Basin power facilities to demand centers, the remote threat of nuclear contamination of coastal waters, and/or extensive power development on the Susquehanna may be unacceptable trade-offs for a free flowing Delaware.

A comparison of the sites in the Delaware River Basin postponed or abandoned by the utilities with the sites outside the Basin promoted to an earlier construction date would be instructive, and

[c]One example is the Pennsylvania-New Jersey-Maryland ("PJM") Interconnection, which ties together a territory slightly larger than the Service Area shown in Fig. 7–1.

might be undertaken using various social and environmental indices. Such a study can now be done: the schedule for construction of sites outside the Basin, which was not contained in the first two Master Siting Studies, has finally appeared in the public record.[d] A comparison of upstream and downstream sites *within* the Basin is itself instructive; it is our central concern in the next two sections of this essay.

III. WATER DEMANDS FOR COOLING

Almost all the power development proposed in the 1971 and 1974 Master Siting Studies consists of major steam-electric generating stations. The fresh water impact will be largely determined by the quantity of heat they reject, their cooling method, and their location within the Basin. The quantitative details are found in Box 1.

Ordinarily, the heat rejected by a power plant is simply dispersed to the environment, and is referred to as waste heat. The heat does not *have* to be "wasted." It could become someone else's useful heat. The pairing of generating stations with industrial plants, to form so-called "total energy systems," can keep the heat from dispersing into the environment until it is used in a manufacturing process or in driving a building heating and cooling system. Not only is energy saved, but also water, since the rejected heat eventually gets dissipated to the atmosphere, without the help of a special cooling system. However, this scheme is rarely adopted. There are problems in matching heat requirements with electricity generating schedules, and these are exacerbated by the regulatory processes of the state public utility commissions. In virtually every power plant, the rejected heat is carried away unused.

A. Cooling the Coolant

What happens to the heat carried away by the coolant? It is dissipated through a cooling system in one or more of three ways: conductance to the ground, radiation and convection to the atmosphere, and evaporation. Cooling systems differ considerably in the relative importance of these three processes. Since of the three only evaporation involves a consumptive loss of water, the type of

[d]One of the accomplishments of the 1975 consultants' report (see Essay 3, sections V and VI) was to extract these plans from the utilities.

Box 1 Quantitative Estimates of the Consumptive Use of Water for Cooling

When one cubic foot of water evaporates, at ambient temperatures, it entrains about 65,000 btu of heat. The corresponding statement in different units is: Heat can be removed at a rate of 1,000 megawatts (thermal energy) by the evaporation of water at a rate of 15 cubic feet per second (cfs). In a practical calculation of consumptive use of water from a power plant, one must use this fact of nature together with (a) the electric efficiency of the power plant; (b) the fraction of the rejected heat that is dissipated directly to the atmosphere, instead of being rejected at the power plant's condensers; and (c) if water is used to cool the condensers, the fraction of the cooling done by evaporation instead of by temperature rise in the liquid state.

Finally, as is discussed in the text, the significance of a given level of consumptive use of water depends critically on where the plant is located. In particular, for a site in an estuary or bay, it is possible (though difficult) to estimate a fraction that gives the relative impact of consumptive use on, for example, the salt front of the river, relative to the impact of the same consumptive use occurring in the fresh water portion of the river. The fraction will be less than one.

Electric Efficiency. The Second Law of Thermodynamics states that disordered energy (heat) cannot be converted to ordered energy (electricity) with 100 percent efficiency. As a consequence, when electrical energy is produced from a chemical or nuclear fuel through the intermediate step of hot steam, more fuel must be consumed than emerges as electrical energy. More precisely, the efficiency of such a conversion cannot be greater than $(T_1 - T_2)/T_1$, where T_1 and T_2 are the intake and outlet temperatures of the conversion engine, measured on an absolute temperature scale. Practical power plants come within about a factor of two of that ideal efficiency.

The rate at which electrical energy is produced, divided by the rate at which chemical or nuclear energy is consumed, the "efficiency," is about 40 percent for large fossil fuel plants and it is about 33 percent for current nuclear plants (which, for reasons related to safety, operate with lower

cooling system adopted can significantly influence the water quantity accounts in a river basin.

There are essentially four methods of cooling: (1) once-through cooling, (2) cooling ponds, (3) wet cooling towers, and (4) dry cooling towers. In once-through cooling, water is simply drawn from a river, passed through the power plant condensers (where it absorbs the rejected heat), and discharged back to the river. Because a substantial fraction of the heat in the discharged water is removed from temperature steam than fossil fuel plants). The remaining 60 percent for a fossil fuel plant or 67 percent for a nuclear plant is rejected in the form of heat at the power plant.

Losses to the Atmosphere. Of the heat rejected at the power plant, a fraction is lost directly to the atmosphere, rather than appearing at the condensers. For a fossil fuel plant, which must exhaust hot gases up a flue, the fraction is about 25 percent; for nuclear plants it is about 7 percent. Combining this characteristic with the previous one, the reader will find that when electric power is produced at a rate of 1,000 megawatts at a fossil fuel plant, heat is produced at the condensers at a rate of 1,000 (60/40) (0.75) = 1,100 megawatts; whereas when electric power is produced at a rate of 1,000 megawatts at a current nuclear plant, heat is produced at the condensers at a rate of 1,000 (67/33) (0.93) = 1,900 megawatts. Thus current nuclear plants generate almost twice as much heat at the condensers as fossil fuel plants delivering the same electric output.

Role of Evaporation (Consumptive Use) in Cooling. In wet cooling towers and in cooling ponds, essentially all the removal of heat from the condensers occurs by means of evaporation. In "once-through" cooling, evaporation still occurs, because the river, warmed by the heated water returning from the condensers, cools down not only by convection and radiation to the atmosphere but also by evaporation to the atmosphere. A typical fraction of the heat loss ultimately associated with evaporation is 0.6. In dry cooling towers, there is no loss by evaporation—there is no water! All the heat is removed from the condensers by convection and radiation to the atmosphere. Thus, the rate of water consumption we estimate here for 1,000-megawatt fossil fuel plants is 17 cfs, 10 cfs, and 0 cfs, and for a 1,000-megawatt nuclear plant is 28 cfs, 17 cfs, and 0 cfs, for wet cooling towers, once-through cooling, and dry cooling towers, respectively. These values are in rough agreement with those quoted in Table 7–3 below. Among the effects we have not included, one important one is the carrying away of droplets in liquid form from a cooling tower (called "drift"). These droplets evaporate, and add to the consumptive use.

the river by convection, conduction, and radiation, the once-through system does not typically lead to as large an evaporative loss of water as other methods of cooling.

Once-through cooling has been the most common method of cooling in most parts of the world. From an environmental standpoint, it has a major drawback: the heated water disrupts the local aquatic ecology, killing or driving away cold water species of fish and other aquatic life and attracting warm water species. Even the latter may be killed if suddenly the plant is shut down for repairs. These environmental problems have led to regulations on discharges of heated water (so-called thermal pollution) in the United States, forcing the utilities to employ other cooling systems. Only three of the power facilities proposed in MSS-74 (Summit, Salem, and Delaware Bay) use once-through cooling. All three are located in the estuary or Bay, where large quantities of water are available to dissipate the rejected heat.

Cooling ponds and spray ponds cool the heated water by circulating it between the power plant and an artificial pond. Cooling ponds require an acre or two for each megawatt of capacity; thus, a 1,000-MW plant requires more than a square mile. Cooling ponds transfer most of the waste heat to the air by evaporation from the pond's surface, and hence have a large rate of consumptive use of water. Spray ponds, on the other hand, can be significantly smaller, and will consume less water since there is radiative and convective heat transfer from the spray to the air. Spray ponds, however, sometimes cause local fogging and icing. Because large amounts of land are not available and because the topography is generally unfavorable in the Delaware Basin, the utilities do not plan to use either cooling or spray ponds with any of the proposed power plants.

Wet cooling towers also work by evaporating water. In the tower, hot water from the steam condenser splashes down over the fill, or packing, breaking into small droplets that evaporatively cool themselves in the air flowing through the tower. The cooled water is collected under the fill and recirculated through the power plant. In addition to water lost to evaporation, some water is lost in droplets that are not recollected but are blown out with the air current. Water consumption is about twice that of once-through cooling. Not surprisingly, wet cooling towers can contribute to local fogging and icing.

The air flow through a cooling tower may either be provided by natural convection or by mechanical means. Natural draft cooling towers must be huge structures, often 300 to 400 feet high and 200 to 300 feet in diameter at their bases. The initial construction costs are two to three times the costs for once-through cooling. Mechanical draft wet cooling towers are less costly to build but more costly to operate. Much smaller, they use motor driven fans to drive air through the tower. The utilities in the Delaware River Basin currently plan to use natural draft cooling at most of their new power plants.

Dry cooling towers have no evaporative losses. Cooling water is circulated through finned tube bundles in the base of the tower, and waste heat is rejected directly to the air by conduction and convection. Because there is no evaporation, dry cooling towers require large air flow rates and large heat exchange surface areas. Their performance is sensitive to the ambient air temperatures; they function most poorly in hot weather, just when generating capacity is most needed to supply peak electric demands.

The use of dry cooling towers is presently limited to generating units of relatively low capacity. The large surface area and large air flow rates make dry towers substantially more expensive than wet cooling towers. Dry cooling towers can increase the capital cost of a power plant by 25 percent. This higher investment cost, however, can be partially offset by savings in transmission costs. This will be the case when load centers are far from substantial water supplies, as in the arid southwest of the United States; an air cooled power plant sited close to the load may compete favorably with a water cooled power plant hundreds of miles away. The relative costs of dry cooling may come down, as heat exchangers and turbines are improved, in which case wet and dry cooling towers may compete everywhere.

A summary comparison of the four methods of cooling is presented in Table 7–3.

B. Siting and Water Use

Ultimately, the magnitude of a water use must be measured by its effects on competing water uses. The quantity of water evaporated by a power plant may by itself be an insufficient measure of use since a gallon taken from one place may affect other uses more strongly than a gallon taken from another place. This is in fact the case on the Delaware River. Cooling water evaporated from the fresh water reaches of the river has a greater aggravating effect on salt intrusion than an equal quantity of water evaporated from the saline estuary.

A convenient way to quantify this difference is to translate it into demand for reservoir storage: thus the burden of a power plant upon the river may be measured by the amount of additional reservoir storage its presence requires to leave the degree of salt intrusion unchanged. By this measure, plants on the fresh water part of the river are substantially more burdensome than plants on the middle or lower estuary. According to a recent study, consumptive use near the Chesapeake and Delaware Canal, where Delmarva's Summit Power Station is proposed, requires only about 33 percent of the storage required by a fresh water plant. Use near Artificial Island, where the Salem plant is under construction and the Hope Creek Station is proposed, was shown to require only 20 percent storage, and use

Table 7-3. Comparative Costs and Advantages of Cooling Water Systems

	Water Consumption[a] *(cfs/1000Mw)*		*Investment Cost*[b] *($/kw)*					
Cooling Type	*Fossil Fuel*	*Nuclear Fuel*	*Fossil Fuel*	*Nuclear Fuel*	*First Cost*	*Water Consumption*	*Thermal Discharge to Rivers*	*Other Difficulties*
Once-through	10-15 (11.5)	15-20 (17)	2-3	3-5	Low	Low	Yes	Large withdrawal requirements
Cooling ponds	15-30	25-40	4-6	6-9	High	High	No	Large land requirements; local fogging and icing.
Wet cooling towers	18-30 (20)	27-40 (29)			High	High	No	Vapor plumes contribute to fogging and cloud cover
Natural draft			6-9	9-13				Mechanical draft towers are noisy
Mechanical draft			5-8	8-11				
Dry cooling towers	0	0			High	None	No	Large size, penalties in lost capacity in warm weather, but flexible siting
Natural draft			20-24	28-32				
Mechanical draft			18-20	26-28				

[a]Adapted from *The 1970 National Power Survey*, p. 1-10-8, or (for values in parentheses) a weighted average of the maximum rates of consumptive use for all facilities of each kind proposed for the Delaware Basin in the 1974 Master Siting Survey.

[b]*The 1970 National Power Survey*, p. 1-10-17. Relative costs probably remain reliable even though the costs for each method have risen considerably.

below the Cohansey River, where the Delaware Bay plant is proposed, was shown to need no storage.[9]

C. Factors Determining Water Use

To summarize: several significant factors intervene between the demand for electricity in the service area and the resulting demand for reservoir storage in the Delaware Basin. These are:

1. *The fraction of demand in the entire Service Area that is to be met by plants located in the Delaware Basin.* This is a complex matter of environmental cost, economic efficiency, and social equity. Among the elements to be considered are the relative population, area, runoff, and existing power capacity of the Basin, as well as economic trade-offs among cooling costs, transmission costs, and fuel transportation costs.
2. *Type of plant.* Present nuclear plants, for example, add almost twice as much waste heat to the cooling water, per kilowatt hour of electricity, as present fossil plants.
3. *Type of cooling.* Wet towers, required on the fresh water part of the river to protect aquatic life, evaporate more than one-and-one-half times as much water per btu of rejected heat as once-through systems. Dry cooling towers, though presently expensive, would make this factor close to zero.
4. *Location within the basin.* A gallon of water evaporated from the saline estuary requires substantially less compensating reservoir storage than a gallon evaporated from the fresh water reaches of the river. At locations on the estuary currently proposed for power plants, this factor varies from one-third to zero.

When these four factors are multiplied together, they translate kilowatt hours of electric demand in the Service Area into storage capacity (or cubic-feet-per-second of safe yield) in the Delaware Basin.

The relevant kilowatt-hours of demand are those that occur during periods of low river flow; all calculations are based, in fact, on severe drought conditions. Implicit, therefore, is a judgment about the price we are willing to pay to avoid a shortfall of power on rare occasions. Since low flow episodes are almost certain to occur during the summer air conditioning season, one may speculate that the main consequence of at least a moderate shortfall would be a forfeiture of some air conditioning. How much are we willing to pay to prevent such a forfeiture on rare occasions? Today's planners do not pose the problem of costs in this form. The possibility of any shortfall, though it always exists at some probability level, is considered unthinkable.[e]

All the four factors listed above can be varied substantially by planning decisions. This will be appreciated as we now consider how the changes in plans for power plant siting between the 1971 and 1974 Master Siting Studies for the Delaware River Basin (introduced in section II) affected the safe yield projections for the Basin's water supply.

IV. PROJECTIONS OF WATER FOR COOLING IN THE DELAWARE BASIN

The two Master Siting Studies present an interesting comparison of utility planning under different regulatory policies. The 1971 Master Siting Study reflects the absence of specific policies regulating the utilities' use of Delaware River water. Consequently, it could be considered as an indication of the power plants the utilities would develop if allowed unconstrained water use.

In the 1971 Study, the rate of consumptive use of water associated with the power plants installed between 1971 and 1986 had a maximum value of 700 cfs and an average value of 560 cfs.[f] The utilities retained the consulting firm, Tippetts, Abbett, McCarthy, and Stratton (TAMS), to examine the consequence of such consumptive losses for the water resources of the Basin. Using a modified version of the HEC-3 computer model of the Corps of Engineers,[10] and making the important assumption that all the DRBC Comprehensive Plan reservoirs including Tocks Island would be in operation, the TAMS study (March 1972) concluded:

> If the drought of the 60's were to recur when non-power consumptive uses in the Delaware River Basin have grown to levels projected in this study for 1986:
>
> a. Freshwater flow to the estuary would exceed the Delaware River Basin Commission flow goal of 3000 cubic feet per second by about 10 percent, and
>
> b. DRBC salinity limits would not be exceeded.[11]

However, if the Tocks Island Dam were not built, but all other Basin

[e] The problem of power shortfall due to drought is closely analogous to that of water shortfall. The latter is discussed in some detail in Essay 5.

[f] Both Master Siting Studies have chosen to emphasize the average, rather than the maximum rate of consumptive use of water. The average rate is about 80 percent of the maximum rate, and the choice of the average rate amounts to the judgment that even during the months of peak consumption, about 20 percent of the capacity will not be available.

reservoirs were built, the TAMS study concluded, "the minimum flow at Trenton will be reduced to 2,409 cfs."[12]

When the 1971 Master Siting Study became public in January 1972, the dependence of the proposed power plants on the Tocks Island Dam immediately became an issue. Proponents of the dam gained a significant argument in their favor, because of the shortage of electricity and the apprehension about future supply. Critics questioned the need for such an extensive proliferation of power plants and challenged the propriety of the federal government constructing the Tocks Island Dam to provide water to the power companies.[g]

The DRBC, too, was disturbed by the utilities' Master Siting Study. The DRBC appeared not to have expected water consumption associated with electric power plant cooling to grow to the level that the utilities proposed for 1986 until after the year 2000. Figure 7–6 shows the tremendous difference in the projected water consumption between the power companies' December 1971 Master Siting Study and the DRBC's November 1971 staff paper on water demands.[h] The DRBC's reaction to the 1971 Master Siting Study was that the Commission "by no means" would allow the amount of water for electric power generation to approach the utilities' stated requirements.[13]

Before the 1971 Master Siting Study was completed, the utilities had filed with the DRBC and the AEC a statement of intent to construct two 2200-MW nuclear power plants, one at Newbold Island and one at Limerick.[i] For a long time, the DRBC, presuming the Tocks Island Dam would be available to provide cooling water for these plants, did not consider what it would require of the utilities if the dam were not ready. Only when the DRBC was pressed by the Philadelphia Electric Company and the AEC in late 1972 did the DRBC confront that issue. Concerning the Limerick station, the AEC Safety and Licensing Board staff concluded that the AEC should not assume that the large quantities of water required by Limerick's wet cooling towers would be provided in periods of low flow by releases from the Tocks Island reservoir. Accordingly, the AEC directed Philadelphia Electric

> . . . to furnish evidence of a firm commitment, not contingent on the approval of the Tocks Island project, from the Delaware River Basin

[g]The TAMS study (p. IX-6) estimates that it would cost the utilities about 30,000 dollars per year for each cfs of consumptive use, if small offstream reservoirs were used.

[h]The DRBC study is discussed in more detail in Essay 5 on water supply.

[i]Newbold Island is on the Delaware between Trenton and Philadelphia. Limerick is on the Schuykill River above Philadelphia (see Figs. 7–4 and 7–5).

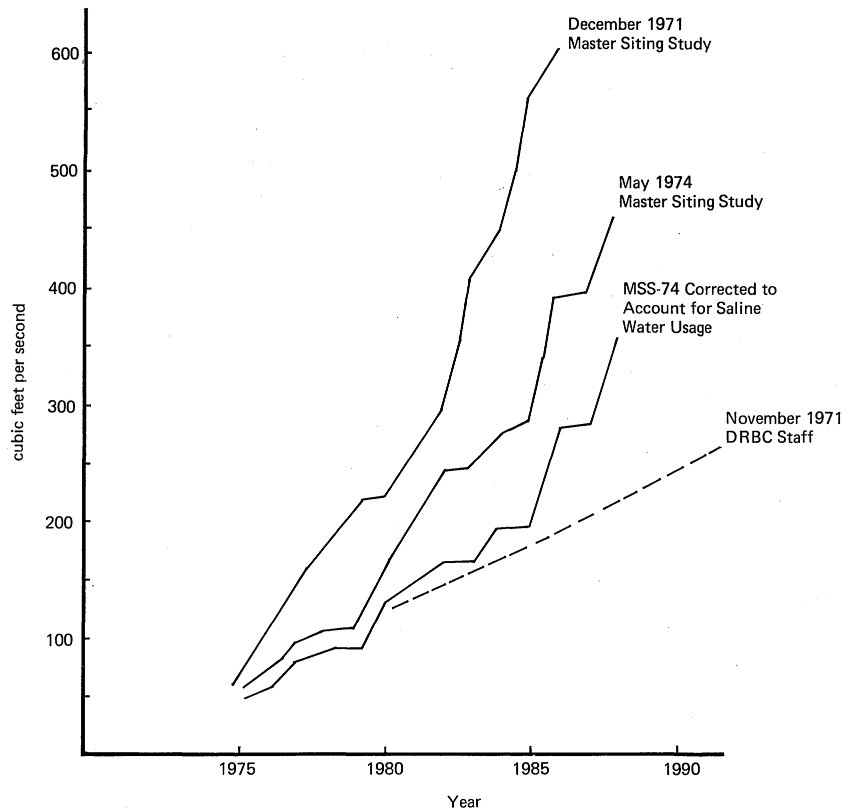

Figure 7-6. Projections of Average Consumptive Water Use by Electric Generating Plants Proposed in the Delaware Basin

The DRBC-71 curve figures importantly in the discussion of the DRBC water projections in Essay 5. The DRBC evidently anticipated a much smaller growth of power plant capacity in the Basin than the utilities.

Commission to allocate the required amount of water for plant operation.[14]

In March 1973 the DRBC conditionally approved Limerick's water supply, setting a precedent for Newbold Island and the other proposed power plants. Among the constraints imposed by the DRBC were two that had significant repercussions on the utilities' planning. First, whenever flow in the river at Trenton fell below the 3,000 cfs standard, the generating stations could be operated "only at such percentages of full load as the available water supply allows, as determined by the Commission."[15] This could mean the loss of generating capacity during periods of low flow, which (as we have said) occur in late summer during the air conditioning peak. Second, the DRBC insisted on a mechanism to avoid the imposition of such cutbacks.

> Prior to January 1, 1977, the Commission will, in its sole discretion, determine the adequacy of the then existing storage facilities on the Delaware River or its tributaries together with additional storage to be built to supply all needs (including the applicant's) for water supply from that source by the year 1980. If the Commission then determines that the storage will not be adequate for all projected needs of the basin, the applicant will build or cause to be built, at its own expense, at a location approved by the Commission, for service in 1980, a reservoir of sufficient storage capacity to assure the water supply needed for consumptive use by the Limerick plant, during periods when such use would reduce the flow in the Delaware River at Trenton gage below 3000 cfs. Storage and release of water in such facility will be under the Commission's regulation, at the expense of the applicant.[16]

Within this framework, the DRBC stated that *if* Tocks Island or an alternative were not available by 1980, both the Limerick and Newbold Island power plants would be required to provide their own water storage.[17]

The effect of these policies was to tie the utilities' planning directly to the Tocks Island project. As a result, the power companies had a strong interest in the construction of the dam. Separately and in groups the utilities testified on behalf of the dam before Senate and House Appropriations Committee hearings. But they only briefly mentioned their own need for Tocks water; instead they argued that Tocks was a "sorely needed" multipurpose project.[18] In the same period, the Philadelphia Power and Light Company made preparations to provide backup water storage for the Limerick Power plant. Public Service Electric and Gas acceded to the request of the AEC that it move the Newbold Island plant into Delaware Bay, to a location ("Hope Creek") alongside the Salem plant, which was already under construction[j] And all the Basin's utilities set about revising their Master Siting Study.

[j]The principal reasons for the AEC request were more related to safety than to water supply. One of the ironies of the move is that, at least in current plans the plant is to be moved lock, stock and cooling tower. The cooling towers have a far less obvious justification at a site on the Bay than at a site where the river is narrow, and, moreover, salt water cooling towers have special problems, associated with the salt. The decision to retain a possibly unnecessarily costly cooling system apparently stems from a hope to avoid further delays in the licensing process.

In the 1974 Master Siting Study, the proposed total increase in steam-electric generating capacity in the Delaware River Basin by 1988 is 21,670 megawatts, more than 12,000 megawatts less than the construction proposed in the 1971 Study. Moreover, only one-fourth is to be in operation by 1980. On the average, water consumption is 25 percent less than projected in 1971 and is delayed three to four years, reaching 420 cfs in 1988. Although significantly less than the water needs claimed in the 1971 Master Siting Study, the revised needs still total over twice those projected by the DRBC in their November 1971 staff paper. The water consumption associated with new capacity is shown in Figure 7–6 (above).

The delay in construction and the drop in capacity are particularly striking for the two regions above Wilmington, as seen in Table 7–2 (section II). Below Wilmington, the previously planned power expansion is delayed only a year due to snags in construction, and the relocation of the Newbold Island plant to Hope Creek actually increases the total consumptive use of saline water.

For some time the DRBC refused to recognize the lesser impact of cooling water taken from saline parts of the estuary. The 1974 Master Siting Study also makes no allowance for this. But the DRBC's decision to require the utilities to provide their own water storage in the absence of Tocks led two utilities to sponsor the United Engineers study (mentioned earlier in this section)[19] to persuade the Commission that its policy of full compensation is unwarranted when the cooling water is taken from the saline estuary. The DRBC's latest plan for water supply indicates that they now accept the United Engineers' argument.[20]

In Figure 7–6, we show the results of a calculation of the "effective" consumptive losses of water when the United Engineers' adjustment factors are imposed on the MSS-74 projections. The adjustment for brackish water consumption dramatically reduces the MSS-74 projections of water needs. The adjusted consumptive losses of water associated with MSS-74 power plants are seen to be roughly half as large as the unadjusted consumptive losses associated with MSS-71 power plants. Of the 600 cfs water loss rate projected for 1985 in MSS-71, 200 cfs has been eliminated by the delay of power plants or their relocation out of the Basin, and 100 cfs has been eliminated by the United Engineers' reappraisal of the relatively small effect of the consumption of saline water on fresh water storage requirements.

The argument that the Tocks Island Dam is needed to provide water for the cooling of nuclear power plants on the fresh water reaches of the Delaware, after all, permits counterargument. The rate

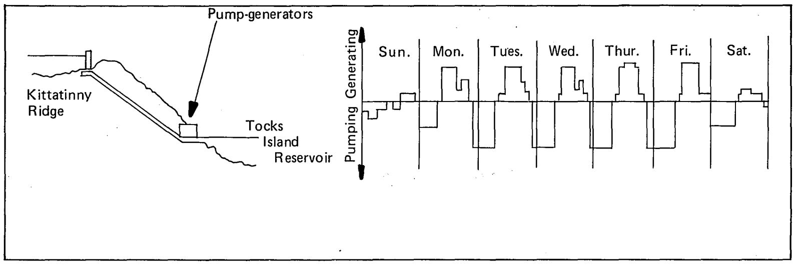

Figure 7-7. Sketch of Pumped-Storage Scheme and Pumping-Generating Cycle (From Corps of Engineers, "A Comprehensive Evaluation of Environmental Quality," 1971)

of growth of demand for electrical energy may be exaggerated. The Delaware Basin may not be the best place to put the plants. It may make sense to locate the Delaware Basin plants in the brackish Bay, and to choose fossil fuel plants. Perhaps through taxes related to the flow of the river, it may make sense to restrict electric consumption in the rare periods of very low water flow.

V. POWER AT TOCKS ISLAND

A. Pumped Storage

The Tocks Island Dam is linked to electric power generation in two distinct ways: first (as we have just seen), it could provide cooling water for the big downstream plants in time of drought; and second, it could be an element in a pumped-storage system, whose purpose is to match the steady output of the big plants to the daily fluctuations of demand. The pumped-storage system would work as follows. At night or on weekends, when the demand is at its lowest, power would be transmitted to Tocks Island to pump water from the Tocks reservoir to another reservoir on top of Kittatinny Ridge. Then, during the day, when electric demand is at a peak, the stored water would be released to spin turbines and regenerate part of the original power. Figure 7-7 illustrates the facility and the pumping-generating cycle.

While the arrangement consumes about three kilowatt hours for every two it produces, its potential economic advantage comes from converting low value off-peak energy into high value on-peak energy. The energy losses inherent in pumped storage can only be justified economically if the fuel cost of electric generation is low, as it has been for nuclear plants. Until nuclear plants were imminent, few pumped-storage systems were built. Despite their inefficiency, the utilities argue, "pumped storage is an ideal solution to the problem of providing peaking power" and is "essential to the continuing health, welfare and long term productivity" of the region.[21]

Prior to 1960, pumped storage was a relatively untried idea. Public Service had looked into the concept as early as 1947, but it was not until the mid 1950s that reversible pump-turbine development made pumped storage economically attractive and technically feasible. In 1956, New Jersey Power and Light began an investigation of pumped-storage possibilities on both sides of Kittatinny Mountain. One project consisted of a lower reservoir formed by a dam across Yards Creek and an upper reservoir constructed on top of Kittatinny Mountain about a mile from the Tocks Island dam site and a half-mile from Sunfish Pond.[22] This project was built in 1967 and is now in operation. New Jersey Power and Light also investigated a second pumped-storage facility that used the north side of Kittatinny Mountain and the Delaware River. Conceived before the Tocks project, this plan did not depend on the Tocks Island Dam. Rather, a lower pool was to be created by constructing a low weir across the Delaware River. The upper reservoir was again to be on Kittatinny Mountain, located between the Yards Creek reservoir and Sunfish Pond.[23]

The Tocks Island Dam project, as authorized by Congress in 1962, provided continuous hydroelectric power at the dam site (about 70 megawatts), where the water would fall about 100 feet from the lake behind the dam to the riverbed on the downstream side. This isn't very much power nowadays, when new power plants come on line 1,000 megawatts at a time. But this power had symbolic value for those in Congress and in the utilities who were veterans of the historic public-versus-private power controversies. Perhaps in part to remove public power from the scene, the utilities proposed to build and operate a facility that combined the hydroelectric plant and the pumped-storage plant, a Y-shaped unit that could direct the water from the mountaintop reservoir either back to the lake or down to the riverbed. There were substantial cost savings as well, relative to separate hydroelectric and pumped-storage facilities, and the proposal was incorporated in the Corps of Engineers' overall plans for the environs of the dam.

The utilities, in one version of their plans, shifted the location of the upper reservoir of the pumped-storage system to the natural lake known as Sunfish Pond. There followed an outbreak of "Save Sunfish Pond" bumper stickers and the first politically significant opposition by environmental groups. As described in more detail in

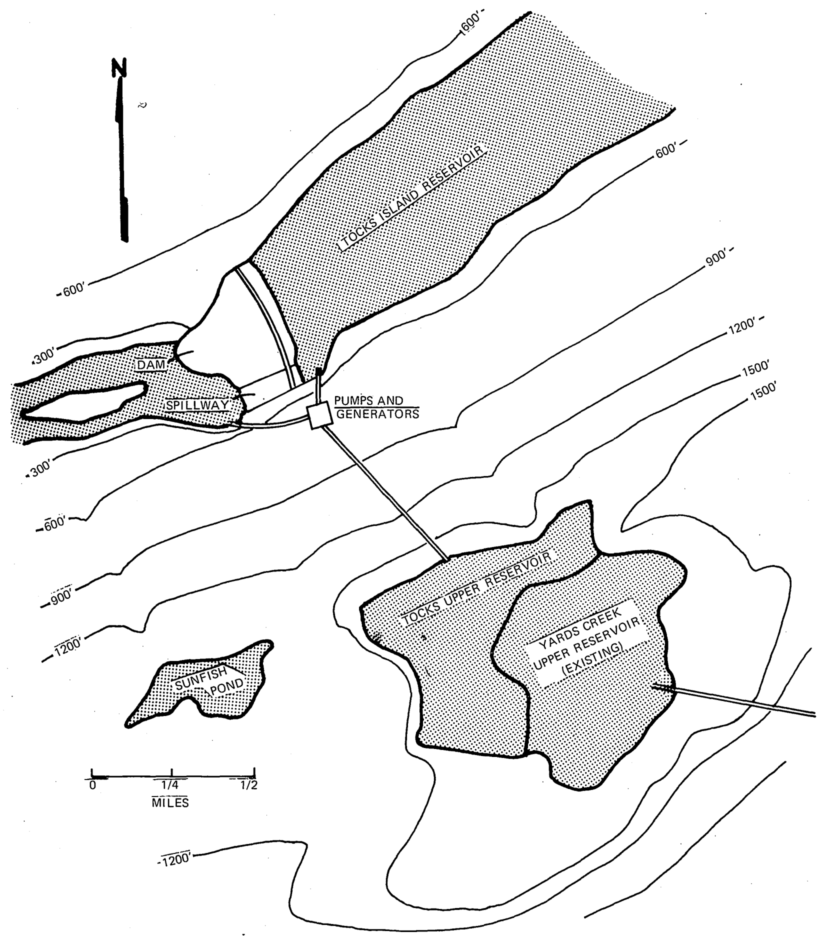

Figure 7–8. Revised Pumped–Storage Plan, 1971.

Essay 2, the utilities finally agreed to revise their plans again, and to build an upper reservoir separate from Sunfish Pond. The revised schematic plan for that facility is shown in Figure 7–8. It would expand the Yards Creek upper reservoir and connect this to the Tocks Island reservoir through underground conduits. The peak power that could be generated by this system would be 1,300 megawatts, a rate that would be sustained for about six hours per day. The daily shift of water would cause a 100-foot fluctuation in the level of the upper reservoir and about a one-foot fluctuation in the lower one.

There is considerable doubt about whether this compromise plan really protects Sunfish Pond. The proposed new upper reservoir would cover 16 percent of Sunfish Pond's watershed, and its waters might well leak into the Pond. There is also controversy about the cost effectiveness of pumped storage at Tocks Island. Especially with the future of nuclear power in the Basin somewhat uncertain, there may now be alternative storage schemes both economically and environmentally superior.

B. The Alternatives to Pumped Storage

Pumped storage is one of several approaches to peak power generation. In general, currently available and proposed peaking units can be divided into two broad categories: (1) those, like pumped storage, that draw their energy from other power plants during off-peak night hours, store it, and release it during the day; and (2) those that use "raw" fuels to generate power directly as needed to meet the variable daytime load pattern. Tables 7–4 and 7–5, respectively, list devices of the two types. The potential economic advantage of pumped storage stems from its low capital cost, long life, and low maintenance costs. Since pumped storage is intended to supply peak electric demands that occur for only four to eight hours each day, its low investment cost for every kilowatt of capacity is particularly important, while relatively high operating costs for each kilowatt hour produced may be acceptable.

The investment costs of the utilities' proposed Kittatinny Mountain project would clearly be greatly reduced if the government were to construct the Tocks Island Dam. Also, although the advantages of some pumped-storage facilities are offset by the expense of high capacity transmission lines to and from the project, the proposed Kittatinny Mountain development requires only the upgrading of the existing Yards Creek transmission facilities. Excluding land and transmission costs, the capital cost of the Kittatinny Mountain pumped-storage project was estimated to be just under $100 per kw of capacity in the utilities' 1969 analysis.[24] This cost is probably near $150/kw at current prices and will continue to climb each year with construction costs.

The relative operating costs of pumped storage and other storage devices are highly dependent on the availability of base load generating stations that would otherwise be idle. Any estimate of the cost of energy from pumped storage necessarily has to assume a schedule for introducing new base load power plants. Indeed, a great deal of the utilities' optimism about pumped storage results from the anticipated installation of relatively high efficiency base load steam-electric units, which are designed for continuous operation. Particularly, the planned rapid expansion of nuclear power capacity, with its low incremental cost per kilowatt hour, enhances the economics of pumped and other types of energy storage. Their advantages, however, may be reduced if recent nuclear construction delays, soaring construction costs, and questions about nuclear safeguards persist.

Storage techniques other than pumped storage are relatively untried, but recent advances in materials and design could make several techniques viable by 1980 or earlier. Flywheel storage, in particular, seems to be a promising alternative. Attractive energy-to-weight ratios have been made possible by fiber composite materials initially developed for aerospace uses. A 15-foot diameter flywheel can store over 10,000 kwh with 93–95 percent efficiency. Costs per kilowatt of installed capacity in one estimate were near $110 at 1973 prices. They can be expected to fall as new and better fibers are brought into large scale production. Flywheels have the further advantage of easy local siting near load centers, cutting the transmission costs and friction losses associated with pumped storage.[25] The other storage types of peaking units listed in Table 7–4 appear less attractive, although they are all being actively investigated.

The generating types of peaking units listed in Table 7–5 are different from the storage devices in that they produce electricity directly from fuels and are decoupled from the base load plants. Their attractiveness is highly dependent on the future availability of clean fuels, which in turn depends on the development of supplies of low btu or other synthetic gases produced from coal. Again, because of low capital costs, the higher fuel costs of these units may be acceptable.

Combustion turbines and combined-cycle plants appear especially attractive schemes of the generating type. Combustion turbines are simple cycle turbines and are, essentially, aircraft engines adapted to ground use. In the past they have had low efficiency and have placed high demands on the clean fuels they burn. With higher inlet temperatures, efficiencies are expected to improve to 35 percent by 1980 and reach nearly 40 percent by 1990. Combined-cycle plants couple combustion turbines with steam turbines. By capturing the heat from the exhaust jet of a combustion turbine and using it to help fire a steam-electric plant, the combined-cycle plant makes better use of the fuel's energy. Higher operating temperatures are expected to push efficiencies to 50 percent by 1980 and 55 percent by 1990.[26]

Because of this high efficiency, the use of high quality fuels in combined-cycle plants may not be unduly wasteful. Both kinds of

Table 7-4. Storage Devices for Peaking Power

Device	Projected Device Efficiency (%)[a]	*General Advantages* *independent of oil and gas* *Specific Additional Advantages*	*General Disadvantages* *fuel and pollution penalty due to inefficiencies* *running time limited by storage capability* *Specific Additional Disadvantages*
Pumped storage (river to mountain top or river to below-ground cave)	67	low outages low maintenance costs long life low capital cost	land requirements remote location from demand centers
Flywheel	95	easy location near demand centers small land requirements low capital cost	—
Fuel cell (with hydrogen storage)	60	easy location near demand centers	low unit capacity
Storage battery	70–80	easy location near demand centers	low power and energy density low unit capacity short life
Compressed air storage	80–90	flexible siting possible near present generating stations or near demand centers	requires sizeable storage tank or cavern

[a]The listed efficiency is that of electricity storage and regeneration. The overall energy efficiency of storage schemes, including original electric generation and transmission energy losses, would be about one-third of the device efficiency.

Table 7-5. Generators for Peaking Power

		General Advantages	*General Disadvantages*
		easy location near demand centers can operate for extended periods if necessary low pollution	dependent on oil and gas until coal conversion technologies are commercialized
Device	*Projected Efficiency (%)*	*Specific Additional Advantages*	*Specific Additional Disadvantages*
Combustion turbine	35	—	loss of efficiency at part load costly maintenance NO_x formation
Combined cycle	50	—	—
Fuel cell	40	improved efficiency at part load	moderate life low unit capacity
Steam peaking	30	—	requires cooling water
Diesel	25-30	—	low unit capacity

plants are clean burning devices that are suited for local siting near load centers. Also, because they are factory fabricated, packaged systems, they can be installed at competitive costs, near $100 to $150 per kw at 1973 prices.

Other generating types of devices also hold promise. For example, fuel cells using hydrocarbon fuels are expected to achieve efficiencies near 40 percent in small units (25 megawatts) by 1980, and Public Service has already scheduled installation of several fuel cell units by 1982. Aside from high efficiency, fuel cells have the advantage of clean operation and they are usually air cooled, rather than water cooled.

There is also a nondevice alternative to pumped storage. As we noted in section II, modifications in the price of electricity can affect demand. Rates that penalize daytime use and encourage nighttime use could broaden the daily peaks, allowing the more efficient application of fewer peaking units.

C. Current Status

The Tocks Island Dam now (as of November 1975) seems likely to be deferred, perhaps indefinitely, and the utilities must decide what to do. As long as the construction of pumped storage was linked to the construction of the dam, the utilities presented a small target to environmentalist critics. In principle, the utilities could now revive their old plan for a weir in the river (that is, for pumped storage without a major dam); politically, this would almost surely be a mistake. The utilities must now, with new vigor, turn to alternative ways of providing storage and peaking power.

Perhaps, this time around, the utilities will make more of their analyses public, and will document them fully. Only two years ago, a utility executive told us that "the utilities have made the decision to undertake pumped storage and are running with it," and that was that! Well, they seem to have been tackled. The choices among peak pricing programs, storage systems, and peak period generating systems ought to be public choices. The external costs of each of these alternatives can only be properly evaluated through open and substantive public discussion.

NOTES

1. Delaware River Basin Commission Resolution No. 71–3, adopted April 7, 1971.

2. *Master Siting Study: Major Electric Generating Projects, Delaware River Basin, 1972–1986*, report to the Delaware River Basin Commission by the Delaware River Basin Electric Utilities Group, December 1971 (hereafter, MSS-71).

3. *Master Siting Study: Major Electric Generating Projects, Delaware River*

Basin, 1974–1988, report to the Delaware River Basin Commission by the Delaware River Basin Electric Utilities Group, May 1974 (hereafter, MSS-74).

4. MSS-74, p. 3.

5. Duane Chapman, Timothy Tyrrell, and Timothy Mount, "Electricity Demand Growth and the Energy Crisis," *Science* 178 (1972): 703–708 (hereafter, CTM). In CTM, annual electric power consumption (not, incidentally, peak demand) is studied in a model that also incorporates regional population, price of natural gas, and regional per capita income. Short run and long run elasticities are distinguished, as are three classes of consumers (residential, commercial, and industrial).

6. U.S. Federal Power Commission, *The 1970 National Power Survey* (Washington, D.C.: U.S. Government Printing Office, 1971).

7. *A Time to Choose: America's Energy Future*, Final Report by the Energy Policy Project of the Ford Foundation (Cambridge, Mass.: Ballinger, 1974).

8. U.S. Federal Energy Administration, *Project Independence Report* (Washington, D.C.: U.S. Government Printing Office, 1971).

9. G.A. Englesson and R.H. Anderson, *Delmarva Power and Light Company Summit Power Station Units 1 and 2: The Impact of Consumptive Use of Water on the Salinity Distribution in the Delaware Estuary*, (Philadelphia: United Engineers and Constructors Inc., 1974).

10. Generalized Computer Program HEC-3, developed by the Hydrologic Engineering Center of the U.S. Army Corps of Engineers, Davis, California.

11. Tippetts-Abbett-McCarthy-Stratton, *Water Resources Study for Power Systems*, March 1972, p. 1.

12. *Ibid.*, p. VIII. 12.

13. Letter to Commissioner Maurice K. Goddard from James F. Wright, Director of the DRBC, July 24, 1972.

14. As quoted in Delaware River Basin Commission, *Docket No. D-69-210CP*, March 29, 1973. p. 3.

15. Delaware River Basin Commission, *Docket No. D-69-210CP*, March 29, 1973, p. 7.

16. *Ibid.*

17. DRBC, *Supplemental Comments on Limerick and Newbold Nuclear Generating Stations, Delaware River Basin*, enclosure with letter to Daniel R. Mueller Directorate of Licensing, U.S. Atomic Energy Commission, June 6, 1973, p. 6. (The emphasis on "if" is the DRBC's.)

18. See, for example, U.S. Congress, House of Representatives, Committee on Appropriations, *Public Works for Water and Power Development and Atomic Energy Commission Appropriations, 1975*, 93rd Congress, 2nd Session, April 1974, pp. 444–451, 458–460, 474–476.

19. G.A. Englesson and R.H. Anderson, *op. cit.*

20. DRBC, Resolution No. 74-6, Adopted May 22, 1974, Section 5-3.3.

21. Jersey Central Power and Light and Public Service Electric and Gas, *Yards Creek Pumped Storage Electric Generating Station* (undated pamphlet).

22. U.S. Army Corps of Engineers, *Delaware River Basin Report*, December 1960, Appendix T, p. T-52.

23. *Ibid.*, p. T-53.

24. Jersey Central Power and Light Company, New Jersey Power and Light

Company, and Public Service Electric and Gas Company, *Third Amendment and Supplement to Application Approved August 1962, DRBC Docket No. D-62-2, for Approval of Kittatinny Mountain Project*, March 1971, Exhibit 2-3.8(a)(7).

25. Richard F. Post and Stephen F. Post, "Flywheels," *Scientific American* 229, (6) (December 1973): 17–23.

26. U.S. Federal Power Commission, *The National Power Survey*, Advisory Committee Report: Energy Conservation (Washington, U.S. Government Printing Office, 1974): 96–98.