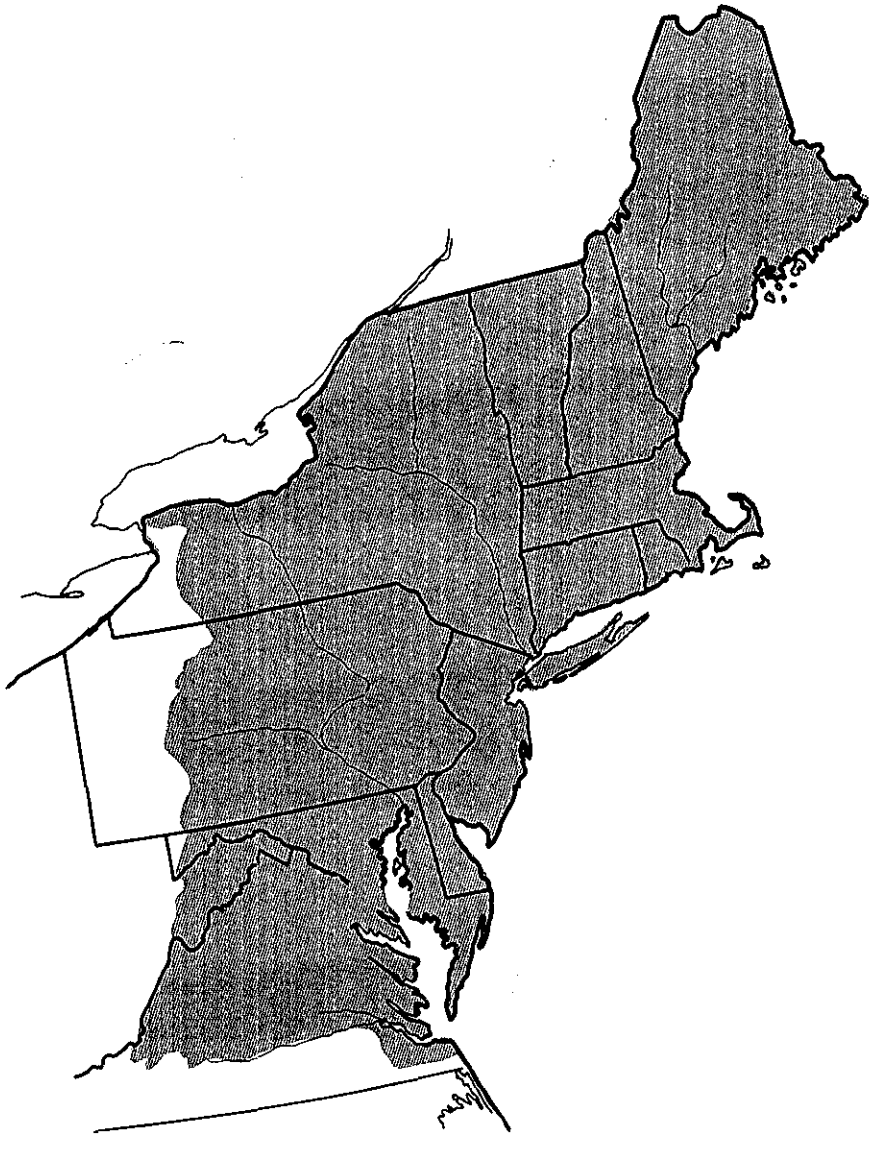
NORTHEASTERN UNITED STATES WATER SUPPLY STUDY

APPENDIX - HUDSON RIVER PROJECT

PART II - TECHNICAL REPORT



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NEWS SUMMARY REPORT

APPENDIX - PART II

HUDSON RIVER PROJECT
TECHNICAL REPORT

SECTION D - SOCIO-ECONOMIC ANALYSIS

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NORTHEASTERN UNITED STATES
WATER SUPPLY STUDY

North Atlantic Division
U.S. Army Corps of Engineers

PART II - TECHNICAL REPORT

SECTION D - SOCIO-ECONOMIC ANALYSIS

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A. SUMMARY

1. Purpose

This section of the Technical Report presents an analysis of the social and economic benefits and costs of the three alternative Hudson River Projects. This analysis was utilized to develop the benefit-cost ratio for the project. This ratio involves comparison of average annual project costs to the average annual cost of the most likely alternative (a proxy for project benefits). Comparison of project costs to directly-estimated project benefits is also presented as a supplement.

2. Structure

Part A presents a summary of the major findings. Part B presents historical and projected economic base profiles for the region and the project service areas, with summary data for individual counties. The future economic base profiles depict the anticipated status of the area in the absence of any major new water supply source development. Part C contains project implementation profiles, which present the area's future condition given the construction and operation of each of the three projects in turn. The regional impacts of each project are displayed as the differences between the future economic base and project implementation profiles. Part D presents the benefit-cost ratios of the three alternative projects, on the basis of project average annual costs and the average annual cost of the most likely alternative. A comparison of project average annual costs and average annual benefits, as estimated from the impacts derived in Part C, is also included. The National Economic Development account tables for the three projects are in Part E. Part F contains an analysis of the potential impacts of a recurrence of a drought like that of the 1960's, now and in the year 2000, in the absence of new regional water supply development.

3. Synopsis of Findings

In the absence of major new water supply source development, the following changes in the region's economic base profile are anticipated:

	1970	2020
Population	18,308,349	26,213,300
Employment	7,409,744	12,228,800
Earnings*	$ 99.4 billion	$492.9 billion
Total personal income*	$128.5 billion	$616.2 billion
Per capita income*	$7,018	$23,510

* 1975 dollars

With project construction over the 1982-1990 period, average regional impacts in any given year would be:

	East Bank-Rhinebeck	West Bank - West Point	West Bank - Spring Valley
Population	104,600	106,800	107,100
Employment	46,600	47,600	47,700
Earnings*	$0.97 billion	$0.99 billion	$0.99 billion
Total personal income*	$1.25 billion	$1.27 billion	$1.28 billion
Total output*	$3.19 billion	$3.24 billion	$3.26 billion

* 1975 dollars

About one-fourth of the employment and earnings impacts would be in the construction industry, which has been seriously depressed in this region in recent years.

By the year 2020, the long-run impacts of project operation would be as follows, relative to future economic base levels:

	East Bank - Rhinebeck	West Bank - West Point	West Bank - Spring Valley
Population	268,900	269,100	325,500
Employment	126,400	126,500	152,800
Earnings*	$ 4.90 billion	$ 4.90 billion	$ 5.93 billion
Total personal income*	$ 6.13 billion	$ 6.13 billion	$ 7.41 billion
Total output*	$16.20 billion	$16.20 billion	$19.59 billion

* 1975 dollars

The greatest proportional impact would be in the manufacturing sector, which would account for 25% of the total regional earnings impact and 30% of the total employment impact. Geographically, project impacts on the region tend to be concentrated in New York City and its immediate environs.

The most likely alternative to Federal action is identified as the East Bank-Rhinebeck project with non-Federal financing and implementation at the same future time. The average annual cost of the three projects and the most likely alternative, and the resulting benefit-cost analysis, are displayed below:

	avg. ann. cost*	B/C	net benefits*
Most Likely Alternative	466.6		-
East Bank-Rhinebeck	332.8	1.40	133.8
West Bank-West Point	344.0	1.36	122.6
West Bank-Spring Valley	345.7	1.35	120.9

* Millions of 1975 dollars; discounted to 1990.

This benefit cost analysis implicitly assumes that all three projects have the same benefits. The projects, however, differ significantly in their service areas (that of the West Bank-Spring Valley project is larger than the other two), and therefore in their regional benefits. The project's impact on

regional total output can be adopted as the national economic benefit, converted to an average annual value, and compared to project average annual cost. To do so with confidence, however, is extremely difficult, because of the uncertainties of the data and the complexities of the analysis, and the results of this effort are not displayed here. The available information does indicate that, if directly-estimated benefits were related to costs, all three projects would have very high B/C ratios, and that the West Bank-Spring Valley alternative would have both the highest ratio and the highest level of net benefits.

A recurrence at the present time of a five-year severe drought like that of the 1960's would lead to emergency conservation efforts and inferior source utilization in New York City and Nassau and Westchester Counties, with mandatory curtailment of water using industries in Nassau and part of Westchester by the fifth year. Total fifth-year impacts on the NYMA would include 10,000 man-years of unemployment, reduced regional earnings of $160 million, and reduced regional output of $756 million (both in 1975 dollars). Social impacts, comprising diminished quality of life and social stability and vitality, would be locally serious.

Occurrence of such a drought in the year 2000 would result in emergency conservation and source use in New York City and Dutchess, Nassau, Orange, Putnam, Rockland, Ulster and Westchester Counties, with grave social disruption and partial economic paralysis in New York City, Dutchess, Nassau and Westchester. Total fifth-year impacts on the region would include unemployment of eight million, reduced regional earnings of $167 billion and reduced regional output of $496 billion (in 1975 dollars). Social disruption would be general and severe, with long-term damage to the region's stability and viability, and locally serious risk to life, health and property. Water systems would be so overused relative to their drought safe yields, moreover, that even a season or two of insufficient rainfall would cause serious social and economic disruption that would persist well beyond the end of the dry spell itself.

B. ECONOMIC BASE PROFILES

1. Methodology

a. Present Profiles - The socio-economic analysis of the Hudson River Projects is based on the 1972 OBERS Series E projections of population and economic activity, prepared for the Water Resources Council by the U.S. Department of Commerce. The OBERS projections, based on certain assumptions concerning future national fertility and economic growth, are presented on several different, nationally consistent regional bases. One such basis, that of the Functional Economic Area or FEA, is particularly suited to this analysis, and FEA 14 - a region very similar in geographic scope to the NYMA - was selected for the regional analysis. The historical OBERS data was supplemented by Census Bureau compilations in preparing the regional economic base profile.

The profiles of the project service areas are based on county-level Census data, and include local government fiscal information.

b. Future Profiles - The OBERS future projections for FEA 14 needed to be modified to account for the effects of the eventual water shortages that will result from the lack of major new source development, since OBERS specifically assumes no resource-related constraints on economic activity. The future economic base profile assumes that the risk of water shortage caused by water supply deficits, as they arise, would put a ceiling on earnings in water-using manufacturing industries, as projected in OBERS. This primary negative impact on the region, converted into total (i.e., primary plus secondary) impacts by means of an economic base-service multiplier model consistent with the OBERS formulation, comprises the future economic base profile for the region. This profile was disaggregated to the county level with techniques similar to those used in the OBERS projections to break down national projections to regions. The resulting county projections of population and economic activity were empirically related to demographic, social, and fiscal measures, and were recompiled into service areas.

2. The Region

a. General Characteristics - The New York-New Jersey-Connecticut metropolitan area is the most populous urban area in the nation, and is the centerpiece of the Boston-to-Washington megalopolis. It contains the country's largest city, and is possessed of such physical, cultural and political diversity as to defy concise summarization, even within the limited scope of this analysis. The region has an area of 9,015 square miles, and in 1970 had a population of 18,308,349, of whom 94% resided in urban areas, and 43% in New York City alone. The average population density in 1970 was 2,031 persons per square mile, although varying enormously within the region, from 124 per square mile in Ulster County, New York to 66,923 per square mile in Manhattan.

b. Problems -

i. Demographic and Social - The region has historically enjoyed consistent growth in population and per capita income. Rapid development of other regions of the country has, however, eroded its relative position and led to rising emigration of people and businesses. This long-term trend has been exacerbated by the severe national recession that began in the early 1970's and by the fiscal disruptions in New York City. Within the region, there continues to be an outmigration from the heavily urban core to the outlying counties, which worsens the problems of the former while creating growth management dilemmas in the latter. The closer-in suburban counties, which had formerly been the beneficiaries of this migration, now find themselves in a static or declining situation as they are passed over in favor of less-developed areas.

ii. Economic - As would be expected in a very large, heterogeneous region, economic trends are gradual and free of dramatic changes. These trends have been away from activities most sensitive to increased scarcity and cost of land, labor, and (more recently) energy: namely, agriculture, forestry and fisheries, and manufacturing. The latter industry, which was the biggest employer in the region until the 1960's, has since declined not only relatively, but in absolute terms. Its continued decline, and the accompanying adverse social and fiscal impacts, are a matter of serious concern to economic planners in the region. On the other hand, this decline has been balanced by expansion in the finance, insurance and real estate and ser-

vices industries, which (although nominally residentiary industtries) are "exported" significantly from the region to the rest of the country and the world.

iii. Fiscal - Little can be side about local fiscal conditions on the regional level, because the diversity of local conditions makes generalization difficult. The fiscal strain of the respective state governments and the near-collapse of New York City have been widely publicized, but the good general health of county-level finances outside the city have not.

c. Present Economic Base Profile -

i. Demographic and Social - The population of the region increased 44% between 1940 and 1970, from 12,708,987 to 18,308,349. The bulk of this growth, which was notably consistent over time, occurred in the ring of suburban counties surrounding the urban core, encouraged by the development of both commuter railroads and highways from the core to its hinterlands. Per capita income increased from $4,288 in 1950, 33% above the national average, to $7,018 in 1970, 29% above. This increase in affluence also occurred disproportionately in the suburbs, as a result of both their own indigenous development and the emigration to them of the more well-to-do and mobile residents of the old central cities. Polarization of the cities and their suburbs, and of neighborhoods within both, along economic and cultural lines has been a destabilizing consequence. The strong growth of the suburbs has not been without its costs, in terms of uncontrolled, sprawling development, environmental degradation, and greatly increased demands for government services. See Table II-D-1 for detailed data.

ii. Economic - Total income in the region more than doubled between 1950 and 1970, from $60.9 billion to $128.5 billion, while total earnings grew at a slightly smaller rate, the difference comprising the growth of various government programs of transfer payments. Earnings and employment in agriculture, forestry and fisheries have declined overall between 1950 and 1970, both absolutely and in their already small share of the regional totals. Mining, an even smaller sector, has grown in absolute terms and maintained its relative share. Construction and manufacturing have followed similar patterns, increasing in absolute employment from 1940 to 1960 then declining significantly by 1970. Earnings in both continued to grow through 1970, however, and in fact high wage rates in these industries have probably contributed to their recent decline in this region. The six major water-using

manufacturing industries accounted for 25% of all manufacturing employment in 1970, and 29% of all manufacturing earnings. The transportation, communications and public utilities group has grown at very nearly the same rate as the economy as a whole, as have wholesale and retail trade, while finance, insurance and real estate enjoyed significant relative expansion. The primary growth industry, however, is services, which by 1970 had displaced manufacturing as the leader in employment (but not earnings). Government has also grown notably in relative terms, with a very high growth rate in earnings in state and local government. Finally, the employment-population ratio has increased from 0.378 in 1940 to 0.405 in 1960, and remained unchanged by 1970. This lack of continued increase may reflect a rising proportion of unemployed or otherwise dependent persons in the region. See Tables II-D-2 and II-D-4.

iii. Fiscal - Fiscal data on the regional level is of limited meaning as such. From consideration of county-level information, however, certain very general trends become apparent: sharp increases in per capita revenues and expenditures; a decline of the relative importance of property taxes in total revenues and a simultaneous growth in the role of the intergovernmental transfers; and a tendency toward chronic budget deficits. (The most spectacular example of all of these trends is, of course, New York City.) These are regional tendencies to the extent that they result from common influences, such as the relative loss of population and business to other parts of the country as part of long-term national trends, or the effect of Federal policies and programs with regard to environmental protection, social welfare, national defense, energy resource management, and the like. But it should be noted that within these overall regional tendencies, there is great variety of local experience, from fiscal crisis to robust fiscal good health.

d. Future Economic Base Profile -

i. Demographic and Social - The population of the region is projected to increase to 26,213,300 by 2020 under the future economic base assumptions. This represents growth at an average rate of 7.4% per decade, compared to 12.9% per decade over the period 1940-1970, with most of this future growth occurring before 2000. Concurrently, mean population density will increase from 2,031 per square mile to 2,908. Constant dollar per capita income will more than triple to $23,510 by 2020, but will continue to converge toward the lower but more swiftly growing national average ($20,570). Average earnings per worker will follow

a similar pattern, growing from $13,409 in 1970 to $40,300 in 2020, but converging toward the national average ($35,870). This growth will continue to occur outside of the urban core, implying intensive development and urbanization in the middle and outer suburbs, unless local and land-use planners deliberately block such pressures. See Table II-D-1.

ii. Economic - Total income in the region is projected to increase from $128.5 billion to $616.2 billion over 1970-2020, with total earnings growing from $99.4 billion to $492.9 billion. Agriculture, forestry and fisheries is projected to continue its historical decline in employment, stabilizing after 2010; earnings will, however, increase significantly from present levels, reflecting technological advances in agricultural production. Mining employment will drop about one-third by 2000 and grow slowly thereafter, while earnings continue consistently to increase, particularly in nonmetallic mining. Construction is projected to reverse its decline of recent years, and maintain a slowly growing share of the regional economy. Manufacturing, similarly, is expected to recover from its present slump and grow substantially until 2000, after which employment will slowly decline because of both the long-range evolution of the region's economic base and the water-related constraints of the future economic base assumptions. (Official policy statements by the States of New Jersey and Connecticut indicate that such constraints will not affect those states, and will influence only certain counties in the New York subregion.) Earnings in manufacturing will continue to grow through 2020. By that year the six major water-using manufacturing industries will comprise 4.5% of all employment (versus 6.3% in 1970). Transportation, communications and public utilities, wholesale and retail trade, and finance, insurance and real estate will follow similar patterns: growth in absolute terms, but very gradual declines relative to the economy as a whole. Services will grow swiftly, with employment more than doubling and earnings increasing almost eight-fold by 2020, making it by far the dominant industry in the region's economy. Government, particularly state and local, will also increase its relative role, albeit to a much more moderate degree. Finally, the employment-population ratio is projected to increase from 0.405 to 0.473 over 1970-2000, due in part to greater participation by women and other groups, then receding to 0.466 by 2020 under the influence of various technological and demographic pressures. See Tables II-D-3 and II-D-5.

iii. Fiscal - Only the broadest of generalities are possible concerning the fiscal future of the region. Since state and local governments are inherently incapable of long-term deficit financing, it is to be expected that more aggressive

local revenue development and/or restrictions on local government expenditures will prevail. To the extent that per capita revenues in general can be expanded in a region already notable for its heavily taxed character, property taxes are unlikely to be materially increased, and will therefore be further reduced in relative importance. (Reforms in the methods of assessment and collection of property taxes, coupled with steadily rising land values from increasing development and urbanization, could alter this conclusion.) It would seem, then, that there will be greater reliance on intergovernmental transfers, a curtailment of some state and local government services, a takeover of certain currently-local government functions by state or Federal authorities, or (most likely) some combination of these measures.

TABLE II-D-1

REGION: HISTORICAL AND FUTURE ECONOMIC BASE DATA

	1940	1950	1962	1970
Population	12,708,987	14,214,921	16,955,610	18,308,349
% change from prev. dec.		11.8	19.3	8.0
Pop. density (per sq. mi.)	1,410	1,577	1,881	2,031
Total income (mill. '75 $)		60,950.0	91,505.2	128,489.6
Per cap. income ('75 $)		4,288	5,937	7,018
Per cap. inc. rel. (US=1)		1.33	1.34	1.29
Mean earn./wrkr. ('75 $)		8,579		13,409
Earn./wrkr. rel. (US=1)				1.21

	1990	2000	2010	2020
Population	21,711,500	23,400,900	24,740,700	26,213,300
% change from prev. dec.	9.7	7.8	5.7	6.0
Pop. density (per sq. mi.)	2,408	2,596	2,744	2,908
Total income (mill. '75 $)	258,200	358,930	469,350	616,200
Per cap. income ('75 $)	11,890	15,340	18,970	23,510
Per cap. inc. rel. (US=1)	1.23	1.20	1.17	1.14
Mean earn./wrkr. ('75 $)	20,720	25,290	31,900	40,300
Earn./wrkr. rel. (US=1)	1.17	1.16	1.14	1.12

TABLE II-D-2

REGION: HISTORICAL EMPLOYMENT

	1940	1950	1960	1970
Agriculture, Forestry & Fisheries	69,374	66,407	52,748	44,445
Mining	5,631	5,802	8,304	9,122
Contract Construction	254,145	322,270	345,386	339,889
Manufacturing	1,403,050	1,803,630	2,052,442	1,852,060
Trans., Comm. & Public Utilities	418,435	541,193	558,705	631,744
Wholesale & Retail Trade	982,963	1,233,680	1,273,131	1,446,615
Finance, Insurance & Real Estate	347,910	382,045	473,162	600,301
Services	1,124,013	1,187,010	1,540,220	2,063,475
Government	202,672	294,951	347,497	422,093
TOTAL	4,808,193	5,836,988	6,651,595	7,409,744
Emp./Pop. Ratio	.378	.412	.405	.405
Water-Using Mfg. Inds.	-	486,581	531,515	465,554
Food & Kind. Prods.	111,807	127,973	167,179	104,382
Textile Mill Prods.	119,465	110,844	84,525	71,256
Paper & Alld. Prods.	N.A.	48,507	58,635	52,887
Chemicals & Alld. Prods.	83,290	115,491	138,501	164,433
Petroleum Refining	N.A.	35,342	24,211	21,321
Primary Metals	N.A.	48,424	58,464	51,275

TABLE II-D-3

REGION: FUTURE ECONOMIC BASE EMPLOYMENT

	1990	2000	2010	2020
Agriculture, Forestry & Fisheries	21,300	19,500	18,900	19,000
Mining	7,500	6,700	6,900	7,000
Contract Construction	490,100	594,300	633,200	670,900
Manufacturing	2,274,000	2,556,800	2,522,400	2,511,100
Trans., Comm. & Public Utilities	774,500	859,300	873,100	892,000
Wholesale & Retail Trade	1,742,800	1,920,300	1,967,400	2,020,100
Finance, Insurance & Real Estate	656,900	687,700	698,200	710,400
Services	3,046,800	3,646,600	4,068,300	4,503,800
Government	657,700	778,700	833,800	894,500
TOTAL	9,671,600	11,069,900	11,622,200	12,228,800
Emp./Pop. Ratio	0.445	0.473	0.470	0.466
Water-Using Mfg. Inds.	567,800	618,400	580,000	547,100
Food & Kind. Prods.	125,700	138,700	123,100	109,900
Textile Mill Prods.	68,400	66,900	55,300	45,700
Paper & Alld. Prods.	75,400	86,100	84,300	82,900
Chemicals & Alld. Prods.	225,100	256,100	255,000	253,300
Petroleum Refining	18,900	16,400	14,900	13,600
Primary Metals	54,300	54,200	47,400	41,700

TABLE II-D-4

REGION: HISTORICAL EARNINGS
(MILLIONS OF 1975 DOLLARS)

	1950	1962	1970
Agriculture, Forestry & Fisheries	398.9	313.6	339.8
Mining	71.4	89.4	106.6
Contract Construction	2,791.9	4,344.5	5,138.0
Manufacturing	15,914.3	21,830.9	25,558.5
Trans., Comm. & Public Utilities	4,498.2	6,395.7	8,833.0
Wholesale & Retail Trade	10,600.3	13,816.9	17,582.3
Finance, Insurance & Real Estate	3,695.7	6,106.1	8,802.5
Services	7,644.0	12,830.8	19,289.4
Government	4,463.5	8,192.3	13,709.8
TOTAL	50,078.2	73,920.2	99,359.8
Water-Using Mfg. Inds.			7,344.9
Food & Kind. Prods.			1,791.3
Textile Mill Prods.			776.7
Paper & Alld. Prods.			814.8
Chemicals & Alld. Prods.			2,724.0
Petroleum Refining			403.3
Primary Metals			834.8

TABLE II-D-5

REGION: FUTURE ECONOMIC BASE EARNINGS
(MILLIONS OF 1975 DOLLARS)

	1990	2000	2010	2020
Agriculture, Forestry & Fisheries	410	460	530	610
Mining	130	150	170	200
Contract Construction	10,910	14,900	19,240	24,860
Manufacturing	41,320	53,230	66,060	82,260
Trans., Comm. & Public Utilities	16,430	22,300	28,980	37,800
Wholesale & Retail Trade	30,990	41,200	52,280	66,360
Finance, Insurance & Real Estate	18,620	26,320	35,160	46,990
Services	50,540	76,150	106,730	149,960
Government	31,090	45,220	61,540	83,810
TOTAL	200,430	279,930	370,700	492,870
Water-Using Mfg. Inds.	12,090	15,290	18,180	21,700
Food & Kind. Prods.	2,440	2,850	3,220	3,640
Textile Mill Prods.	1,030	1,170	1,250	1,340
Paper & Alld. Prods.	1,510	1,880	2,250	2,680
Chemicals & Alld. Prods.	5,470	7,500	9,360	11,700
Petroleum Refining	670	820	970	1,140
Primary Metals	960	1,060	1,130	1,200

3. Project Service Areas

a. General Characteristics - The East Bank-Rhinebeck and West Bank-West Point service areas comprise New York City and the Counties of Dutchess, Nassau, Orange, Putnam, Ulster and Westchester. The West Bank-Spring Valley service area includes these, and Rockland County as well. The service areas, like the region of which they form a major part, possess enormous physical, cultural and political diversity, and contain the premier metropolitan area in the nation. The service areas have less than half of the region's total area, but more than half of its 1970 population, of whom nearly three-fourths resided in New York City alone. The service areas therefore have a somewhat higher mean population density than the region as a whole, although they include both the most sparsely populated county in the region, Ulster, and the most crowded, Manhattan.

b. Problems -

i. Demographic and Social - The service areas have historically shared the region's consistent growth in population and per capita income, but have likewise been adversely affected by the booming growth of other regions of the nation, the severe recession of recent years, and, of course, New York City's fiscal crisis. There is ongoing outmigration from New York City to outer Long Island, the upstate counties, and other areas outside the subregion, eroding the City's economic base while creating growth management problems elsewhere. The nearer suburbs, in Nassau and Westchester, formerly the chief beneficiaries of this exodus, increasingly find themselves passed over in favor of less-developed areas.

ii. Economic - As would be expected, economic trends in the service areas are similar to those in the region at large: i.e., away from activities most sensitive to increased scarcity and cost of land, labor, and (more recently) energy, such as agriculture, forestry and fisheries, and manufacturing. The latter industry, which was the biggest employer in the region until the 1960's, has since declined not only relatively, but in absolute terms; in fact, the service areas' numerical decline in manufacturing employment exceeded that of the region as a whole, to the consternation of local economic planners. On the other hand, this decline has been balanced by strong expansion in the transportation, communications and public utilities, finance, insurance and real estate, and services industries, which are "exported" significantly to the rest of the country and the world.

iii. Fiscal - The fiscal strain of the New York State government and the near-collapse of New York City have justly commanded a great deal of attention, and have succeeded in overshadowing the good general health of county-level finances outside the city.

c. Present Economic Base Profile -

i. Demographic and Social - The population of the service areas increased by about one-third between 1940 and 1970, compared to the region's 44% in the same period. The bulk of this growth, which was notably consistent over time, occurred in the ring of suburban counties surrounding New York City, encouraged by the development of commuter railroads and highways to Long Island and upstate new York. Per capita income has been nearly identical to that in the region at large, but this increase in affluence occurred disproportionately in the suburbs, particularly in Nassau and Westchester, as a result of both their own indigenous development and the emigration to them of the more well-to-do and mobile residents of the old central city. (An important exception is New York County [Manhattan] which retains significant concentrations of both rich and poor.) Polarization of the cities and their suburbs, and of neighborhoods within both, along economic and cultural lines has been a destabilizing consequence. The strong growth of the suburbs has not been without its costs, in terms of uncontrolled sprawling development, environmental degradation, and greatly increased demands for government services.

ii. Economic - The total income in the subregion has almost doubled between 1950 and 1970, while its share in regional total income fell slightly. Between 1940 and 1970, subregion total employment grew from 3.3 million to 4.5 million, and also declined relative to the regional total. Structurally, the service areas' economy has evolved in close similarity to that of the region, with a striking exception: the decline in manufacturing employment between 1960 and 1970 was greater in the service areas than in the region. Closer examination reveals that, within the service areas, this decline was localized entirely within New York City and Nassau County, with moderate-to-strong growth in Suffolk County and upstate. Also, the relative importance of the transportation, communications and public utilities, finance, insurance and real estate, and services industries, is mildly greater in the service areas than in the region. The employment-population ratio has been nearly identical in level and pattern of change over time in the service areas and the region.

iii. Institutional - As with the region, consideration of county-level information yields certain trends: sharp increases in per capita revenues and expenditures; a decline of the relative importance of property taxes in total revenues and a simultaneous growth in the role of intergovernmental transfers; and a tendency toward chronic budget deficits. These reflect, in part, regional tendencies. But it should be noted that within these overall tendencies, there is great variety of local experience, from fiscal crisis to robust fiscal good health.

d. Future Economic Base Profile -

i. Demographic and Social - The subregion's population is projected to increase to 13.4 million by 2020 for the East Bank-Rhinebeck and West Bank-West Point service area, and 13.8 million for the West Bank-Spring Valley service area. This would be about half of the regional population, compared to about 60% in 1970. This represents growth at an average rate of 4.4% per decade over 1970-2020, compared to 10% per decade over the period 1940-1970; most of this future growth will be concentrated in the upstate counties. Concurrently, mean population density will increase by about 700 persons per square mile for the former two service areas, and by about 600 per square mile for the latter. It is expected that the percentage of population in urban places will increase, to an extent determined by local land use plans. Constant dollar per capita income will grow to $23,720 and $23,610, respectively, by 2020, an increase of 237%. It will therefore be above the regional average, and growing at a slightly faster rate. Orange County is expected to have the fastest-growing, and second-highest, per capita income by 2020. It is anticipated that general existing trends, toward a progressively more middle-income, better-educated populace, will continue, and that national tendencies toward lower fertility and increasing longevity will raise the median age and the percent of the population over 65 years old. Quantitative projections, however are not feasible with the data available in this analysis. See Table II-D-6.

ii. Economic - Total employment in the service areas is projected to grow some 41 percent over 1970-2020, with total constant dollar earnings in 2020 of $255 billion and $260 billion. The dominant industry is projected to be services, with 44% of total employment in 2020, compared to a 35% share of total employment in 1970. Manufacturing, in particular, will comprise 14% of subregion employment in 2020, with 2% in the six major water-using manufacturing industries, in contrast to 21% and 4%, respectively,

in 1970. The employment-population ratio is projected to be slightly below the 0.466 anticipated for the region as a whole. By far the greatest proportional growth will occur in the upstate counties, especially Orange, Putnam and Dutchess. See Table II-D-6.

iii. Fiscal - The same generalities apply to the service areas as to the region: namely, that the future will see more aggressive local revenue development and/or restrictions on local government expenditures, further reduction in the relative importance of property taxes, and greater reliance on intergovernmental transfers, including a takeover of certain currently-local government functions by state or Federal authorities. Within the large projected overall increase in revenues net of intergovernmental transfers, particulary rapid growth is anticipated in the more distant upstate counties of Orange, Putnam and Dutchess, as a result of the relatively much swifter growth of their tax bases.

TABLE II-D-6

ECONOMIC BASE DATA FOR SERVICE AREAS

	Population		Total Employment	
	1970	2020	1970	2020
Bronx	1,471,690	1,474,100	532,867	563,600
Kings	2,602,012	2,616,300	974,672	1,015,100
New York	1,539,233	1,574,000	713,682	886,600
Queens	1,986,473	2,170,500	883,396	1,139,300
Richmond	295,443	665,000	113,550	302,300
N.Y.C.	7,894,851	8,499,900	3,218,167	3,906,900
Dutchess	222,295	587,000	83,531	283,400
Nassau	1,428,075	1,736,100	575,678	792,800
Orange	221,657	788,300	86,958	370,900
Putnam	56,696	213,900	20,325	84,000
Ulster	141,241	205,900	52,784	96,500
W'chester	894,104	1,411,300	376,791	696,500
E.B.-R'BECK, W.B.-W. POINT SERVICE AREA	10,858,919	13,442,400	4,414,234	6,231,000
Rockland	229,903	345,600	85,475	145,000
W.B.-SPR. VAL. SERVICE AREA	11,088,822	13,788,000	4,499,709	6,376,000
Suffolk	1,124,950	2,114,400	393,003	937,000

TABLE II-D-6 (cont.)

ECONOMIC BASE DATA FOR SERVICE AREAS

	Total Income*		Per Capita Income**	
	1970	2020	1970	2020
Bronx	7,763	28,790	5,275	19,530
Kings	13,726	57,460	5,520	21,960
New York	14,550	44,890	9,454	28,520
Queens	14,400	55,530	7,249	25,580
Richmond	1,876	17,160	6,349	25,800
N.Y.C.	52,315	203,830	6,626	23,980
Dutchess	1,335	13,910	6,004	23,690
Nassau	12,030	37,980	8,424	21,870
Orange	1,224	21,410	5,523	27,160
Putnam	352	4,170	6,205	19,510
Ulster	774	4,470	5,478	21,730
W'chester	8,205	33,080	9,177	23,440
E.B.-R'BECK, W.B.-W. POINT SERVICE AREA	76,235	318,850	7,020	23,720
Rockland	1,560	6,750	6,784	19,520
W.B.-SPR. VAL. SERVICE AREA	77,795	325,600	7,015	23,610
Suffolk	6,836	44,640	6,077	21,110

* Millions of 1975 dollars.

** 1975 dollars.

TABLE II-D-6 (cont.)

ECONOMIC BASE DATA FOR SERVICE AREAS

	Revenues Net Of Intergovt'l Trans*		Property Tax Revenues*	
	1972	2020	1972	2020
Bronx	-	-	-	-
Kings	-	-	-	-
New York	-	-	-	-
Queens	-	-	-	-
Richmond	-	-	-	-
N.Y.C.	6,239	52,250	2,686	22,150
Dutchess	89	1,280	74	1,050
Nassau	1,082	5,510	871	4,410
Orange	93	2,590	78	2,180
Putnam	34	510	31	470
Ulster	62	500	47	380
W'chester	628	3,900	529	3,290
E.B.-R'BECK, W.B.-W. POINT SERVICE AREA	8,227	66,540	4,316	33,930
Rockland	146	1,070	124	720
W.B.-SPR. VAL. SERVICE AREA	8,373	67,610	4,440	34,650
Suffolk	655	6,340	505	4,940

* Millions of 1975 dollars.

C. PROJECT IMPLEMENTATION PROFILES

1. Methodology

a. Regional Construction Effects - The first cost of each alternative project component, as abstracted from Volume III - Engineering and Design of the Technical Report, was converted into direct requirements for labor of different types, and direct earnings impacts on various industries. Total regional impacts on population and economic activity were computed from the direct earnings impacts by means of an economic base-service multiplier model closely similar to that used for the future economic base and (long-range) project implementation profiles.

b. Long-Range Impacts - Implementation of the Hudson River Project would postpone the arrival of water supply deficits, and the constraint on water-using manufacturing earnings that would result from them (see Section B. 1. b.). The project implementation profile, like the future economic base profile, is based on the OBERS projections for FEA 14, but with a smaller, later-occurring negative impact related to water shortages, and with minor positive impacts created by expenditures for the operation and maintenance of the project. The regional project implementation profile therefore has higher levels of population and economic activity than the future economic base profile, and the project's impacts consist of the differences between the two. The regional project impacts are distributed among counties, and summed into to service areas, in the same manner as in the future economic base profile.

2. Regional Construction Effects

a. East Bank-Rhinebeck Alternative -

i. Direct Impacts - Construction of this project would require the following expenditures over the 1982-1990 period, in millions of 1975 dollars.

	Intake, Pumping Sta. & Tr. Plant	Tunnel & Shafts above Kensico	Conveyance below Kensico	TOTAL
Construction, Misc. & Contingencies	326.1	765.3	2,026.0	3,117.4
Engr. & Design	34.5	61.2	162.0	257.7
Land & Acquisition	8.4	3.5	20.0	31.9
Sup. & Admin.	23.9	49.8	132.0	205.7
TOTAL	392.9	879.8	2,340.0	3,612.7

Expenditures on construction materials are estimated to be $1,546 million for the tunnels, shafts, and conveyance facilities, and $243 million for the intake, pumping station and treatment plant, which together would create an earnings impacts on wholesale and retail trade of $758 million.

Labor costs are estimated to be $1,265 million for the tunnels, shafts and conveyance facilities, and $83 million for the intake, pumping station and treatment plant. These expenditures, together with engineering and design costs, would result in a $1,424 million earnings impact in the construction industry.

Land and acquisition costs represent a $4 million impact on earnings in finance, insurance and real estate, and supervisory and administrative expenses yield a $100 million impact on professional services earnings.

The changes in employment over the 1982-1990 period corresponding to these earnings impacts are as follows, in man-years:

	Intake, Pumping Sta. & Tr. Plant	Tunnel & Shafts above Kensico	Conveyance below Kensico	TOTAL
Construction				
Prof. & Admin.	170	2,460	6,490	9,120
Operating Engrs.	90	4,920	13,000	18,010
Skilled Trades	2,430	4,920	13,000	20,350
Unskilled	1,580	4,100	10,820	16,500
SUBTOTAL	4,260	16,410	43,290	63,960
Wholesale & Retail Trade	5,840	10,110	26,660	42,610
Fin., Ins. & Real Est.	40	20	90	150
Professional Services	700	1,460	3,860	6,020
	10,840	28,000	73,900	112,740

ii. Total Impacts - The direct impacts described above would result in the total impacts on the region, shown in Table II-D-7, expressed as an average for any year in the 1982-1990 period.

TABLE II-D-7

YEARLY AVERAGE CONSTRUCTION IMPACTS OF
EAST BANK-RHINEBECK ALTERNATIVE

	Earnings (millions of '75 $)	Employment
Agr., For. & Fish.	0	0
Mining	0	0
Construction	240	10,520
Manufacturing	32	1,790
Trans., Comm., & Pub. Ut.	49	2,300
Wh. & Ret. Trade	265	14,900
Fin., Ins., & Real Est.	62	2,200
Services	204	12,290
Government	212	2,560
TOTAL	971	46,560

Population	104,640
Pers. Inc. (mill. '75 $)	1,251
Output (mill. '75 $)	3,186

b. West Bank-West Point Alternative -

i. Direct Impacts - Construction of this project would require the following expenditures over the 1982-1990 period, in millions of 1975 dollars:

	Intake, Pumping Sta. & Tr. Plant	Tunnel & Shafts above Kensico	Conveyance below Kensico	TOTAL
Construction, Misc. & Contingencies	334.4	812.7	2,026.0	3,172.1
Engr. & Design	35.3	65.0	162.0	262.3
Land & Acquisition	8.4	3.8	20.0	32.2
Sup. & Admin.	24.7	52.9	132.0	209.6
TOTAL	402.8	934.4	2,340.0	3,677.2

Expenditures on construction materials are estimated to be $1,571 million for the tunnels, shafts, and conveyance facilities, and $249 million for the intake, pumping station, and treatment plant, which together would create an earnings impact in wholesale and retail trade of $771 million.

Labor costs are estimated to be $1,286 million for the tunnels, shafts and conveyance facilities, and $85 million for the intake, pumping station and treatment plant. These expenditures, together with engineering and design costs, would result in a $1,449 million earnings impact in the construction industry.

Land and acquisition costs represent a $4 million impact on earnings in finance, insurance and real estate, and supervisory and administrative expenses yield a $102 million impact on professional services earnings.

The changes in employment over the 1982-1990 period corresponding to these earnings impacts are as follows, in man-years:

	Intake, Pumping Sta. & Tr. Plant	Tunnel & Shafts above Kensico	Conveyance below Kensico	TOTAL
Construction				
Prof. & Admin.	170	2,610	6,490	9,270
Operating Engrs.	90	5,230	13,000	18,320
Skilled Trades	2,490	5,230	13,000	20,720
Unskilled	1,620	4,360	10,820	16,800
SUBTOTAL	4,370	17,430	43,290	65,090
Wholesale & Retail Trade	5,990	10,740	26,660	43,390
Fin., Ins., & Real Est.	40	20	90	150
Professional Services	720	1,550	3,860	6,130
TOTAL	11,120	29,740	73,900	114,760

ii. Total Impacts - The direct impacts described above would result in the total impacts on the region shown in Table II-D-8, expressed as an average for any year in the 1982-1990 period.

TABLE II-D-8

YEARLY AVERAGE CONSTRUCTION IMPACTS OF
WEST BANK-WEST POINT ALTERNATIVE

	Earnings (millions of '75 $)	Employment
Agr., For. & Fish.	0	0
Mining	0	0
Construction	241	10,840
Manufacturing	32	1,790
Trans., Comm., & Pub. Ut.	50	2,360
Wh. & Ret. Trade	270	15,190
Fin., Ins., & Real Est.	64	2,250
Services	208	12,510
Government	124	2,610
TOTAL	989	47,550

Population	106,850
Pers. Inc. (mill. '75 $)	1,274
Output (mill. '75 $)	3,241

c. West Bank-Spring Valley Alternative -

i. Direct Impacts - Construction of this project would require the following expenditures over the 1982-1990 period, in millions of 1975 dollars:

	Intake, Pumping Sta. & Tr. Plant	Tunnel & Shafts above Kensico	Conveyance below Kensico	TOTAL
Construction, Misc. & Contingencies	334.4	829.7	2,026.0	3,190.1
Engr. & Design	35.3	66.3	162.0	263.6
Land & Acquistion	8.4	4.0	20.0	32.1
Sup. & Admin.	24.7	54.0	132.0	210.7
TOTAL	402.8	954.0	2,340.0	3,696.8

Expenditures on construction materials are estimated to be $1,571 million for the tunnels, shafts, and conveyance facilities, and $249 million for the intake, pumping station, and treatment plant, which together would create an earnings impact in wholesale and retail trade of $775 million.

Labor costs are estimated to be $1,294 million for the tunnels, shafts and conveyance facilities, and $85 million for the the intake, pumping station and treatment plant. These expenditures, together with engineering and design costs, would result in a $1,457 million earnings impact in the construction industry.

Land and acquisition costs represent a $4 million impact on earnings in finance, insurance and real estate, and supervisory and administrative expenses yield a $102 million impact on professional services earnings.

The changes in employment over the 1982-1990 period corresponding to these earnings impact are as follows, in man-years.

	Intake, Pumping Sta. & Tr. Plant	Tunnel & Shafts above Kensico	Conveyance below Kensico	TOTAL
Construction				
Prof. & Admin.	170	2,670	6,490	9,330
Operating Engrs.	90	5,340	13,000	18,430
Skilled Trades	2,490	5,340	13,000	20,830
Unskilled	1,620	4,450	10,820	16,890
SUBTOTAL	4,370	17,790	43,290	65,450
Wholesale & Retail Trade	5,990	10,960	26,660	43,610
Fin., Ins., & Real Est.	40	20	90	150
Professional Services	720	1,580	3,860	6,160
TOTAL	11,120	30,350	73,900	15,370

ii. Total Impacts - The direct impacts described above would result in the total impacts on the region shown in Table II-D-9, expressed as an average for any year in the 1982-1990 period.

TABLE II-D-9

YEARLY AVERAGE CONSTRUCTION IMPACTS OF WEST BANK-SPRING VALLEY ALTERNATIVE

	Earnings (millions of '75 $)	Employment
Agr., For. & Fish.	0	0
Mining	0	0
Construction	242	10,900
Manufacturing	32	1,790
Trans., Comm., & Pub. Ut.	50	2,360
Wh. & Ret. Trade	271	15,250
Fin., Ins., & Real Est.	64	2,250
Services	208	12,510
Government	124	2,610
TOTAL	991	47,680

Population	107,140
Pers. Inc. (mill. '75 $)	1,278
Output (mill. '75 $)	3,259

3. Long-Range Effects on the Region

a. East Bank-Rhinebeck Alternative

i. Direct Impacts - This project consists of a pumping station and treatment plant in Dutchess County, a tunnel down the east bank of the Hudson to Kensico Reservoir in Westchester County, and conveyance facilities below Kensico. It is assumed to begin operating by the year 1990.

Water supply - This project would augment the drought safe yields of the water supplies in the counties it serves either by providing a new tunnel to be drawn upon or by increasing the water available from existing New York City aqueducts. This would lead to the following direct earnings impacts on industries in the region, in 1975 dollars, relative to the economic base profile:

	2000	2010	2020
Food & kind. prods.	$44,400,000	$109,200,000	$109,200,000
Textile mill prods.	4,800,000	80,300,000	80,300,000
Paper & alld. prods.	87,900,000	220,900,000	220,900,000
Chemicals & alld. prods.	105,400,000	520,800,000	520,800,000
Petroleum ref. & rel. inds.	17,000,000	49,900,000	49,900,000
Primary metals inds.	21,300,000	90,400,000	90,400,000

Commercial and Sport Fishing - Operation of the project may reduce the striped bass and shad populations in the river by about one percent, with a large degree of uncertainty, and therefore impact on regional earnings as follows:

	2000	2010	2020
Forestry and Fisheries	-$1,000,000	-$1,200,000	-$1,500,000

It is considered that a reduction of fish populations of this magnitude would not be great enough to have any perceptible impact on sport fishing activity in the Hudson estuary.

Land Use - Review of extant land use and zoning plans for the potential pumping station and treatment plant site areas indicates that the latter could be developed for a maximum of 35 houses, each worth about $40,000 in 1975 dollars. Although project implementation would displace this potential development, other similar areas are readily available in the county and

elsewhere, and it is considered that no significant earnings impact on the region would result. Certain shaft sites would be located in developed areas, but would occupy so little land in relative terms (typically, a small fraction of an acre) that, again, no significant regional earnings impact would result from displacement of other land uses.

Operations and Maintenance - The following annual expenditures are anticipated:

Interest and amortization	$302,800,000
Taxes (state-owned proj.)	3,188
(city-owned proj.)	13,150,000
Personnel	1,120,000
Chemicals & supplies	1,080,000
Materials & supplies	990,000
Sludge removal	250,000
Electric power	9,360,000
Maintenance & replacement	2,180,000

These expenditures are translated into the following regional earnings impacts:

		(all years)
State & local govt.	(State-owned proj.)	$ 228
	(city -owned proj.)	0
Utilities		1,377,100
Wholesale & retail trade		892,800
Trucking & warehousing		99,000
Business & repair services		601,300

ii. Total Impacts -

Demographic and Social - With this project in operation, it is projected that the region's population will grow to 26,482,200 by 2020, over a quarter of a million more than in the baseline future case. The mean population density would also be slightly higher - 2,938 per square mile compared to 2,908 - but the differential impact of the project would be locally greater in the counties most directly affected by it. Per capita income and average earnings per worker are slightly lower than in the baseline future case, because of greater growth in industries with average earnings per worker below the mean for all industries, but the drop is not significant. Much of the increased growth and development generated by the project would occur

in the outer suburban counties of the New York subregion, and to this extent the regional development patterns suggested in the baseline future profile would be intensified. See Table II-D-10.

Economic - Total regional income in the project implementation case would be $622.3 billion in 2020, $6.1 billion greater than in the future economic base scenario. Total earnings would be $4.9 billion higher, at $497.8 billion, and employment would be increased by about 126,000 jobs. Agriculture, forestry and fisheries would be negatively impacted by the effect on the commercial fishery, but only by one-fourth of one percent. Mining would be unaffected by the project, and construction earnings and employment would be increased by about one percent. Since most of the primary earnings impacts are on the water-using manufacturing industries, it is not surprising that the biggest proportional earnings and employment impact is also on manufacturing: 36,900, with nearly all of this in the water-using industries. The biggest impact is on earnings in services, over $1.3 billion, although this is disproportionately small given the total size of the industry. There would be no impact on the employmentpopulation ratio, since employment and population are considered to vary proportionately. See Tables II-D-11 and II-D-12.

Fiscal - The fiscal implications of the impacts of this project are twofold: a redistribution of revenue among local governments, related to the annual expenses of operating the project; and increases in both the tax base and demands for local government services in counties realizing accelerated development because of the project. These impacts are discussed in Section C. 4. a. ii. below.

TABLE II-D-10

REGION: PROJECT IMPLEMENTATION PROFILE
EAST BANK-RHINEBECK ALTERNATIVE

	2000	2010	2020
Population	23,511,000	25,091,300	26,482,200
% change from prev. dec.	+8.3	+6.7	+5.5
Pop. density (per sq. mi.)	2,608	2,783	2,938
Total income (mill. '75 $)	360,590	475,450	622,340
Per cap. income ('75 $)	15,340	18,950	23,500
Per cap. inc. rel. (US=1)	1.20	1.17	1.14
Mean earn./wrkr. ('75 $)	25,280	31,860	40,290
Earn./wrkr. rel. (US=1)	1.16	1.14	1.12

TABLE II-D-11

REGION: FUTURE EMPLOYMENT
EAST BANK-RHINEBECK ALTERNATIVE

	2000	2010	2020
Agriculture, Forestry & Fisheries	19,500	18,900	19,000
Mining	6,700	6,900	7,000
Contract Construction	597,200	642,100	678,200
Manufacturing	2,571,900	2,572,600	2,548,000
Trans., Comm. & Public Utilities	862,300	882,900	898,700
Wholesale & Retail Trade	1,929,800	1,995,100	2,042,000
Finance, Insurance & Real Estate	690,300	705,400	716,100
Services	3,662,200	4,119,600	4,543,700
Government	782,100	843,500	902,500
TOTAL	11,122,000	11,787,000	12,355,200
Emp./Pop. Ratio	0.473	0.470	0.466
Water-Using Mfg. Inds.	630,500	616,300	575,700
Food & Kind. Prods.	141,300	129,300	114,300
Textile Mill Prods.	67,200	58,800	48,400
Paper & Alld. Prods.	90,100	92,600	89,700
Chemicals & Alld. Prods.	259,900	269,200	264,600
Petroleum Refining	16,700	15,700	14,200
Primary Metals	55,300	50,700	44,500

TABLE II-D-12

REGION: FUTURE EARNINGS
EAST BANK-RHINEBECK ALTERNATIVE
(MILLIONS OF 1975 DOLLARS)

	2000	2010	2020
Agriculture, Forestry & Fisheries	460	530	610
Mining	150	170	200
Contract Construction	14,970	19,510	25,130
Manufacturing	53,550	67,280	83,440
Trans., Comm. & Public Utilities	22,380	29,260	38,090
Wholesale & Retail Trade	41,400	53,010	67,080
Finance, Insurance & Real Estate	26,420	35,530	47,370
Services	76,470	107,970	151,290
Government	45,410	62,260	84,560
TOTAL	281,220	375,510	497,770
Emp./Pop. Ratio	-	-	-
Water-Using Mfg. Inds.	15,580	19,310	22,810
Food & Kind. Prods.	2,900	3,380	3,790
Textile Mill Prods.	1,180	1,340	1,420
Paper & Alld. Prods.	1,970	2,470	2,900
Chemicals & Alld. Prods.	7,610	9,870	12,220
Petroleum Refining	840	1,020	1,180
Primary Metals	1,080	1,230	1,290

b. West Bank-West Point Alternative -

i. Direct Impacts - This project consists of a pumping station and treatment plant in Ulster County, a tunnel down the west bank of the Hudson, crossing under the river near West Point to Kensico Reservoir in Westchester County, and conveyance facilities below Kensico. It is assumed to begin operating by the year 1990.

Water Supply - This project would augment the drought safe yields of the water supplies in the counties it serves either by providing a new tunnel to be drawn upon or by increasing the water available from existing New York City aqueducts. This would lead to the following direct earnings impacts on industries in the region, in 1975 dollars, relative to the economic base profile:

	2000	2010	2020
Food & kind. prods.	$ 44,400,000	$109,200,000	$109,200,000
Textile mill prods.	4,800,000	80,300,000	80,300,000
Paper & alld. prods.	87,900,000	220,900,000	220,900,000
Chemicals & alld. prods.	105,400,000	520,800,000	520,800,000
Petroleum ref. & rel. inds.	17,000,000	49,900,000	49,900,000
Primary metals inds.	21,300,000	90,400,000	90,400,000

Commercial and Sport Fishing - Operation of the project may reduce the striped bass and shad populations in the river by about one percent, with a large degree of uncertainty, and therefore impact on regional earnings as follows:

	2000	2010	2020
Forestry and Fisheries	-$1,000,000	-$1,200,000	-$1,500,000

It is considered that a reduction of fish populations of this magnitude would not be great enough to have any perceptible impact on sport fishing activity in the Hudson estuary.

Land Use - Review of extant land use and zoning plans for the potential pumping station and treatment plant site areas indicates that these facilities could be located on sites that would remain undeveloped. Consequently, the presence of the project would not result in displacement of persons or economic activity, and no earnings impact on the region would result. Certain shaft sites would be located in developed areas, but would

occupy so little land in relative terms (typically, a small fraction of an acre) that, again, no significant regional earnings impact would result.

Operations and Maintenance - The following annual expenditures are anticipated:

Interest and amortization	$308,200,000
Taxes (state-owned proj.)	9,097
(city-owned proj.)	17,620,000
Personnel	970,000
Chemicals & supplies	1,120,000
Materials & supplies	1,090,000
Sludge removal	250,000
Electric power	10,490,000
Maintenance & replacement	2,230,000

These expenditures are translated into the following regional earnings impacts.

State & local govt. (state-owned proj.)	$ 651
(city-owned proj.)	0
Utilities	1,525,700
Wholesale & retail trade	970,800
Trucking & warehousing	99,000
Business & repair services	592,900

ii. Total Impacts -

Demographic and Social - With this project in operation, it is projected that the region's population will grow to 26,482,400 by 2020, over a quarter of a million more than in the baseline future case. The mean population density would also be slightly higher - 2,938 persons per square mile compared to 2,908 - but the differential impact of the project would be locally greater in the counties most directly affected by it. Per capita income and average earnings per worker are slightly lower than in the baseline future case, because of greater growth in industries whose average earnings per worker are lower than the mean for all industries, but the drop is not significant. Much of the increased growth and development generated by the project would occur in the outer suburban counties of the New York subregion, and to this extent the regional development patterns suggested in the baseline future profile would be intensified. See Table II-D-13.

Economic - Total regional income in the project implemenation case would be $622.3 billion in 2020, $6.1 billion greater than in the future economic base scenario. Total earnings would be $4.9 billion higher, at $497.8 billion, and employment would be increased by about 127,000 jobs. Agriculture, forestry and fisheries would be negatively impacted by the effect on the commercial fishery, but only by one-fourth of one percent. Mining would be unaffected by the project, and construction earnings and employment would be increased by about one percent. Since most of the primary earnings impacts are on the water-using manufacturing industries, it is not surprising that the biggest proportional earnings and employment impact is also on manufacturing: 36,900, with nearly all of this in the water-using industries. The biggest impact in dollar terms is on earnings in services, over $1.3 billion, although this is disproportionately small given the total size of the industry. There would be no impact on the employment-population ratio, since employment and population are considered to vary proportionally. See Tables II-D-14 and II-D-15.

Institutional - The fiscal implications of the impacts of this project are twofold: a redistribution of revenue among local governments, related to the annual expenses of operating the project; and increases in both the tax base and demands for local government services in counties realizing accelerated development because of the project. These impacts are discussed in Section C. 4. b. ii. below.

TABLE II-D-13

REGION: PROJECT IMPLEMENTATION PROFILE
WEST BANK-WEST POINT ALTERNATIVE

	2000	2010	2020
Population	23,511,000	25,091,300	26,482,400
% change from prev. dec.	+8.3	+6.7	+5.5
Pop. density (per sq. mi.)	2,608	2,783	2,938
Total income (mill. '75 $)	360,590	475,450	622,340
Per. cap. income ('75 $)	15,340	18,950	23,500
Per cap. inc. rel. (US=1)	1.20	1.17	1.14
Mean earn./wrkr. ('75 $)	25,280	31,860	40,290
Earn./wrkr. rel. (US=1)	1.16	1.14	1.12

TABLE II-D-14

REGION: FUTURE EMPLOYMENT
WEST BANK-WEST POINT ALTERNATIVE

	2000	2010	2020
Agriculture, Forestry & Fisheries	19,500	18,900	19,000
Mining	6,700	6,900	7,000
Contract Construction	597,200	642,100	678,200
Manufacturing	2,571,900	2,572,600	2,548,000
Trans., Comm. & Public Utilities	862,300	882,900	898,700
Wholesale & Retail Trade	1,929,800	1,995,100	2,042,000
Finance, Insurance & Real Estate	690,300	705,400	716,100
Services	3,662,200	4,119,600	4,543,800
Government	782,100	843,500	902,500
TOTAL	11,122,000	11,787,000	12,355,300
Emp./Pop. Ratio	0.473	0.470	0.466
Water-Using Mfg. Inds.	630,500	616,300	575,700
Food & Kind. Prods.	141,300	129,300	114,300
Textile Mill Prods.	67,200	58,800	48,400
Paper & Alld. Prods.	90,100	92,700	89,700
Chemicals & Alld. Prods.	259,900	269,600	264,600
Petroleum Refining	16,700	15,700	14,200
Primary Metals	55,300	50,700	44,500

TABLE II-D-15

REGION: FUTURE EARNINGS
WEST BANK-WEST POINT ALTERNATIVE
(MILLIONS OF 1975 DOLLARS)

	2000	2010	2020
Agriculture, Forestry & Fisheries	460	530	610
Mining	150	170	200
Contract Construction	14,970	19,510	25,130
Manufacturing	53,550	67,280	83,440
Trans., Comm. & Public Utilities	22,380	29,260	38,090
Wholesale & Retail Trade	41,400	53,010	67,080
Finance, Insurance & Real Estate	26,420	35,530	47,370
Services	76,470	107,970	151,290
Government	45,410	62,260	84,560
TOTAL	281,220	375,510	497,770
Emp./Pop. Ratio	-	-	-
Water-Using Mfg. Inds.	15,580	19,310	22,810
Food & Kind. Prods.	2,900	3,380	3,790
Textile Mill Prods.	1,180	1,340	1,420
Paper & Alld. Prods.	1,970	2,470	2,900
Chemicals & Alld. Prods.	7,610	9,870	12,220
Petroleum Refining	840	1,020	1,180
Primary Metals	1,080	1,230	1,290

c. West Bank-Spring Valley Alternative -

Direct Impacts - This project consists of a pumping station and treatment plant in Ulster County, a tunnel down the west bank of the Hudson, crossing under the river near Spring Valley, N.Y., to Kensico Reservoir in Westchester County, and conveyance facilities below Kensico. It is assumed to begin operating by the year 1990.

Water Supply - This project would augment the drought safe yields of the water supplies in the counties it serves either by providing a new tunnel to be drawn upon or by increasing the water available from existing New York City aqueducts. This would lead to the following direct earnings impacts on industries in the region, in 1975 dollars, relative to the economic base profile:

	2000	2010	2020
Food & kind. prods.	$ 44,400,000	$113,800,000	$113,800,000
Textile mill prods.	4,800,000	80,800,000	80,800,000
Paper & alld. prods.	87,900,000	246,300,000	246,300,000
Chemicals & alld. prods.	105,400,000	714,400,000	714,400,000
Petroleum ref. & rel. inds.	17,000,000	49,900,000	49,900,000
Primary metals inds.	21,300,000	95,100,000	95,100,000

Commercial and Sport Fishing - Operation of the project may reduce the striped bass and shad populations in the river by about one percent, with a large degree of uncertainity, and therefore impact on regional earnings as follows:

	2000	2010	2020
Forestry and Fisheries	-$1,000,000	-$1,200,000	-$1,500,000

It is considered that a reduction of fish populations of this magnitude would not be great enough to have any perceptible impact on sport fishing activity in the Hudson estuary.

Land Use - Review of extant land use and zoning plans for the potential pumping station and treatment plant site areas indicates that these facilities could be located on sites that would remain undeveloped. Consequently, the presence of the project would not result in displacement of persons or economic activity, and no earnings impact on the region would result. Certain shaft sites would be located in developed areas, but

would occupy so little land in relative terms that (typically, a small fraction of an acre) again, no significant regional earnings impact would result.

Operations and Maintenance - The following annual expenditures are anticipated:

Interest and amortization	$309,900,000
Taxes (state-owned proj.)	9,097
(city-owned proj.)	17,620,000
Personnel	1,120,000
Chemicals & Supplies	1,080,000
Materials & Supplies	1,090,000
Sludge removal	250,000
Electric power	10,490,000
Maintenance & replacement	2,230,000

These expenditures are translated into the following regional earnings impacts.

		(all years)
State & local govt.	(state-owned proj.)	$ 651
	(city-owned proj.)	0
Utilities		1,525,700
Wholesale & retail trade		970,800
Trucking & warehousing		99,000
Business & repair services		592,900

ii. Total Impacts -

Demographic and Social - With this project in operation, it is projected that the region's population will grow to 26,538,800 by 2020, over 300,000 more than in the baseline future case. The mean population density would also be slightly higher - 2,944 persons per square mile compared to 2,908 - but the differential impact of the project would be locally greater in the counties most directly affected by it. Per capita income and average earnings per worker are slightly lower than in the baseline future case, because of greater growth in industries with average earnings per worker lower than the mean for all industries, but the drop is not significant. Much of the increased growth and development generated by the project would occur in the outer suburban counties of the New York subregion, and to this extent the regional development patterns suggested in the baseline future profile would be intensified. See Table II-D-16.

Economic - Total regional income in the project implementation case would be $623.6 billion in 2020, $7.4 billion greater than in the future economic base scenario. Total earnings would be $5.9 billion higher, at $498.8 billion, and employment would be increased by about 153,000 jobs. Agriculture, forestry and fisheries would be negatively impacted by the effect on the commercial fishery, but only by one-fourth of one percent. Mining would be unaffected by the project, and construction earnings and employment would be increased by about 1.3 percent. Since most of the primary earnings impacts are on the water-using manufacturing industries, it is not surprising that the biggest proportional earnings and employment impact is also on manufacturing: 44,700 jobs, with nearly all of this in the water-using industries. The biggest impact is on earnings in services, about $1.6 billion, although this is disproportionately small given the total size of the industry. There would be no impact on the employment-population ratio, since employment and population are considered to vary proportionally. See Tables II-D-17 and II-D-18.

Institutional - The fiscal implications of the impacts of this project are twofold: a redistribution of revenue among local governments, related to the annual expenses of operating the project; and increases in both the tax base and demands for local government services in counties realizing accelerated development because of the project. These impacts are discussed in Section C.4. c. ii. below.

TABLE II-D-16

REGION: PROJECT IMPLEMENTATION PROFILE
WEST BANK-SPRING VALLEY ALTERNATIVE

	2000	2010	2020
Population	23,511,000	25,151,100	26,538,800
% change from prev. dec.	+8.3	+7.0	+5.5
Pop. density (per sq. mi.)	2,608	2,790	2,944
Total income (mill. '75 $)	360,590	476,560	623,620
Per. cap. income ('75 $)	15,340	18,950	23,500
Per cap. inc. rel. (US=1)	1.20	1.17	1.14
Mean earn./wrkr. ('75 $)	25,280	31,860	40,290
Earn./wrkr. rel. (US=1)	1.16	1.14	1.12

TABLE II-D-17

REGION: FUTURE EMPLOYMENT
WEST BANK-SPRING VALLEY ALTERNATIVE

	2000	2010	2020
Agriculture, Forestry & Fisheries	19,500	18,900	19,000
Mining	6,700	6,900	7,000
Contract Construction	597,200	643,800	679,700
Manufacturing	2,571,900	2,582,300	2,555,800
Trans., Comm. & Public Utilities	862,300	884,500	900,100
Wholesale & Retail Trade	1,929,800	1,998,100	2,046,600
Finance, Insurance & Real Estate	690,300	706,800	717,300
Services	3,662,200	4,128,500	4,552,000
Government	782,100	845,300	904,100
TOTAL	11,122,000	11,815,100	12,381,600
Emp./Pop. Ratio	0.473	0.470	0.466
Water-Using Mfg. Inds.	630,500	623,400	581,300
Food & Kind. Prods.	141,300	129,800	114,700
Textile Mill Prods.	67,200	58,900	48,400
Paper & Alld. Prods.	90,100	93,600	90,500
Chemicals & Alld. Prods.	259,900	274,500	268,800
Petroleum Refining	16,700	15,700	14,200
Primary Metals	55,300	50,900	44,700

TABLE II-D-18

REGION: FUTURE EARNINGS
WEST BANK-SPRING VALLEY ALTERNATIVE
(MILLIONS OF 1975 DOLLARS)

	2000	2010	2020
Agriculture, Forestry & Fisheries	460	530	610
Mining	150	170	200
Contract Construction	14,970	19,510	25,190
Manufacturing	53,550	67,280	83,690
Trans., Comm. & Public Utilities	22,380	29,260	38,150
Wholesale & Retail Trade	41,400	53,010	67,230
Finance, Insurance & Real Estate	26,420	35,530	47,440
Services	76,470	107,970	151,570
Government	45,410	62,260	84,720
TOTAL	281,220	375,510	498,800
Emp./Pop. Ratio	-	-	-
Water-Using Mfg. Inds.	15,580	19,310	23,050
Food & Kind. Prods.	2,900	3,380	3,800
Textile Mill Prods.	1,180	1,340	1,430
Paper & Alld. Prods.	1,970	2,470	2,930
Chemicals & Alld. Prods.	7,610	9,870	12,410
Petroleum Refining	840	1,020	1,180
Primary Metals	1,080	1,230	1,290

d. Comparative Project Impacts - Tables II-D-19, II-D-20 and II-D-21 present the significant comparative impacts of the alternative projects, in terms of deviations from the future economic base profile of the region as of 2020.

TABLE II-D-19

REGION: COMPARATIVE PROJECT IMPACTS, 2020

	East Bank-Rhinebeck	West Bank-West Point	West Bank-Spring Valley
Population	268,900	269,100	325,500
% change from prev. dec.	1.1	1.1	1.3
Pop. density (per sq. mi.)	30	30	36
Total income (mill. '75 $)	6,130	6,130	7,410
Total output (mill. '75 $)	16,200	16,200	19,590

TABLE II-D-20

REGION: COMPARATIVE EMPLOYMENT IMPACTS, 2020

	East Bank-Rhinebeck	West Bank-West Point	West Bank-Spring Valley
Agriculture, Forestry & Fisheries	0	0	0
Mining	0	0	0
Contract Construction	7,300	7,300	8,800
Manufacturing	36,900	36,900	44,700
Trans., Comm. & Public Utilities	6,700	6,700	8,100
Wholesale & Retail Trade	21,900	21,900	26,500
Finance, Insurance & Real Estate	5,700	5,700	6,900
Services	39,900	40,000	48,200
Government	8,000	8,000	9,600
TOTAL	126,400	126,500	152,800
Emp./Pop. Ratio	-	-	-
Water-Using Mfg. Inds.	35,900	35,900	42,900
Food & Kind. Prods.	5,700	5,700	6,200
Textile Mill Prods.	3,600	3,600	3,600
Paper & Alld. Prods.	8,300	8,300	9,300
Chemicals & Alld. Prods.	14,200	14,200	19,500
Petroleum Refining	800	800	800
Primary Metals	3,300	3,300	3,500

TABLE II-D-21

REGION: COMPARATIVE EARNINGS IMPACTS, 2020
(MILLIONS OF 1975 DOLLARS)

	East Bank-Rhinebeck	West Bank-West Point	West Bank-Spring Valley
Agriculture, Forestry & Fisheries	-1.6	-1.6	-1.6
Mining	0	0	0
Contract Construction	269.0	269.0	325.9
Manufacturing	1,176.8	1,176.8	1,430.1
Trans., Comm. & Public Utilities	285.3	285.4	342.7
Wholesale & Retail Trade	718.5	718.5	870.4
Finance, Insurance & Real Estate	376.8	376.8	453.6
Services	1,330.1	1,330.3	1,604.9
Government	748.3	748.5	903.2
TOTAL	4,903.2	4,903.7	5,929.2
Emp./Pop. Ratio	-	-	-
Water-Using Mfg. Inds.	1,109.3	1,109.3	1,346.9
Food & Kind. Prods.	147.0	147.0	160.4
Textile Mill Prods.	80.3	80.3	80.8
Paper & Alld. Prods.	220.9	220.9	246.3
Chemicals & Alld. Prods.	520.8	520.8	714.4
Petroleum Refining	49.9	49.9	49.9
Primary Metals	90.4	90.4	95.1

4. Long-Range Impacts on Service Areas

a. East Bank-Rhinebeck Alternative -

i. Direct Impacts - The direct impacts on the service area are identical to those on the region, as described in 3. a. i. above.

ii. Total Impacts -

Demographic and Social - With the project in operation, it is anticipated that the service area's population will grow to about 13.6 million by 2020, 183,700 (1.4%) more than in the future economic base profile. More than half of this impact is in New York City; 35% is in Nassau and Westchester Counties. Average population density would be increased from 3,319 to 3,364, with considerably larger increases in New York City and Nassau. Total income would be 1.2% higher, at $323 billion, but per capita income would not be significantly affected. More than half of the impact on total income would be in New York City, with the largest proportional increase in Nassau (2.1%). See Table II-D-22.

Economic - Total earnings in 2020 would be 1.2% higher, at $258 billion, and total employment would be increased by 84,300, including nearly all of the regional impact on manufacturing. This industry would enjoy the largest impacts (35,600 jobs and $1.1 billion in earnings, or 2.8%), followed by services. Geographically, about half of the total impacts would be located in New York City, but the biggest share of the impact on manufacturing would be in Nassau (40%), followed by New York City (36%). See Table II-D-22.

Fiscal - Aggregate local fiscal capability, as measured by revenues net of intergovernmental transfers, would be increased by $775 million, or 1.2%. Locally, the biggest absolute increase would be in New York City ($550 million, or 1.1%) and the largest proportional increases would be in Nassau (2.1%) and Westchester (1.5%). Property tax revenues would be increased $415 million (1.2%) overall, with the same geographic distribution. See Table II-D-22.

TABLE II-D-22

SERVICE AREAS: PROJECT IMPACTS, 2020
EAST BANK-RHINEBECK ALTERNATIVE

	Population	Total Employment	Total Income*	Revenues Net Of Int. Trns.*	Property Tax Revenues*
Bronx	12,250	4,680	240	-	-
Kings	42,990	16,680	791	-	-
New York	13,230	7,450	379	-	-
Queens	25,730	13,510	613	-	-
Richmond	5,630	2,560	145	-	-
N.Y.C.	99,830	44,880	2,168	550	230
Dutchess	9,570	4,620	196	18	15
Nassau	42,410	19,380	811	118	94
Orange	6,940	3,260	188	23	19
Putnam	1,450	570	28	3	3
Ulster	1,340	630	30	3	3
W'chester	22,170	10,930	504	60	51
E.B.-RH'BECK, W.B.-W. POINT SERVICE AREA	183,710	84,270	3,925	775	415
Rockland	2,320	970	49	8	5
W.B.-SPR. VAL. SERVICE AREA	186,030	85,240	3,974	783	420
Suffolk	13,020	5,770	291	41	32

* Millions of 1975 dollars.

b. West Bank-West Point Alternative -

i. Direct Impacts - The direct impacts on the service area are identical to those on the region, as described in 3. b. i. above.

ii. Total Impacts -

Demographic and Social - With the project in operation, it is anticipated that the service area's population will grow to about 13.6 million by 2020, 183,800 (1.4%) more than in the future economic base profile. More than half of this impact is in the New York City; 35% is in Nassau and Westchester Counties. Average population density would be increased from 3,319 to 3,364 with considerably larger increases in New York City and Nassau. Total income would be 1.2% higher, at $323 billion, but per capita income would not be significantly affected. More than half of the impact on total income would be in New York City, with the largest proportional increase in Nassau (2.1%). See Table II-D-23.

Economic - Total earnings in 2020 would be 1.2% higher, at $258 billion, and total employment would be increased by 84,300, including nearly all of the regional impact on manufacturing. This industry would enjoy the largest impacts (35,600 jobs and $1.1 billion in earnings, or 2.8%), followed by services. Geographically, about half of the total impacts would be located in New York City, but the biggest share of the impact on manufacturing would be in Nassau (40%), followed by New York City (36%). See Table II-D-23.

Fiscal - Aggregate local fiscal capability, as measured by revenues net of the intergovernmental transfers, would be increased by $775 million, or 1.2%. Locally, the biggest absolute increase would be in New York City ($550 million, or 1.1%) and the largest proportional increases would be in Nassau (2.1%) and Westchester (1.5%). Property tax revenues would be increased $414 million (1.2%) overall, with the same geographic distribution. See Table II-D-23.

TABLE II-D-23

SERVICE AREAS: PROJECT IMPACTS, 2020
WEST BANK-WEST POINT ALTERNATIVE

	Population	Total Employment	Total Income*	Revenues Net Of Int. Trns.*	Property Tax Revenues*
Bronx	12,250	4,680	240	-	-
Kings	42,990	16,680	791	-	-
New York	13,230	7,450	379	-	-
Queens	25,730	13,510	613	-	-
Richmond	5,630	2,560	145	-	-
N.Y.C.	99,830	44,880	2,168	550	230
Dutchess	9,380	4,530	189	17	14
Nassau	42,410	19,380	811	118	94
Orange	6,940	3,260	188	23	19
Putnam	1,450	570	28	3	3
Ulster	1,580	740	38	4	3
W'chester	22,170	10,930	504	60	51
E.B.-RH'BECK, W.B.-W. POINT SERVICE AREA	183,760	84,290	3,926	775	414
Rockland	2,320	970	49	8	5
W.B.-SPR. VAL. SERVICE AREA	186,080	85,260	3,975	783	419
Suffolk	13,020	5,770	291	41	32

* Millions of 1975 dollars.

c. West Bank-Spring Valley Alternative -

i. Direct Impacts - The direct impacts on the service area are identical to those on the region, as described in 3. c. i. above.

ii. Total Impacts -

Demographic and Social - With the project in operation, it is anticipated that the service area's population will grow to about 14.0 million by 2020, 224,600 (1.6%) more than in the future economic base profile. Half of this impact is in the New York City; 31% is in Nassau and Westchester Counties. Average population density would be increased from 3,263 to 3,316 per square mile, with considerably larger increases in New York City and Nassau. Total income would be 1.5% higher, at $330 billion, but per capita income would not be significantly affected. More than half of the impact on total income would be in New York City, with the largest proportional increase in Rockland (5.1%). See Table II-D-24.

Economic - Total earnings in 2020 would be 1.5% higher, at $264 billion, and total employment would be increased by 102,400, including nearly all of the regional impact on manufacturing. This industry would enjoy the largest impacts (42,600 jobs and $1.3 billion in earnings, or 3.3%), followed by services. Geographically, about half of the total impacts would be located in New York City, but the biggest share of the impact on manufacturing would be in Nassau (34%), followed by New York City (31%). See Table II-D-24.

Fiscal - Aggregate local fiscal capability, as measured by revenues net of intergovernmental transfers, would be increased by $943 million, or 1.4%. Locally, the biggest absolute increase would be in New York City ($640 million, or 1.2%) and the largest proportional increases would be in Rockland (5.1%) and Nassau (2.3%). Property tax revenues would be increased $511 million (1.5%) overall, with the same geographic distribution. See Table II-D-24.

TABLE II-D-24

SERVICE AREAS: PROJECT IMPACTS, 2020
WEST BANK-SPRING VALLEY ALTERNATIVE

	Population	Total Employment	Total Income*	Revenues Net Of Int. Trns.*	Property Tax Revenues*
Bronx	14,740	5,630	290	-	-
Kings	47,580	18,460	893	-	-
New York	15,990	9,000	457	-	-
Queens	29,330	15,400	706	-	-
Richmond	6,770	3,080	175	-	-
N.Y.C.	114,410	51,570	2,521	640	270
Dutchess	10,250	4,950	210	19	16
Nassau	44,860	20,500	868	126	101
Orange	8,340	3,920	227	28	23
Putnam	1,710	670	36	4	4
Ulster	1,860	870	44	5	4
W'chester	24,480	12,070	560	66	56
E.B.-RH'BECK, W.B.-W. POINT, SERVICE AREA	205,910	94,550	4,466	888	474
Rockland	18,640	7,810	345	55	37
W.B.-SPR. VAL. SERVICE AREA	224,500	102,360	4,811	943	511
Suffolk	15,820	7,010	352	50	39

* Millions of 1975 dollars.

D. BENEFIT-COST ANALYSIS

Benefit-cost analysis of the alternative projects was performed by two procedures. The first procedure relates the average annual cost of each project to the average annual cost of the most likely alternative, which is adopted as a proxy for annual project benefits. The second procedure, which is experimental in nature, attempts to develop project benefit estimates directly, utilizing the regional impact information from the economic base and project implementation profiles.

The short-run and long-run socioeconomic analyses produce project impacts that are specific to future years. It is necessary, however, that project benefits be expressed in average annual terms, in order to relate them to project costs. These costs are computed on a 50-year operational life, and are converted to average annual costs, by computing the hypothetical constant annual cost whose discounted present value would be equal to that of the actual stream of project costs. Project benefits, however, increase over time in a mathematically complex way (unlike costs), and they persist beyond 2020, the last year of detailed impact analysis. In addition, it was decided to compute non-monetary economic benefits on an average annual basis, to illuminate further the relation of project benefits to costs.

1. Benefit-Cost Analysis by Comparative Costs

The yearly expenses of any of the projects under analysis comprise operations, maintenance and replacement charges, and debt service (interest and amortization). The construction cost is converted to interest charges during the eight-year construction period, and annual interest and amortization over a 50-year operational life (i.e., 1990-2040), at an interest rate of 6.375% per year. Yearly operations and maintenance expenses over the period are based on the engineering analysis of the project.

The most likely alternative to the projects under consideration is non-Federal implementation, at the same future time, of the project among the three with the lowest average annual cost: the East Bank-Rhinebeck alternative. Average annual cost was chosen as the criterion because of the limited fiscal resources of state and local governments; moreover, some preference for this alternative was expressed by State and City authorities in public hearings. The cost stream differs from that of the same project with Federal implementaion in three respects: (1) interest and amortization costs are payable immediately, rather

than after the eight-year construction period, (2) interest and amortization costs are computed at 8.5% rather than 6.375%, and (3) the payback period is reduced from 50 to 35 years.

The average annual cost of the most likely alternative to the proposed Federal project is adopted as a proxy for the benefits of the project. Table II-D-25 displays the costs, benefit-cost ratios and net benefits of the Hudson River projects.

TABLE II-D-25

PROJECT AVERAGE ANNUAL COSTS AND B/C ANALYSIS

	Avg. Ann. cost*	B/C	Net benefits*
"Most Likely Alternative"	466.6	-	-
East Bank-Rhinebeck	332.8	1.40	133.8
West Bank-West Point	344.0	1.36	122.6
West Bank-Spring Valley	345.7	1.35	120.9

*Millions of 1975 dollars, base year 1990.

2. Benefit-Cost Analysis by Direct Benefit Estimation

The project benefits credited to national economic development are required to be those which reflect changes in the availability of goods and services on a national, as opposed to regional or local, level. The benefits may be estimated directly, as the difference between regional dollar output of goods and services with and without the project (the project implementation and future economic base cases).

The increase in the region's dollar output is considered a national benefit because of the nature of the OBERS projections on which this impact is based. One of the fundamental assumptions underlying the OBERS projections is that reasonably full employment will prevail in the nation as a whole and (allowing for local variations) in each of its component regions. In the future economic base profile prepared for the region, it was assumed that reduced availability of water would result in lower levels of employment, population and economic activity than in the unadjusted OBERS projections (which assume no such resource constraints), but would not result in unemployment per se, since workers in affected industries would emigrate with their families to other regions. Those other regions,

however, are taken to be in a condition of full employment, implying full utilization of housing, public utilities, and other infrastructure components. To this extent, the other regions would be undergoing optimal development in the OBERS scenario, and the displacement of additional population and economic activity to them in the future economic base case could cause their subsequent growth to be suboptimal, leaving them worse off than they would otherwise have been. Quantitative conclusions cannot be drawn without constructing an interregional model of the entire national economy, which is clearly beyond the scope of this study. The conservative assumption is adopted, therefore, that the economic and demographic displacement of the baseline future scenario would have a net neutral impact on the economy of the rest of the nation. The total national benefits of the project would therefore be identical to the regional benefits, in terms of preventing this displacement from occurring.

The impact on the region's dollar output is obtained from each project's impacts on regional earnings. The earnings impact on each of the nine major economic sectors is multiplied by the appropriate ratio of output to employee compensation computed from the 1967 U.S. input-output table prepared by the U.S. Department of Commerce, and the resulting products are summed over sectors to arrive at the regional total.

In this manner, output impacts were obtained for each of the alternative project configurations for the years 2000, 2010, and 2020. It was necessary, however, to interpolate values for intermediate years in order to discount the total stream of benefits to a present value. Furthermore, the benefit stream must be extrapolated beyond 2020 to properly account for project benefits realized in the remaining economic life of the project - up to the year 2040, assuming 50-year amortization beginning in 1990 (following an 8-year construction period). The total period of interest, then, is 1982-2040.

For 1990-2020, the appropriate interpolating function is exponential in form, since the benefits of the project are the difference in the (exponential) growth of the region's output with the project and without it. These growth rates vary from decade to decade; in addition, construction benefits must be considered for the 1982-1990 period.

For 2020-2040, the so-called "normal" benefit function was adapted. This function implies that a project's benefits grow at an increasing rate in the first half of its life, and continue to grow, but at a decreasing rate, in the second half, reaching zero growth at the end. Since this function is applied after

the midpoint of this project's life, only the declining-rate-of-growth portion applies. This benefit function is appropriate because it acknowledges that benefits will continue to grow beyond 2020, but provides that they will slow to a constant level by 2040. The OBERS Series E projections indicate that the nation will achieve zero population growth by about 2050. Since OBERS also projects that this region will have slower economic growth than the nation as a whole, it is reasonable to adopt a benefit stream that assumes that the project's effects on the region's further growth will decline to insignificance by 2040.

Before displaying the results of this analysis, it is appropriate at this point to consider its major limitations. The analytical model that was used, a base-service multiplier model, has the virtues of computational simplicity and realistic depiction of a region's response to an exogenous economic shock, but it is not as satisfactory on grounds of theory as less-tractable techniques like input-output analysis. A major simplifying assumption was that the only economic response to increased risk of water shortage would be a ceiling on earnings in the six major water-using manufacturing industries. Also, economic benefits can be meaningfully related to project costs only if the latter include secondary regional costs, such as the increased burden on local governments consequent to accelerated economic development. These secondary regional costs would be very difficult to quantify. (This problem does not arise with the indirect benefit-cost approach, since it applies equally to the project and to the most likely alternative with which the project is being compared.) Finally, the mathematical formulae used to interpolate and extrapolate the benefits in specific future years, in order to compute average annual values, are complex and subject to their own limitations.

The meaning of these caveats is that the directly-estimated average annual benefits and costs are not formally complete, and the benefit-cost analysis displayed in Table II-D-26 illuminates the analysis of the preceding section without displacing it.

TABLE II-D-26

DIRECT ESTIMATE AVERAGE ANNUAL BENEFITS AND B/C ANALYSIS

	East Bank-Rhinebeck	West Bank-West Point	West Bank-Spring Val.
Avg. ann. benefits*	9,548	9,585	10,814
Avg. ann. costs*	333	344	346
B/C	28.7	27.8	31.3
Net benefits*	9,215	9,241	10,468

*Millions of 1975 dollars, base year 1990.

It should be noted that the direct approach to benefit estimation produces B/C ratios which are not only extremely high, but which also result in a different ranking of the three projects than the indirect technique. (The rankings are relatively close with either procedure, however.) The magnitude of the B/C ratios is so great with the direct approach because an attempt has been made to gauge the long-term economic value of a public good, whose continuous, assured availability is a precondition for the undisrupted functioning of society. Although the disruption that would be prevented by such projects is not large in percentage terms - total dollar output of the region would be increased by a little over one percent in 2020 - the region in question is so large and diversely productive, and the period of analysis is so long, that the absolute value of these benefits is enormous. It overwhelms the cost of such a project, even though that cost is very large in ordinary terms.

The indirect technique disregards the benefits of the projects per se, comparing their costs to a fixed quantity - the cost of the most likely alternative (which, under this approach, would also have a very large B/C ratio). Since it therefore implicitly assumes that all of the projects have the same benefits, the ranking reduces to one of average annual cost: the least costly project ranks highest. The assumption of equal benefits breaks down, however, since the West Bank- - Spring Valley alternative has a larger service area and the three alternatives would induce somewhat different distributions of secondary impacts.

3. Annualization of Non-Monetary Benefits

The rational for attempting to annualize non-monetary benefits (or determine their discounted present value, which is effectively the same thing) is the same as for monetary values: to put benefit streams and cost streams of differing temporal characteristics onto a comparable footing. The interpretation of average annual change in employment, for instance, is likewise identical to that of average annual change in dollar output, or cost: the hypothetical constant annual increment whose discounted present value is equal to that of the actual benefit stream. Moreover, valuable insights are revealed by considering the ratio of an average annual non-monetary benefit to average annual dollar cost - continuing the example of employment, such a ratio would reflect the number of jobs created per dollar of project cost.

Non-monetary impacts may be discounted to present value by application of the same compound interest rate expansion as for monetary impacts, and using the same interest rate of 6.375% per year. Interest rates exist, both in economic theory and in the real world, because a good (in the economic sense) is more desirable in the present than the same good certain to be received at a point in the future, and the difference in desirability increases with the temporal separation. (Risk, the non-zero probability that the future good will not materialize as expected, is excluded here; its effect is to increase the difference in desirability without changing its nature.) That difference in desirability - the rate of social time preference - is as applicable in principle to an increase in employment or population as it is to the repayment of a sum of money. Furthermore, the designated Federal discount rate of 6.375% per year is a reasonable proxy for the rate of generalized, risk-free social time preference, and is used as such in this analysis.

It is acknowledged that this approach assumes that a constant unit value for each non-monetary benefit; e.g., when the year 2000 arrives, an increase in X jobs will be perceived to be as desirable as the same increase was in 1990. This assumption is also implicit in the more common monetary analysis, and is considered appropriate for non-monetary economic benefits. (Application of this technique to social or environmental impacts, however, could require explicit estimation of time variable unit value.)

The non-monetary project impacts required interpolation for intervening years, and extrapolation to 2040, in the same manner as did monetary output impacts, and an exponential function of closely similar form, with changes in the constant terms, was used for the 1990-2020 period. Beyond 2020, it was discovered by inspection that impacts on population, employment, and the other non-monetary measures would change at rates so low as to be of little significance, and those impacts were therefore assumed to remain constant at 2020 levels.

Note must be made of the Public Facilities impact measure, which was not computed in the project implementation profiles from which the remainder of the impacts are drawn. The only public facilities impacts attributable to the project (other than the project facilities themselves) are those associated with the secondary impact on population and the resulting requirements for augmented infrastructure items, such as schools and hospitals. It was assumed that these requirements would be met in such a way as to maintain their present availability.

E. THE NATIONAL ECONOMIC DEVELOPMENT ACCOUNT

Tables II-D-27, II-D-28 and II-D-29 present the significant beneficial and adverse impacts of the three projects under the N.E.D. account. Except as noted, the impacts are annual averages (discounted to 1990); are shown for the service areas and counties (as a range of values) as well as for the region.

TABLE II-D-27

N.E.D. ACCOUNT: EAST BANK-RHINEBECK ALTERNATIVE

SIGNIFICANT BENEFICIAL IMPACTS

Indicator	Measure	County (range)	Service Area	Region
1. Property values	Change in property tax revenues, millions of 1975 $, avg. ann.	2 to 113	223	325
2. Land use	Change in population density, avg. ann.	0.7 to 712	28	25
3. Public facilities	Change in number, 2020 - classrooms	7 to 1,300	5,600	8,400
	- hosp. beds	5 to 1,200	4,900	7,400
4. Public services	Change in expenditures net of capital outlays and intergovt'l transfers, millions of 1975 $, avg. ann.	0.7 to 130	252	367
5. Population	Change, avg. ann	700 to 49,800	141,800	213,300
6. Earnings	Change, millions of 1975 $, avg. ann	5 to 702	1,984	2,886
7. Employment	Change, avg. ann	200 to 21,300	65,100	98,863
8. Output	Change, millions of 1975 $, avg. ann.	11 to 2,631	6,776	9,548
9. Growth	Change in % growth of pop., avg. ann.	0.5% to 1.8%	1.1%	1.1%

SIGNIFICANT ADVERSE IMPACTS

Indicator	Measure	County (range)	Service Area	Region
1. Public services	Project operation, maintenance and amortization cost, millions of 1975 $, avg. ann.	2 to 116	333	333
2. Capital investment	Project construction cost and interest during construction, millions of 1975 $	-	4,533	4,533

TABLE II-D-28

N.E.D. ACCOUNT: WEST BANK-WEST POINT ALTERNATIVE

SIGNIFICANT BENEFICIAL IMPACTS

Indicator	Measure	County (range)	Service Area	Region
1. Property values	Change in property tax revenues, millions of 1975 $, avg. ann	0.7 to 113	228	333
2. Land use	Change in population density, avg. ann.	3 to 741	28	25
3. Public facilities	Change in number, 2020 - classrooms	14 to 1,300	5,600	8,400
	- hosp. beds	9 to 1,200	4,900	7,400
4. Public services	Changes in expenditures net of capital outlays and intergovt'l transfers, millions of 1975 $, avg. ann.	0.7 to 131	254	371
5. Population	Change, avg. ann.	700 to 52,000	145,600	214,100
6. Earnings	Change, millions of 1975 $, avg. ann.	7 to 703	1,989	2,892
7. Employment	Change, avg. ann.	300 to 22,300	66,900	99,400
8. Output	Change, millions of 1975 $, avg. ann.	16 to 2,640	6,719	9,585
9. Growth	Change in % growth of pop., avg. ann.	1.3% to 2.0%	1.1%	1.1%

SIGNIFICANT ADVERSE IMPACTS

Indicator	Measure	County (range)	Service Area	Region
1. Public services	Project operation, maintenance and amortization cost, millions of 1975 $, avg. ann.	2 to 121	344	344
2. Capital investment	Project construction cost and interest during construction, millions of 1975 $	-	4,615	4,615

TABLE II-D-29

N.E.D. ACCOUNT: WEST BANK-SPRING VALLEY ALTERNATIVE

SIGNIFICANT BENEFICIAL IMPACTS

Indicator	Measure	County (range)	Service Area	Region
1. Property values	Change in property tax revenues, millions of 1975 $, avg. ann.	0.8 to 125	256	377
2. Land use	Change in population density, avg. ann.	3 to 775	31	26
3. Public facilities	Change in number as of 2020 - classrooms	25 to 1,400	6,800	10,100
	- hosp. beds	16 to 1,400	6,000	8,900
4. Public services	Change in expenditures net of capital outlays and intergovt'l transfers, millions of 1975 $, avg. ann.	0.8 to 143	282	416
5. Population	Change, avg. ann.	800 to 54,300	157,900	235,100
6. Earnings	Change, millions of 1975 $, avg. ann.	8 to 749	2,194	3,238
7. Employment	Change, avg. ann.	300 to 23,400	72,500	109,000
8. Output	Change, millions of 1975 $, avg. ann.	21 to 2,874	7,565	10,814
9. Growth	Change in % growth of pop., avg. ann.	1.5% to 2.1%	1.3%	1.3%

SIGNIFICANT ADVERSE IMPACTS

Indicator	Measure	County (range)	Service Area	Region
1. Public services	Project operation, maintenance and amortization cost, millions of 1975 $, avg. ann.	2 to 111	346	346
2. Capital investment	Project construction cost and interest during construction, millions of 1975 $	-	4,639	4,639

F. POTENTIAL DROUGHT LOSSES IN THE NO-ACTION CASE

To put into perspective the need for a new regional water source development like the Hudson River Project, it is useful to consider the social and economic consequences of a drought in the absence of such development.

The first section below describes the stages of probable local response as a drought persists and worsens, and characterizes the general social, economic, environmental and institutional impacts that would follow. The next two sections develop scenarios of recurrence of a major drought in the NYMA on a year-by-year basis, commencing now and in the year 2000, respectively. The emphasis is on estimating the economic impacts of the more drastic measures needed to meet the emergency, with all values given in 1975 dollars. The final section considers the implications of the frequency of occurrence of droughts of lesser duration.

1. Drought Response: A General Scenario

Local government response to a water supply deficiency changes materially with the severity and duration of the event. This response may be described as occurring in three phases of increasing severity, based on the experiences of New York City during the droughts of 1949-50 and 1961-66. These phases are (I) a campaign for public education and (largely voluntary) conservation, (II) emergency utilization of water sources not usually considered desirable, and (III) severe, mandatory water use restrictions on businesses and households.

a. Phase I - A drought begins as a season of low rainfall, which may leave the water supply system's reserves (reservoir storages or groundwater levels) at abnormally low levels. Faced with imminent shortage, the system's managers institute a public education campaign to promote voluntary compliance with the following measures:

- Curtail lawn sprinkling in municipal parks and golf courses and if necessary extend to private lawns and gardens.

- Substitute chlorinated non-potable water for city water for street flushing operations.

- Intensify efforts to find and correct major distribution system leaks.

- Install harnesses or spray caps on fire hydrants and strictly enforce laws against illegal hydrant openings.

- Reduce the amount of water used for cleaning subway cars and buses.

- Shut down ornamental fountains.

- Ban the use of water and steam for cleaning the exteriors of buildings.

- Prohibit the filling of public and private swimming pools.

- Place restrictions on car washing.

- Prohibit the operation of automatic flush plumbing fixtures.

- Curtail the operation of skating rinks.

- Restrict the bleeding of water lines for the purpose of maintaining a constant flow to prevent freezing.

Various combinations of the above measures can be imposed, depending on the severity of a water shortage. Also, certain measures apply only to hot weather, such as restrictions on swimming pools, while others pertain to winter, such as the prohibition of water line bleeding. The total reduction in water demand from such a program would probably not exceed ten percent, and voluntary compliance would be difficult to sustain for an extended period of time.

The Phase I measures would entail adverse social and economic impacts which would probably be of minor magnitude. Social impacts would incude the general inconvenience or dissatisfaction associated with dirty cars, streets and public facilities, empty swimming pools, browned-out lawns, altered personal habits, and the general reduction in municipal services and urban visual amentities. Economic effects could comprise decreased sales of water-related products such as clotheswashers, dishwashers, swimming pools and supplies; temporary reductions in property values could also result. A minor economic benefit could also accrue, in the form of

increased sales of plumbing repair supplies, water-saving models of appliances and plumbing fixtures, and water recirculation equipment.

b. Phase II - A continuation of dry weather would further degrade the reserves and dependable yield of the system, overtaking the savings realized from Phase I measures and necessitating the use of unorthodox supplemental supply sources. These sources can include changed operating rules for existing withdrawal and storage facilities, utilization of highly treated water from inferior sources, and source augmentation techniques such as injection wells for groundwater replenishment with treated wastewater or cloud seeding.

The conservation campaign of Phase I would still be in force, so that its impacts would continue into Phase II of the dry spell. In addition, Phase II emergency source utilization would cause minor-to-moderate environmental disruption, in terms of altered salinity, nutrient and flow patterns in estuaries; saline or wastewater contamination of aquifers; drying of wetlands and surface streams from groundwater depletion; and ecological impacts associated with these physical changes. A further adverse social impact could result from the appearance of esthetically displeasing water (taste, color, etc.) in the system. Finally, an adverse institutional impact could result if Phase II measures lead to violation of existing agreements on water rights or common source use.

Extraordinary sources, like ordinary ones, would be diminished in capacity by the drought, and potential environmental and institutional effects would constrain their use. In general, Phase II measures could not be relied upon to increase system supplies by more than five percent.

c. Phase III - With further lack of sufficient rain or snow, system reserves and safe yield fall to the point where supplies, as increased by Phase II measures, are simply unable to meet demands, as descreased by Phase I programs. In such a crisis, some form of water rationing must be imposed. Minimal residential water requirements, and the needs of vital public facilities such as hospitals, would require the most protection. The steps taken to meet a progressively worsening disaster, which would need to be enforced until the drought breaks, would include:

- Curtail or shut down major water-consuming manufacturing plants, water-intensive commercial establishments, and general businesses.

- Cut off water supplies to buildings, including residences, for several hours each day, on a rotation schedule by geographic area.

- Turn off water mains for several hours each day on a rotation schedule by geographic area, if a way could be found to handle fire emergencies in such areas during temporary dry periods.

- Mass shipments of drinking water from outside areas if the quantity or quality of water from the tap is insufficient for drinking and cooking purposes.

A major, long-term economic disruption would accompany the Phase III drought response, as temporary, seasonal, or duration-of-emergency curtailment or closing of businesses would result in decreased dollar output, earnings, personal income, and employment. Some firms would be forced out of business or prompted to relocate in other, unaffected regions, and the attractiveness of the area for new investment would be seriously diminished, at least for the duration of the drought and probably beyond. Property values would be reduced by drought-induced damage to lawns and other plantings, curtailed municipal services, and emigration from the stricken area. Municipal revenues would be reduced because of curtailed business activity (and decreased water sales), while increased expenditures would be required for enforcement of water use restrictions and unemployment relief, increasing the fiscal burden on the local government.

Equally severe social dislocations would occur, including altered income, age and education profiles as the most mobile segments of the population - the relatively younger, better educated, more affluent persons and families - leave the affected region, temporarily or permanently, in pursuit of improved circumstances. Low water pressure and intermittent loss of water service, inconveniences in themselves, would result in increased fire hazard, and a possible public health risk from poor water source quality or accidental cross-contamination of water supply and wastewater systems. Also, the enforcement of water rationing could require a certain loss of privacy or, in the extreme, of civil liberties.

2. Drought-of-Record Recurrence: Present Impacts

Different localities in the New York State part of the NYMA would have widely varying responses to the onset of a drought at the present time, depending upon the relative sizes of their current water demands and the safe yields of their supplies (that is, the minimum level of dependable yield during the drought of record).

The first area to respond to a dry season now, on that basis, would be Nassau County, whose water companies would note lower water tables and increased salt water intrusion in coastal areas in the first dry year. Phase I conservation efforts would be expected to start in that year on a scattered basis (owing to the diversity of public and private water systems in the county). No other areas would need to take such action.

If dry weather extended to a second year, Phase I efforts would be pressed in earnest in Nassau, reducing demand from about 185 mgd to about 166 mgd. Some Phase II measures would be undertaken, comprising continued overpumping of the aquifer and some recharge with treated wastewater. The New York City water supply system would initiate a Phase I conservation campaign as its reservoir levels fall, but conservation efforts could only be presumed effective within New York City itself, since it has no actual control over the water use practices of its outside customers. Total system demand is 1,470 mgd, 1,374 within the City and 96 outside, nearly all in Westchester. Phase I conservation would therefore reduce system demand by 137 mgd, from 1,470 to 1,333. A Phase I effort would also be needed in the portion of Westchester not supplied by the City system, reducing its demand from 36 mgd to 32.

A third year of drought would see the start of Phase III demand curtailment in Nassau, probably starting with paper, chemicals, and primary metals manufacturing plants, which account for nearly all (about 40 mgd) of the industrial fresh water use in the county. A difficulty would arise, however, in that nine-tenths of this industrial use is self-supplied (albeit from the same source as public systems), and compliance would be difficult to enforce without local political authorities ordering plants to close altogether. In the New York City system, Phase II source utilization would be accomplished by reactivation of the Chelsea pumping plant, increasing system yield by 50 mgd on an average annual

basis. In conjunction with Phase I conservation efforts, this would meet the total system's needs through a fifth year of drought. Phase II source augmentation in the self-supplied part of Westchester would increase its system yields by about 1.4 mgd.

Fourth and fifth years of drought would result in shutdown of one-fifth of Nassau County's water-intensive manufacturing plants on an average annual basis, in addition to all conservation and groundwater recharge efforts. The economic impacts in the fifth year would be direct unemployment of 1,880 man-years, and reductions in earnings of $30 million and $142 million in output. In the part of Westchester outside the City system, Phase III water use restrictions would be required to reduce demand by about 2.6 mgd; as in Nassau, this implies curtailment of paper, chemicals, and primary metals manufacturing plants. About one-fifth of such plants in that area would need to be closed by the fifth year, with direct unemployment of 610 man-years, reduced earnings of $10 million, and reduced output of $47 million.

To summarize, a recurrence now of a five-year drought, similar in pattern to the drought of record, would lead to emergency conservation efforts in Nassau County in the first year, spreading to New York City and part of Westchester in the second year, and entailing the relatively minor social and economic adverse impacts of personal inconvenience, loss of urban amenities, and aesthetic degradation. By the third year mandatory water use restrictions would be required in Nassau, and in part of Westchester by the fourth year, with locally severe social and economic penalties including inadequate water pressure and quality, increased fire and health risks, significant unemployment, demographic disruptions, and increased local fiscal burden. The total regional economic impacts, approximately four times larger than the sum of the direct local impacts, would be 10,000 persons unemployed in the fifth year, regional earnings reduced by $160 million, and regional output reduced by $756 million. The effective cost of the water saved by curtailing manufacturing activity is therefore nearly $180,000 per million gallons. Social impacts on the region would comprise diminished quality of life and decreased attractiveness of the NYMA as a place to live and work, persisting beyond the end of the drought.

3. Drought-of-Record Recurrence: Year 2000

Between now and the end of the century, water demands on public systems, and fresh water requirements of industry,

will grow substantially. It cannot be assumed that the various conservation measures recommended as prerequisites for a Hudson River Project would be implemented in the absence of such a project. (Increases in industrial recirculation are, however, assumed to take place as projected regardless, because they would result from full application of existing law.) In addition, the dependence of upstate communities on the New York City water supply system will grow substantially, especially in Putnam and Westchester Counties where local sources are limited, while remaining insignificant in Orange and Ulster. Under these conditions, water demands in the year 2000 would be as shown below:

NYC*	1,522 mgd
Dutchess	63
Nassau	219
Orange	79
Putnam*	15
Rockland	68
Suffolk	308
Ulster	16
Westchester*	186
*NYC System	1,683

A dry season occurring at that time would prompt immediate implementation of Phase I emergency conservation measures and Phase II emergency source utilization in Dutchess and Nassau Counties. The Phase I measures would reduce demands to 57 mgd in Dutchess and 197 mgd in Nassau; Phase II efforts would increase supplies in those counties by about 2 mgd and 8 mgd respectively. The New York City system would initiate Phase I conservation programs, although it has no actual control over its upstate customers, and conservation would be confined to the city proper. Orange, Rockland, Suffolk and Ulster Counties would not need to take any action.

A second year of insufficient precipitation would require the start of Phase III emergency restrictions in Dutchess and Nassau Counties, in the form of production cutbacks or closings of paper, chemicals and primary metals manufacturing plants. The adverse economic and social impacts on these areas would reach serious proportions. Phase I conservation in New York City would reduce its total system water demand to 1,531 mgd, and Phase I efforts would be initiated in Orange, Rockland and Ulster Counties, and in the part of Westchester County not served by the City system.

The third drought year would see complete shutdown of water-intensive manufacturing for the duration of the emergency in Dutchess, as well as initial closings of other manufacturing and commercial establishments. Economic and social hardship would be widespread and could be critical in some isolated localities. Nassau would experience a spread of manufacturing plant closings, and the New York City system would take the Phase II measure of reactivating the Chelsea pumping station, increasing its system capacity on an average annual basis by 50 mgd. Phase I conservation efforts in Orange, Rockland, Ulster and the self-supplied part of Westchester would reduce demands in those counties to 71, 16, 14, and 32 mgd, respectively. Phase II source utilization in the latter area would increase its supplies by 1.4 mgd. Suffolk County would experience no restrictions.

Continuation of the drought into fourth and fifth years would result in partial economic paralysis in Dutchess, with mandatory shutdowns affecting half of the county's commercial activity. Social disruption would be general and severe, with significant local threat to life and property from inadequate water supply. Direct unemployment in the county would reach 88,700 man-years in the fifth year, or 43 percent of the labor force, with reduced earnings of $1.9 billion and reduced output of $5.9 billion. Nassau County would have over three-fourths of its water-intensive manufacturing closed down in the fifth year, with direct unemployment of 7,500 man-years, reduced earnings of $188 million, and reduced output of $857 million. Phase III mandatory restrictions would be required in New York City to meet the deficit in its system service area, since such restrictions could not be enforced outside the City, resulting in shutdowns in the fifth year affecting all of the publicly supplied water-intensive manufacturing activity (self-supplied industrial fresh water being nonpotable well water) and two-thirds of the commercial activity in the City. This would result in economic catastrophe: direct unemployment of 1,891,000 man-years (48 percent of total employment), reduced earnings of $39.7 billion, and reduced output of $117.0 billion. As in Dutchess, fire and health risks would be a local problem, in addition to the general social upheaval. Minor implementation of Phase II source augmentation would be sufficient to meet water demands in Orange, Rockland and Ulster Counties through the fifth year, with relatively minor direct social and economic impacts. The self-supplied portion of Westchester would require some Phase III demand curtailment, resulting in direct unemployment of 900 man-years, reduced earnings of $23 million, and reduced output of $112 million. Again, Suffolk County would experience no restrictions.

In summary, a recurrence of a severe five-year drought starting in the year 2000 would result in emergency conservation in New York City, Putnam, Westchester, Dutchess and Nassau in the first year, with emergency supply utilization in Dutchess and Nassau. Inconvenience and loss of amenities and aesthetic values would ensue. In the second year, emergency conservation efforts would be mobilized in all areas except Suffolk County, with probable adverse environmental impacts from overuse of sensitive source areas, and mandatory water use restrictions would begin in Dutchess and Nassau Counties. These would intensify in the third year, with increasing social and economic disruption, and emergency sources would be employed for New York City, Putnam, and Westchester. In the fourth and fifth years, mandatory demand curtailment would spread to New York City and part of Westchester, and would reach severe levels; emergency sources would be in use in every county but Suffolk, which would remain unaffected. Grave social and economic hardship would be widespread, with massive unemployment, increased risk to life, health and property, heavy financial and administrative burdens on local governments, and general interruption of private and public life. The total impacts on the region's economy in the fifth year, approximately four times larger than the sum of the direct local impacts, would be catastrophic, with nearly eight million persons (about two out of three workers) unemployed, regional earnings reduced by $167 billion, and regional output reduced by $496 billion. The effective cost of the water saved by curtailing economic activity would therefore be about $5.4 million per million gallons. The experience of such a drought would be a region-wide disaster, that would cost the NYMA jobs, population, and social and economic vitality for many years after the immediate crisis has ended.

4. Drought Frequency: Implications

The drought of record is a hydrological event with a small probability of recurring at any given time (although it is possible for it to recur at any time). But droughts of shorter duration occur more frequently. As the foregoing indicates, by the year 2000, in the absence of new regional supply developments, even a year or two of dry weather would result in serious local social and economic disruption, because water systems will be used beyond their capacity for reliable supply in any but normal or wet years.

Beyond the year 2000, water shortage as a semiregular occurrence would spread from Dutchess and Nassau Counties to engulf Rockland and Orange Counties and the New York City

regional system. The quality of life and the economic health of the NYMA would suffer, beyond the extent suggested by the dollar losses estimated above. First, the social hardships of periodic water shortage would have economic consequences which cannot be estimated directly, since they deal with people's attitudes toward the desirability of living and working in the affected areas. Second, the social and economic effects of short dry spells would be cumulative: although much smaller in scale than the effects of mandatory water rationing, they would occur much more often.

The region's growth and well-being would therefore be disturbed for some years after a particular drought incident would have ended. Moreover, patterns of growth within the region would be distorted as population and economic activity would try to shift to relatively unaffected counties like Ulster or Suffolk. Stagnation in some areas and possibly disruptive growth pressures in others would result, within the general regional framework of diminished prosperity.

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NEWS SUMMARY REPORT

APPENDIX - PART II

HUDSON RIVER PROJECT
TECHNICAL REPORT

SECTION E - WATER CONSERVATION MEASURES
FOR THE NEW YORK METROPOLITAN AREA

NORTHEASTERN UNITED STATES
WATER SUPPLY STUDY

North Atlantic Division
U.S. Army Corps of Engineers

PART II - TECHNICAL REPORT

SECTION E - WATER CONSERVATION MEASURES FOR THE NEW YORK METROPOLITAN AREA

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CHAPTER 1. SUMMARY

A. SUMMARY OF FINDINGS

The basic purpose of the New York Metropolitan Area (NYMA) Water Supply Study was to develop plans which, if implemented, will insure that the region will have enough water to meet demands through the year 2020 even if the conditions of the 1960's drought were to reoccur. The water supply deficit - which is the difference between projected demands and the safe yields of existing sources - could be eliminated by increasing supplies, reducing demands, or a combination of both. This Section describes an implementation program for water conservation measures, a way of managing demand. The program consists of certain public actions that either suggest methods by which the public can voluntarily conserve water or which require compliance with mandatory conservation measures. Certain measures apply to the entire NYMA while other measures focus primarily on New York City. These public actions include the following measures:

1. Metering of Residential Structures in New York City

The City Administrative Code could be amended to allow metering of multiunit residential structures, and approval could be given to universal residential metering by the Board of Estimate. Universal metering of all residential buildings would be implemented over a ten-year period, with priority given to one-unit structures, then two-unit, then multi-unit. The city would purchase the meters in large lots and have them installed by contract. Construction of a meter testing and maintenance shop, and hiring of an expanded force for meter reading and servicing, would also be required. Universal metering would also be undertaken by all water supply systems taking water from the City system or any new regional project.

2. Control of Distribution Leakage in New York City

The City would initiate a leakage survey and control program. A level of effort comparable to similar programs in force twenty years ago would comprise about 80 men and associated equipment, in 16 work gangs. Leakage control programs would also be implemented by all water supply systems taking water from the New York City system or any new regional project.

3. Industrial Recirculation

Achieving the projected level of recirculation would require the State of New York to enforce existing legislation on industrial discharges.

4. Domestic Conservation Devices

Although the design and enforcement of plumbing codes is primarily the responsibility of local governments, certain state agencies which regulate or fund local government functions could require, as conditions for granting approval or financial aid to localities, that local plumbing codes be amended to require the installation of water saving devices.

Local plumbing codes would be amended as follows:

- limit toilets to 3.5 gallons per flush by requiring the installation of shallow trap toilets or siphon jet toilets.
- limit the flow of showers to 3 gallons per minute through the installation of flow control devices.
- limit the flow of faucets to 2.5 gallons per minute through the installation of aerators, spray taps, or other flow control devices.

5. An Educational Program For Water Conservation In New York City

This program, designed to reduce consumption during non-drought years through voluntary measures, would consist of three phases:

Phase 1 - Identify existing water use attitudes and habits and develop methods and techniques to change those habits which appear to be wasteful.

Phase 2 - Conduct a pilot program which focuses on a small but representative sample of the City's population and evaluate the effectiveness of this pilot program.

Phase 3 - If the pilot program was found to be effective, conduct a city-wide educational campaign.

6. Drought Contingency Plan for New York City

This plan would consist of three successive phases, employing various combinations of voluntary and mandatory measures:

Phase 1 - Conservation campaign such as conducted during previous droughts.

Phase 2 - Tap sources not normally used for water supply

to augment the City system.

Phase 3 - Severe restrictions in the event of a water emergency.

The following summarizes the contents of Chapters 2 through 8 of this section including the assumptions, methods of analysis, and potential savings of the various measures considered for the entire water conservation program. Detailed discussions of each measure are presented in the respective chapters.

B. CHAPTER SUMMARIES

1. Chapter 2 - Residential Water Use and Universal Metering in New York City

This chapter is in three parts. The first part examines the extent to which residential water use in New York City is influenced by the mix of single-unit, two-unit and multiunit housing. The statistical results indicated lower per capita water use in one and two unit dwellings than in multiunit (64.4 gpcd compared to 129.3 gpcd), contrary to the findings of other investigators such as Howe, et. al. This is attributed to fundamentally different housing characteristics in New York City than in other areas, and greater sensitivity to water use by residents of detached housing than by apartment dwellers. It was estimated that, in 1974, one and two-unit structures comprised 83 percent of the City's residential buildings, 29 percent of its dwelling units, 38 percent of its population, and 28 percent of its residential water use.

The second part of the chapter is a reevaluation and expansion of the statistical work done by the Temporary State Commission on the Water Supply Needs of Southeastern New York, relating per capita residential water use to the metering ratio. In the course of the reevaluation and extension of this work, several problems with the data base arose. Consequently, the data base had to be revised and expanded. A statistically significant relationship between water use and the metering ratio was obtained for the entire set of sample cities, but better relationships resulted from breaking the total sample into groups based on percent of the population in multiunit structures, unemployment rate, and average annual precipitation. The findings indicate that metering has the least impact in areas with the greatest porportion in multiunit structures, the highest unemployment rate, and the most rainfall. Considering the known characteristics of New York City, it was concluded that universal metering in New York would not affect water use in multiunit dwellings, and would reduce per capita water use in one and two-unit structures by a maximum of 35.4 gpcd, given

TABLE II-E-1 CONT'D - P. 4

•Hudson River pumping station at Chelsea	NYC, Westchester and Putnam (perhaps Nassau)	50 (annual average yield)	50	Cost of re-activating and operating pumping station.	Capacity of pumping station is 100 mgd but flow conditions in the river would limit withdrawals to about 6 months per year.	Water quality is not as good as reservoir water and prolonged mixing of the two could reduce water quality at the tap.
Educational Program	NYC	unknown	unknown	unknown cost	The public is probably less willing to conserve water on a long term basis during non-drought years than to temporarily reduce consumption during a drought.	It is uncertain whether an educational program during non-drought years will have any effect on individual's water consumption habits.

4. Chapter 4 - Industrial Recirculation

A statistical analysis of the growth trends in industrial reuse of fresh water, as evidenced by the information found in the Census of Manufacturers for 1954-73 for the United States, Delaware-Hudson Region and New York State, was carried out. Maximum and minimum levels for changes in recirculation were estimated and the projected values found in the NYMA compared to this range of values. The resulting comparison indicated that the values assumed in the projections of demand fall within this range and can be considered appropriate. The recirculation levels developed can be achieved but only with a vigorous state enforcement posture.

5. Chapter 6 - Domestic Conservation Devices

Literature on various water-using appliances and devices was reviewed and it was concluded that water-saving devices on toilets, showers, and faucets could yield significant savings if such devices were widely installed.

High, baseline, and low estimates of savings are based on reductions in domestic in-house use of 33%, 15%, and 5%, which represent savings of 26.4 gpcd, 12 gpcd and 4 gpcd, respectively. The cost-effectiveness of immediate installation of domestic conservation devices was analyzed, and it was concluded that gradual replacement of existing fixtures with water saving models, through the amendment of local plumbing codes, would be the most feasible method of implementation. The implementation schedule used in the analysis was based on the following assumptions:

- Plumbing codes would be amended throughout the NYMA by 1980 to require that new and renovated dwelling units be equipped with water-saving toilets, shower heads, and faucets.

- Existing dwelling units will be replaced or renovated at a rate of 2% per year.

Given the above assumptions, baseline estimates of water saved by installing domestic conservation devices throughout the NYMA are 140 MGD by the year 2000 and 273 MGD by 2020.

6. Chapter 7 - An Educational Program For Water Conservation In New York City

A distinction is made in this chapter between an intensive, short term educational campaign, such as those conducted during the droughts of 1949-50 and 1961-1966 and discussed in Chapter 8,

and a long run educational program, conducted during non-drought years, that is oriented toward effecting a gradual, but permanent change in water consumption attitudes and practices. Although the crisis-oriented campaigns conducted during the droughts resulted in substantial short-run savings, it does not necessarily follow that the public would voluntarily reduce consumption when water is plentiful. Rather than to launch a comprehensive, expensive effort that could prove ineffective, it would be more feasible to conduct an educational campaign in several carefully designed phases, as described in Chapter 7.

Phase 1 of the educational program consists of several tasks relating to the collection and analysis of existing water use attitudes and habits, and the development of strategies for implementing Phase 2, which would be a pilot program designed to test educational methods and strategies on a small but representative sample of the City's population. The evaluation of Phase 2 results would determine the feasibility of Phase 3 which would extend the program to New York City as a whole and to other portions of the NYMA. The description of the educational program focuses primarily on Phase 1, because Phases 2 and 3 can neither be designed nor conducted until Phase 1 is completed.

7. Chapter 8 - Drought Contingency Plan For New York City

Official responses to the droughts of 1949-50 and 1961-66 were reviewed as a basis for formulating a contingency plan for future droughts. The first phase of this plan would consist of a conservation campaign such as conducted during previous droughts. Phase 1 consists of an intensive educational program, which attempts to induce the public to voluntarily reduce consumption, combined with temporary restrictions on water use activities such as lawn sprinkling, street cleaning, and others. If Phase 1 did not reduce demand sufficiently during a drought, it would be necessary to proceed to Phase 2 - tapping sources not normally used for water supply to augment the City system. If the reservoirs were to drop to dangerously low levels, in spite of the implementation of the above measures, Phase 3 - severe restrictions - would have to be imposed. Depending on the seriousness of a water shortage, such restrictions could include: the curtailment of water using businesses and industries; restricting the flow of water to parts of the City on a rotating basis by geographic area; and mass shipments of bottled water.

Based on the experience of previous droughts, Phase 1 could reduce consumption by as much as 10% on an average annual basis. Of the Phase 2 measures, a pumping station on the Hudson River at Chelsea, capable of an average annual yield of 50 mgd, appears to be the most reliable way to temporarily augment the

City system's yields. If Phase 3 were to become necessary, the issue would no longer be to reduce demand, but rather to ration extremely limited supplies. If the quantity or quality of tap water were no longer suitable for drinking or cooking, it would be necessary to import approximately 32 mgd of bottled water for these purposes.

8. Summary of Results

Table II-E-1 following contains a summary of estimated yields, costs, critical assumptions and uncertainties for the various elements of the conservation program.

TABLE II-E-1

SUMMARY OF CONSERVATION MEASURES

Conservation Measure	Applicable Area	Estimated Yield (mgd) 2000	2020	Cost	Critical Assumption	Uncertainties
Metering	N.Y.C.	50	50	$154 mil. capital cost $17 mil. annual cost $858/mg	12/74 cost levels @8.5%/yr. @50 mgd	Substantial uncertainties over actual response of residential water use to metering - projected yield is an upper limit. Future political or financial constraints may result in inadequate meter reading and maintenance.
	rest of NYMA	un-known	un-known		Also: Meters are regularly inspected and serviced.	
Leakage Control	N.Y.C.	25	25	$1.35 mil. annual cost $73/mg	12/74 cost levels @25 mgd yield	Growth of system may be at a much slower rate in future; technology of leak detection may improve; future political or financial constraints

TABLE II-E-1 CONT'D - P. 2

	rest of NYMA	un-known	un-known		Also: Leakage control yield is proportional to size of systems, and effort is maintained at full-scale level.	may force curtailment of effort.
Industrial Recirculation	NYMA	2588	5734	No cost to public because legislation to implement recirculation measures.	The states and localities will enforce the existing legislation.	Vigorous enforcement of laws may increase the costs of production and cause industries to locate elsewhere. In order to curtail industrial relocation, state and local governments may choose not to vigorously enforce the laws.
Domestic Conservation Devices	NYMA	125	246	No cost to public agencies because installation of devices would occur when dwelling units are	Local plumbing codes will be amended to require the installation of water saving devices on toilets, showers and faucets in all new or renovated dwelling units.	It will probably be difficult to implement and enforce amended local plumbing codes throughout the NYMA.

TABLE II-E-1 CONT'D - P. 3

	NYS (including) NYC	52	85	constructed or renovated at the builder's expense.	Such plumbing codes will be in effect throughout the NYMA by 1980.	The replacement and renovation rates of existing dwelling units probably very from area to area and according to housing market conditions.
	NYC only	31	45		Existing dwelling units will be renovated or replaced at a rate of 2% per year.	
	N.J.	56	108		Potential savings from conservation devices are 26.4 gpcd, 16 gpcd and 9.6 gpcd for high, baseline and low estimates, respectively.	
	Conn.	17	33			
Drought Contingency Measures						
•Intensive Conservation Campaign	NYC	152 (average annual yield)	168	Minimal, if based on cost of campaigns during previous droughts.	Estimated yield based on a 10% reduction on an average annual basis.	Voluntary cooperation of the public is necessary in order to achieve such savings, which depends on the ability of public officials to convince the public of the need to conserve water during a drought.

TABLE II-E-1 CONT'D - P. 4

•Hudson River pumping station at Chelsea	NYC, Westchester and Putnam (perhaps Nassau)	50 (annual average yield)	50	Cost of re-activating and operating pumping station.	Capacity of pumping station is 100 mgd but flow conditions in the river would limit withdrawals to about 6 months per year.	Water quality is not as good as reservoir water and prolonged mixing of the two could reduce water quality at the tap.
Educational Program	NYC	unknown	unknown	unknown cost	The public is probably less willing to conserve water on a long term basis during non-drought years than to temporarily reduce consumption during a drought.	It is uncertain whether an educational program during non-drought years will have any effect on individual's water consumption habits.

CHAPTER 2. RESIDENTIAL WATER USE AND UNIVERSAL METERING IN NEW YORK CITY

The purpose of this chapter is to examine some of the factors influencing residential water use in New York City, and to infer, from the characteristics of New York City and other cities, the probable water use savings that would result from universal metering in New York. This probable yield is used as the basis of a program for implementing metering.

The following is in three parts. Part A describes an analysis of the influence of housing types - single-unit, two-unit, and multiunit - on residential water use in New York. This is of key importance to a consideration of metering, which has different effects on housing of different types. Part B is an analysis of per capita residential water use related to the metering ratio in a cross-section of cities, essentially an extension of the analysis performed by the Temporary State Commission on the Water Supply Needs of Southeastern New York. This analysis, in conjunction with that in the first part, leads to an estimate of the probable reduction in water use in New York City that would result from universal metering. Part C describes the implementation program for metering, with associated costs.

A review of the theory of consumer behavior as applied to metering can be found in Attachment II-E-1.

A. WATER USE AND THE NATURE OF HOUSING IN N.Y.C.

1. Introduction

Investigators of water use behavior such as Howe, et al., have consistently noted a general tendency toward greater water use by single-unit dwellings than apartments. This is attributed to outdoor water uses (lawn sprinkling, etc.) present in the former case but not the latter. It was desired to examine the extent to which water use in New York City is influenced by the mix of single-unit, two-unit, and multiunit housing. The statistical results were consistent with lower per capita water use in single-unit dwellings than in multiunit, contrary to the experience elsewhere. This is attributed to fundamentally different housing characteristics in New York City than in other areas, and greater sensitivity to water use by residents of one and two unit structures than by apartment dwellers.

2. Analysis

Data was compiled, by year and borough, on residential water use, number of buildings by category, and number of

dwelling units by category.

Residential water use was obtained as the difference between total water use, and the sum of industrial and commercial use, which is metered in New York City, and miscellaneous use (exempt use, distribution system leakage, and underregistration of meters). Total and metered (commercial and industrial) use were obtained from Department of Water Resources annual reports; miscellaneous use was assumed uniformly to be 20 percent of the total, based on extant studies of New York City water use. Data on buildings and dwelling units were obtained from Department of Buildings annual reports for 1970, 1973, and 1974. Tables II-E-2, II-E-3, and II-E-4 below summarize the data collected.

Statistical regressions were then performed, relating water use per dwelling unit in each borough to the proportions of dwelling units in single-unit, two-unit, and multiunit structures. This was done for individual years, and for all three years grouped together with the addition of a time variable. The time variable was found to be not significant, indicating that this grouping of data did not adversely affect the results.

TABLE II-E-2

HOUSING AND WATER USE - 1970

	1-unit	(%)	2-unit	(%)	multi-unit	(%)	TOTAL	(%)
			Buildings					
Bx	30984	40.6	25445	33.3	19973	26.1	76402	100
Bk	93025	35.4	104958	40.0	64615	24.6	262598	100
Mh	8915	24.4	927	2.5	26684	73.1	36526	100
Qu	204674	68.1	76807	25.6	19086	6.3	300567	100
Rd	49083	80.0	11371	18.6	835	1.4	61289	100
NYC	386681	52.4	219508	29.8	131193	17.8	737382	100
			Dwelling Units					
Bx	30984	6.1	50890	10.0	425669	83.9	507543	100
Bk	93025	10.3	209916	23.2	601889	66.5	904830	100
Mh	8915	1.3	1854	0.3	668109	98.4	678878	100
Qu	204674	30.5	153614	22.9	313169	46.6	671457	100
Rd	49083	57.2	22742	26.5	13965	16.3	85790	100
NYC	386681	13.6	439016	15.4	2022801	71.0	2848498	100

Residential Water Use

	Total (MGD)	Per D.U. (gal/day)	Per Cap. (gal/day)
Bx	190	374	129
Bk	280	309	108
Mh	156	230	101
Qu	171	255	86
Rd	21	245	71
NYC	818	287	104

Source: see text, p. II-E-14.

TABLE II-E-3

HOUSING AND WATER USE - 1973

	1-unit	(%)	2-unit	(%)	multi-unit	(%)	TOTAL	(%)
			Buildings					
Bx	30887	40.7	25797	34.0	19246	25.3	75930	100
Bk	92760	35.7	104452	40.2	62623	24.1	259835	100
Mh	8912	24.8	929	2.6	26087	72.6	35928	100
Qu	204133	67.7	78453	26.0	19118	6.3	301704	100
Rd	52296	78.3	13620	20.4	865	1.3	66781	100
NYC	388988	52.5	223251	30.2	127939	17.3	740178	100
			Dwelling Units					
Bx	30887	6.1	51594	10.2	425394	83.7	507875	100
Bk	92760	10.3	208904	23.1	602564	66.6	904228	100
Mh	8912	1.3	1858	0.3	681694	98.4	692464	100
Qu	204133	30.1	156906	23.1	317272	46.8	678311	100
Rd	52296	54.8	27240	28.6	15838	16.6	95374	100
NYC	388988	13.5	446502	15.5	2043032	71.0	2878522	100

Residential Water Use

	Total (MGD)	Per D.U. (gal/day)	Per Cap. (gal/day)
Bx	205	404	141
Bk	297	328	114
Mh	179	258	118
Qu	172	254	84
Rd	24	252	75
NYC	877	305	111

Source: see text, p. II-E-14.

TABLE II-E-4

HOUSING AND WATER USE - 1974

	1-unit	(%)	2-unit	(%)	multi-unit	(%)	TOTAL	(%)
			Buildings					
Bx	30895	40.8	25838	34.2	18877	25.0	75610	100
Bk	92660	35.7	104363	40.3	62199	24.0	259222	100
Mh	8909	24.9	923	2.6	25919	72.5	35751	100
Qu	203755	67.6	78738	26.1	19138	6.3	301631	100
Rd	53098	77.6	14400	21.1	885	1.3	68383	100
NYC	389317	52.5	224262	30.3	127018	17.2	740597	100
			Dwelling Units					
Bx	30895	6.1	51676	10.2	423611	83.7	506182	100
Bk	92660	10.2	208726	23.1	602751	66.7	904137	100
Mh	8909	1.3	1846	0.3	684334	98.4	695089	100
Qu	203755	30.0	157476	23.2	318931	46.8	680162	100
Rd	53098	54.1	28800	29.3	16317	16.6	98215	100
NYC	389317	13.5	448524	15.6	2045944	70.9	2883785	100

Residential Water Use

	Total (MGD)	Per D.U. (gal/day)	Per Cap. (gal/day)
Bx	213	421	147
Bk	290	321	112
Mh	181	260	120
Qu	173	254	84
Rd	27	275	83
NYC	884	307	111

Source: see text, p. II-E-14.

Let:

s = fraction of dwelling units in single unit buildings
t = fraction of dwelling units in two-unit buildings
m = fraction of dwelling units in multiunit buildings
st = fraction of dwelling units in single and two unit dwellings
tm = fraction of dwelling units in two and multiunit dwellings
T = time

The following results were obtained.

	Variables	Significant Variables	R^2	Level of Significance	Std. Err.
1970:	s,t,m	-	.327	-	97.5
	m	-	.095	-	65.3
1973:	s,t,m	-	.381	-	104.9
	m	-	.195	-	69.0
	s,t	-	.382	-	74.1
	s	-	.276	-	65.5
'73+'74:	s,t	-	.295	-	61.0
	s	-	.217	-	60.2
	m	-	.155	-	62.5
'70+'73+ '74:	s	-	.196	-	57.0
	s,t	s	.294	-	55.5
	s,T	-	.222	-	58.3
	s,t,T	s	.314	-	57.2
	m	-	.132	-	59.2
	m,T	-	.159	-	60.6
	T	-	.028	-	62.6
	st	-	.132	-	59.2
	tm	-	.196	-	57.0

It was noted that water use per dwelling unit was considerably higher in the Bronx than elsewhere. Some of regressions were repeated with Bronx deleted from the grouped data, with the following results.

Without Bronx:

s	-	.084	-	31.9
s,t	s,t	.749	1%	17.6
s,T	-	.143	-	32.6
s,t,T	s,t	.785	1%	17.3
m	-	.008	-	33.2
m,T	-	.070	-	33.9

	Variables	Significant Variables	R^2	Level of Significance	Std. Err.
Without	T	-	.062	-	32.3
Bronx	t	-	.100	-	31.7
cont'd	t,T	-	.158	-	32.3
	s,m	s,m	.749	1%	17.6
	t,m	t,m	.749	1%	17.6
Bronx Alone:					
	s	-	.000	-	33.2
	m	m	.867	-	12.1
	T	T	.983	-	4.4

A parameter must, in general, be at least double its standard error to be considered significantly different from zero. R^2, the coefficient of determination, measures how much of the variation in per capita demand is explained by the computed relationship - in this case, about one-half. The F statistic is a measure of "goodness of fit," and must exceed a certain value for the entire relationship to be considered significantly different from random chance.

Pronounced intercorrelations exist among s,t, and m, so that reliance could only be placed on regressions on these variables individually, or in merged form, such as st or tm. It should be noted that a regression on st is the mathematical mirror image of a regression on m, and similarly for s and mt. Such regressions, however, did not produce significant results. By itself, then, the nature of the housing in New York City appears to have no demonstrable effect on water use per dwelling unit.

The water used in a dwelling unit, however, depends also on the number of persons living in it. The average number of persons per dwelling unit is known to differ from borough to borough, and it was desired to determine whether it varies significantly, city-wide, among housing types. Data on population and the number of dwelling units in each borough produced the following estimates of average persons per dwelling unit:

	1970	1973	1974
Bronx	2.90	2.86	2.86
Brooklyn	2.87	2.88	2.86
Manhattan	2.28	2.19	2.17
Queens	2.96	3.02	3.03
Richmond	3.45	3.36	3.31

This was related in each case to the corresponding mix of housing types. It was found that there is a strong, highly significant, negative relationship between average persons per dwelling unit and the fraction of dwelling units in multiunit structures. (A corresponding positive relationship was found between persons per dwelling unit and fraction in single unit structures.) This is in keeping with the conventional wisdom that larger families tend to seek out houses of their own. These relationships are:

$$dp = 3.60 - \underset{(0.16)}{1.18m} \qquad R^2 = 0.813 \quad F(1,13) = 56.598$$

$$dp = 2.54 + \underset{(0.29)}{1.58s} \qquad R^2 = .701 \quad F(1,13) = 30.489$$

where dp = persons per dwelling unit. This implies that, city-wide, the average apartment has 2.42 residents, and the average single-unit dwelling has 4.12 residents. Considering one and two unit dwellings as a group, they have an average of 3.60 persons per unit; if two unit and multiunit dwellings are taken as a group, they have an average of 2.54 persons per unit.

Two of the regressions relating water use per dwelling unit to housing types were repeated, with the addition of persons per dwelling unit. The results were as follows.

(all boroughs, '70 + '73 + '74)

Variables	Significant Variables	R^2	Level of Significance	Std. Err.
s, dp	s, dp	.752	1%	33.0
m, dp	m, dp	.838	1%	26.6

The better of these two is apparently the second:

$$qdu = -852 + \underset{(55)}{436m} + \underset{(42)}{306\ dp} \qquad F(2,12) = 31.146$$

This must be interpreted with caution, however, because m and dp do have a high correlation.

A more satisfactory way to incorporate persons per dwelling unit is to use it to convert water use per dwelling unit into water use per capita.

Symbolically,

$$qpc = \frac{qdu}{dp}$$

Water use per capita was regressed against housing types, with the results below.

(all boroughs, "70 + '73 + '74)

	Variables	Significant Variables	R^2	Level of Significance	Std. Err.
1.	s	s	.690	1%	13.8
2.	s,T	s	.720	1%	13.6
3.	t	t	.419	1%	18.9
4.	t,T	t	.461	5%	18.9
5.	st	st	.654	1%	14.6
6.	tm	tm	.690	1%	13.8
7.	st,T	st	.688	1%	14.4
8.	tm,T	tm	.720	1%	13.6
9.	m	m	.654	1%	14.6
10.	m,T	m	.688	1%	14.4
11.	s,t	s	.690	1%	14.4
12.	s,m	-	.690	1%	14.4
13.	dp	dp	.284	5%	21.0
14.	s,dp	s,dp	.778	1%	12.1
15.	m,dp	m,dp	.861	1%	9.6

The last three relationships are included for sake of completeness only. Since qpc, the dependent variable, was derived from dp, these three relationships must exhibit serious statistical distortion - that is, a variable is being regressed against itself, giving good but spurious results. Of the above relationships, 1,3,5,6, and 9 appear to be the best. In more detail, they are:

Ind. Variable	Intercept	Reg. Coeff.	R^2	F
s = proportion of d.u.'s in one unit structures	124.67	-95.89	0.690	28.894
t = proportion of d.u.'s in two unit structures	129.53	-145.49	0.419	9.378
m = proportion of d.u.'s in multi-unit structures	64.37	64.90	0.654	24.541
st = proportion of d.u.'s in one and two unit structures	129.26	-64.90	0.654	24.525

Ind. Variable	Intercept	Reg. Coeff.	R^2	F
tm = proportion of d.u.'s in two and multiunit structures	28.78	95.89	0.690	28.894

As noted earlier, the relationship with s is the mathematical alter ego of the relationship with tm, and similarly with m and st.

These relationships imply that residential water use per capita is lowest in single-unit dwellings, highest in multiunit, and at an intermediate level in two-unit dwellings. Specifically, they predict that, city-wide, an area with half its dwelling units in one-unit structures would exhibit average per capita use of 77 gallons per day; an area with all of its units in multiunit structures would have an average use of 129 gallons per capita per day; and so on for other combinations.

It is noted that the regressions on s and t have negative coefficients, while the regression on m has a positive coefficient. This reflects the fact that water use behavior in two-unit structures is much closer in nature to that in single-unit structures than in apartment buildings. The reason for this is that, in one and two unit dwellings, the relationship between tenancy and ownership (with its concerns for economy and conservation) is much closer than in an apartment, promoting greater sensitivity to water use in the former case than in the latter. It is therefore considered most appropriate in this analysis to use the regression of per capita use on m, which implicitly lumps s and t together, even though the regression on s alone has slightly higher statistical significance and explanatory power. The expression to be used, then, is:

$$qpc = 64.4 + 64.9m \qquad (13.1)$$

3. Discussion and Conclusions

As noted in the Introduction, the experience of other investigators such as Howe, et al., has been that single-unit dwellings use more water than apartments, because of outdoor uses such as lawn sprinkling. It has generally been found, in this analysis as elsewhere, that single-unit dwellings have more residents than apartments. This would translate into an expectation of roughly equal per capita use in both types of housing.

As has been shown, however, multiunit housing exhibits significantly higher per capita use than one and two-unit

dwellings in New York City. This result may be due to two separate effects. First, a detached dwelling in New York occupies a smaller physical area than comparable housing elsewhere, implying that there is less lawn to be watered, less room for a swimming pool, etc. (In fact, detached houses in the Bronx, Queens and Brooklyn, except in limited high-income neighborhoods, tend to have little or no lawn or yard area.) Second, as mentioned above, since most single-unit and two-unit dwellings are owner-occupied, residents would be expected to have more of a proprietary interest in correcting leaks and avoiding obvious waste. Although such dwellings are almost completely nonmetered, their occupants are nonetheless billed directly for their water (unlike apartment dwellers), and would therefore be more sensitive to its use. This latter point would be much more apparent in a condition of universal metering, in which non-multiunit dwellers would be billed in direct proportion to their magnitude of use, and would have more incentive toward conservation than at present, while apartment dwellers would still not pay for their water in any direct, identifiable fashion.

As noted above, per capita water use is given by:

$$qpc = 64.4 + 64.9m \qquad (13.1)$$

implying that per capita use is 64.4 gpcd in the average one or two unit dwelling, and 129.3 gpcd in the average apartment. The average number of persons per dwelling unit was found to be 3.60 for one and two units and 2.42 for apartments. Applying these figures to the number of units in each class in New York City in 1974 yields the following total use estimates in mgd.

one and two unit dwellings	244
multiunit dwellings	640
TOTAL	884

The data and analysis presented herein indicate that one and two-unit structures represented (in 1974) 83 percent of the residential buildings in New York City, 29 percent of its dwelling units, 38 percent of its population, and 28 percent of its residential water use. While the latter figure seems disproportionately small, there are indications that it may be relatively the most responsive segment of residential use to water conserving policies.

B. METERING AND RESIDENTIAL WATER DEMAND IN NEW YORK CITY

1. Introduction

Many studies have been made of universal metering as a means of reducing residential water use in New York City. Almost all of these studies have concluded that this would be a useful measure to undertake, while disagreeing on the quantity of water that would be saved. The most recent such study, and the only one to attempt a statistically rigorous extrapolation of modern data on actual metering experience elsewhere, is found in Measures to Reduce Water Consumption in Southeastern New York, a 1972 report by the Temporary State Commission on the Water Supply Needs of Southeastern New York.

The analysis below comprises a re-evaluation and expansion of the statistical work done by the Temporary State Commission (TSC). The conclusion of this reanalysis is that, under the most extreme (and improbable) favorable assumptions, residential water use would be reduced by not more than 107 mgd by universal metering, based on 1974 water use levels, and it is possible that no reduction at all would actually be observed. Alternative arbitrary savings of 50, 100, and 125 mgd were used in developing a range of costs for a metering program. An estimate of 50 mgd was adopted for planning purposes after consultation with state and local officials.

2. Analysis

A review has been performed of the statistical analysis relating non-industrial per capita water use to the metering ratio in twenty-six cities and the boroughs of New York City in 1960, as found in the TSC report, Measures to Reduce Water Consumption in Southeastern New York. A table from that report, reproduced below as Table II-E-5, displays population, non-industrial per capita consumption, percent of services metered, percent of population in multi-unit structures, and the metering ratio (the ratio of residential meters to dwelling units), for each city. The resulting regression was given as follows:

$$Q = \underset{(8.185)}{107.05} - \underset{(0.124)}{0.679}M \qquad R^2 = 0.518$$

$$F = 30.06764$$

where Q is per capita demand and M is the metering ratio. The numbers in parentheses are the standard errors of the regression parameters; a parameter must be at least double its standard error to be considered significantly different from zero. R^2, the coefficient of determination, measures how much of the variation in per capita demand is explained by the computed

TABLE II-E-5

WATER USE DATA FROM AMERICAN CITIES
1960
(Source: Temporary State Commission)

City	Population	Non Industrial Consumption (GPCD)	Percent Metered	Percent in Multi-Unit Structures	Metering Ratio
Manhattan and Bronx	3,123,096	134.0	0.0	96.3	0.0
Brooklyn	2,627,319	114.2	0.0	96.0	0.0
Queens	1,809,578	102.0	0.0	71.4	0.0
Richmond	221,991	74.8	0.0	41.9	0.0
Birmingham	480,000	39.8	100.0	23.5	95.2
Cincinnati	502,550	51.7	100.0	61.6	96.6
Columbus	577,780	45.2	100.0	31.3	88.7
Dallas	797,200	56.6	100.0	23.6	79.9
Denver	518,000	155.0	11.0	32.9	7.2
Detroit	1,670,000	62.1	100.0	37.6	70.6
Ft. Worth	356,000	75.9	100.0	16.3	82.4
Houston	900,000	66.0	100.0	18.2	63.0
Indianapolis	575,000	44.5	100.0	26.2	85.7
Kansas City	550,000	34.2	100.0	40.2	72.7
Los Angeles	2,532,000	94.5	100.0	39.1	56.7
Louisville	501,200	50.5	100.0	32.9	85.4
Miami	342,632	61.4	100.0	46.9	76.1
Milwaukee	771,000	45.7	99.0	56.3	57.5
Memphis	535,824	40.8	100.0	22.2	79.0
Newark	405,220	62.2	100.0	88.6	39.5
Omaha	335,000	47.7	100.0	28.1	82.4
Portland	386,694	65.3	100.0	31.1	78.7
Pittsburgh	600,000	42.6	86.0	43.0	53.7
San Antonio	473,600	100.0	100.0	16.2	69.5
San Diego	588,400	75.6	100.0	28.4	71.9
San Francisco	740,000	41.3	100.0	62.9	43.4
St. Louis	600,000	91.4	11.8	63.8	5.7
St. Paul	333,364	52.8	100.0	41.3	74.7
Syracuse	235,000	54.3	100.0	58.0	60.5
Wichita	254,698	40.3	100.0	19.6	73.8

relationship - in this case, about one-half. The F statistic is a measure of "goodness of fit," and must exceed a certain value for the entire relationship to be considered significantly different from random chance.

In the course of the reanalysis of this work, certain uncertainties arose concerning the data that was used by the TSC. First, it was noted that the given populations differed from Census tabulations for the year in question in 23 of the 30 cases. (The discussion of the data in the TSC analysis clearly indicated that the populations in question were municipal populations rather than populations served by water utilities.) These differences ranged from negligible to 29 percent, mostly in the direction of overstating the population. This led to questions about the per capita demand used, since too high a population would lead to too low a per capita demand. Comparison was made with AWWA data (where available) on residential water use by city, divided by Census population data to get per capita demands, and it was found that the AWWA-based data generally agreed with per capita demands arrived at simply by substituting the Census population data for that originally used in the TSC computations. Some serious differences remained, however.

A particular problem was noted with TSC per capita demands for the boroughs of New York City. Correct populations were used, but were applied to total nonmetered water use, which includes not only residential use, but also use by city agencies and other exempt users, leakage from street mains, and underregistration of commercial and industrial meters. By contrast, comparison of the TSC and AWWA data indicates that residential water use alone was used for the other cities. This overstates per capita residential use in New York relative to the other cities. The NEWS Study had developed estimates of residential water use in New York City, net of the nonmetered use items mentioned above, and these estimates were used for revised per capita use figures for the boroughs of New York City. (See page II-E-14.)

Evidence has been adduced, therefore, that the TSC's original analysis was based on data that overstated per capita residential water use in New York City, while understating it in most of the other cities in the sample. Since New York was the only city with a metering ratio of zero, the TSC relationship would therefore have been biased. Table II-E-6 displays these results.

TABLE II-E-6

WATER USE DATA FROM AMERICAN CITIES, 1960, TSC AND REVISED

City	TSC Population	Census Population	TSC water use (gpcd)	TSC water use, Census population (gpcd)(1)	AWWA water use, Census population (gpcd)(2)
Manhattan and Bronx	3,123,096	3,123,096	134.0	134.0	99.6 (3)
Brooklyn	2,627,319	2,627,319	114.2	114.2	85.6 (3)
Queens	1,809,578	1,809,578	102.0	102.0	82.3 (3)
Richmond	221,991	221,991	74.8	74.8	49.6 (3)
Birmingham	480,000	340,887	39.8	56.0	55.9
Cincinnati	502,550	502,550	51.7	51.7	91.7
Columbus	577,780	471,316	45.2	55.4	(NA)
Dallas	797,200	679,684	56.6	66.4	66.5
Denver	518,000	493,887	155.0	162.6	145.2
Detroit	1,670,000	1,670,144	62.1	62.1	62.1
Ft. Worth	356,000	356,268	75.9	75.8	59.8
Houston	900,000	938,219	66.0	63.3	(NA)
Indianapolis	575,000	476,258	44.5	53.7	53.5
Kansas City (Mo)	550,000	475,539	34.2	39.6	36.4
Los Angeles	2,532,000	2,479,015	94.5	96.5	96.3
Louisville	501,200	390,369	50.5	64.8	50.0
Miami	342,632	291,688	61.4	72.1	(NA)
Milwaukee	771,000	741,324	45.7	47.5	46.4
Memphis	535,824	497,524	40.8	43.9	43.8
Newark	405,220	405,220	62.2	62.2	(NA)
Omaha	335,000	301,598	47.7	53.0	53.0
Portland	386,694	372,676	65.3	67.8	(NA)
Pittsburgh	600,000	604,332	42.6	42.3	(NA)
San Antonio	473,600	587,718	100.0	80.6	66.7
San Diego	588,400	573,224	75.6	77.6	76.8
San Francisco	740,000	740,316	41.3	41.3	41.3
St. Louis	600,000	750,026	91.4	73.1	76.2
St. Paul	333,364	313,411	52.8	56.2	56.0
Syracuse	235,000	216,038	54.3	59.1	(NA)
Wichita	254,698	254,698	40.3	40.3	(NA)

(1) TSC per capita use corrected for Census population data.
(2) AWWA residential water use divided by Census population.
(3) NEWS estimated residential water use divided by Census population.
(NA) not available

Before proceeding to a discussion of the further analysis that was performed, attention must be called to the way in which the TSC used its original regression to predict the effect of metering on water demand in New York City. Essentially, the metering ratios for the boroughs were calculated on the assumption of universal metering, and these values were inserted into the derived expression to yield post-metering per capita demands for the boroughs. These were compared with present demands to analyze the magnitude of the reductions.

But there are reservations to using this procedure. Present per capita demands in New York are not the same as the calculated expression would predict, given the present metering ratio of zero. This is because New York differs from the other cities, not only because of the absence of metering, but also because of a host of social, economic, climatic, and other factors. The TSC procedure implicitly assumes that all of these other factors will change at the same time that metering is implemented, moving each of New York's boroughs onto the fitted curve. This is not reasonable on theoretical or practical grounds. The principal effect of this technique is to greatly overstate the savings resulting from metering. This problem can be reduced by using the computed expression to determine the percent reduction in per capita use that would result from a given increase in the metering ratio, and apply that percent reduction to the actual per capita use, to calculate the resulting savings.

To examine the effect of revising the data on the computed relationship between per capita use and the metering ratio, a number of statistical regressions were performed. The analyses included correlation, simple regression and multiple regression. The following steps were taken in this initial analysis:

(1) A simple regression duplicating the original TSC relationship, with the original data.

(2) A multiple regression, still with the original data, adding population, and percent of population in multi-unit structures as independent variables, to see if the explanatory power of the relationship could be increased by considering these other factors in addition to the metering ratio.

(3) Repeating (1) and (2) with New York City deleted from the data set, to ascertain if the relationships found were truly general, or if they reflected only the differences between New York and the rest of the country.

(4) Repeating (1), (2) and (3) with the revised data.

The results were as follows.

(1) This result was

$$Q = 107.05 - \underset{(0.124)}{0.679M} \qquad R^2 = 0.518$$

$$F\ (1,28) = 30.068$$

As expected, this was identical with the TSC relationship.

(2) Let P = population in thousands, m = percent of population in multiunit structures, Q and M as before. Then:

$$Q = 91.23 + \underset{(0.0057)}{0.0105P} - \underset{(0.137)}{0.555M} \qquad R^2 = 0.571 \quad F(2,27) = 18.021$$

$$Q = 126.31 - \underset{(0.225)}{0.271m} - \underset{(0.163)}{0.808M} \qquad R^2 = 0.543 \quad F(2,27) = 16.010$$

$$Q = 117.47 + \underset{(0.0057)}{0.0145P} - \underset{(0.217)}{0.453m} = \underset{(0.152)}{0.724M} \qquad R^2 = 0.633 \quad F(3,26) = 14.954$$

All three of these relationships have significant F statistics, and the last one has the highest R^2 (i.e., explanatory power). Thus, the relationship is improved by including more variables to differentiate among cities: both population and percent in multiunit structures are significant in this respect.

(3) Without New York City data, the four relationships above took the following forms:

$$Q = 108.29 - \underset{(0.183)}{0.696M} \qquad R^2 = 0.376 \quad F(1,24) = 14.444$$

$$Q = 102.16 + \underset{(0.0089)}{0.0075P} - \underset{(0.186)}{0.676M} \qquad R^2 = 0.394 \quad F(2,23) = 7.489$$

$$Q = 148.96 - \underset{(0.232)}{0.649m} - \underset{(0.183)}{0.933M} \qquad R^2 = 0.534 \quad F(2,23) = 13.170$$

$$Q = 143.28 + \underset{(0.0079)}{0.0060P} - \underset{(0.235)}{0.637m} - \underset{(0.186)}{0.912M} \qquad R^2 = 0.546 \quad F(3,22) = 8.809$$

All four relationships are significant, and the fourth one has the highest explanatory power. However, it has one coefficient that is not significantly different from zero, so it is equivalent to the third expression, which is therefore the best of the four. It should be noted that all four have reduced

explanatory power compared to their counterparts with New York City data included - especially the first relationship, the basis of the TSC analysis. Comparing the "equations of best fit" with and without New York City data, it is seen that not much explanatory power is lost, but the parameters have changed markedly. This would not have happened if water use behavior in New York City were similar to the average behavior in the other twenty-six cities. A statistical regression is nothing more than a complex way of describing the average characteristics of a group. If a typical member of that group is removed, the group as a whole is much the same, and the statistical regression would not change substantially. But if the deleted member is markedly unlike the others, its absence will change the average of those that remain. Such is the case here. The conclusion that may be drawn from this is that New York City is fundamentally different from the other cities in the sample, and cannot meaningfully be included with them in a simplistic framework such as this one.

(4) With the revised data on population and water use (for which AWWA or NEWS data was used where available), the four relationships were as follows with New York City included:

$$Q = 84.13 - \underset{(0.121)}{0.324M} \qquad R^2 = 0.205 \quad F(1,28) = 7.207$$

$$Q = 70.78 + \underset{(0.0058)}{0.0087P} - \underset{(0.139)}{0.213M} \qquad R^2 = 0.267 \quad F(2,27) = 4.911$$

$$Q = 86.33 - \underset{(0.2244)}{0.0309m} - \underset{(0.163)}{0.338M} \qquad R^2 = 0.205 \quad F(2,27) = 3.487$$

$$Q = 79.64 + \underset{(0.006)}{0.010P} - \underset{(0.230)}{0.154m} - \underset{(0.164)}{0.269M} \qquad R^2 = 0.279 \quad F(3,26) = 3.356$$

All four relationships are significant at the 5 percent level (i.e., the probability that the true "relationship" is actually random is less than 5 percent). By contrast, however, all of the expressions previously arrived at were significant at the 1 percent level. Correcting the data has caused the "goodness of fit" to suffer. In any of these four expressions, only the metering ratio has a coefficient significantly different from zero, so the best of these four is the first one. It should be noted that the coefficients are notably different than they had been with the original data, and barely one-fifth of the variation in per capita water demand is explained.

With New York City deleted from the analysis, the situation worsens further:

$$Q = 91.60 - \underset{(0.180)}{0.424M} \qquad R^2 = 0.188 \quad F(1,24) = 5.556$$

$$Q = 84.01 + \underset{(0.0088)}{0.0085P} - \underset{(0.184)}{0.388M} \qquad R^2 = 0.219 \quad F(2,23) = 3.233$$

$$Q = 106.81 - \underset{(0.259)}{0.243m} - \underset{(0.203)}{0.512M} \qquad R^2 = 0.218 \quad F(2,23) = 3.203$$

$$Q = 98.64 + \underset{(0.0089)}{0.0079P} - \underset{(0.261)}{0.225m} - \underset{(0.209)}{0.473M} \qquad R^2 = 0.245 \quad F(3,22) = 2.379$$

Now, only the first expression is significant at all, even at the 5 percent level, and its explanatory power is so poor as to make it of little use for predicting the response of residential water demand to metering. It was concluded that other factors affecting water use are at work, factors strong enough to overwhelm the influence of metering. The next step in the analysis, then, was to add more variables to account for the social, economic, and climatic differences among the cities in the sample.

Census data was collected for each of the cities in the sample on its unemployment rate in 1960, and average annual precipitation. The former differentiates among cities on the basis of their relative economic status; the latter measures differences in climate. Excluding New York, to avoid biasing the sample with strongly atypical data, the twenty-six cities were broken into smaller groups on the basis of population, percent of population in multiunit structures, unemployment rate, and precipitation. The specific categories were:

population
- low = less than 400,000 (9 cities)
- med. = 400,000 - 700,000 (11 cities)
- high = more than 700,000 (6 cities)

percent in multiunit structures
- low = less than 25 percent (7 cities)
- med. = 25-50 percent (13 cities)
- high = more than 50 percent (6 cities)

unemployment rate
- low = less than 4.5 percent (6 cities)
- med. = 4.5-6 percent (11 cities)
- high = more than 6 percent (9 cities)

precipitation
- low = less than 30 in./yr. (9 cities)
- med. = 30-40 in./yr. (11 cities)
- high = more than 40 in./yr. (6 cities)

This resulted in a total of twelve smaller samples, each of which was relatively homogeneous with respective to one discriminating variable. The only expression that had proven significant with the revised data, without New York City, was the original simple regression between per capita demand and the metering ratio. Consequently, this type of expression was fitted to each of the twelve data subsets. The results were as follows:

all cities:	$Q = 91.60 - 0.424M$ (0.180)	$R^2 = 0.188$ $F(1,24) = 5.556$ (sig.)
low population:	$Q = 63.79 - 0.085M$ (0.371)	$R^2 = 0.0073$ $F(1,7) = 0.052$ (not sig.)
med. population:	$Q = 112.6 - 0.670M$ (0.326)	$R^2 = 0.319$ $F(1,9) = 4.216$ (not sig.)
high population:	$Q = 70.75 - 0.131M$ (0.428)	$R^2 = 0.023$ $F(1,4) = 0.094$ (not sig.)

Variations in the metering ratio explain virtually none of the variation in water use in the smallest and largest cities, and significant relationships were not obtained. The expression for mid-sized cities is likewise not significant, although it is better than the others. Since water use in the three classes of cities does seem to be at different levels (as indicated by the constant term in each expression) but is not significantly related to the metering ratio in any of the three, it could be concluded that the apparently significant relationship for all 26 cities may result from causes other than their different levels of metering.

Classifying by percent of population in multiunit dwellings yielded the following:

all cities:	$Q = 91.60 - 0.424M$ (0.180)	$R^2 = 0.188$ $F(1,24) = 5.556$ (sig.)
low multiunit:	$Q = 70.06 - 0.173M$ (0.459)	$R^2 = 0.028$ $F(1,5) = 0.143$ (not sig.)
mid. multiunit:	$Q = 140.9 - 1.06M$ (0.24)	$R^2 = 0.645$ $F(1,11) = 19.977$ (sig.)

high multiunit:	$Q = 54.43 - 0.166M$ (0.303)	$R^2 = 0.070$ $F(1,4) = 0.300$ (not sig.)

Again, the relationships are different in the three classes of cities, indicating that water use behavior does in fact vary with the multiunit nature of the housing. The expression for all cities seems to be dominated by the significant relationship found in the mid-multiunit class of cities, since the other two groupings exhibit no such relationship. The reason for this may be made more clear by considering that the metering ratio is negatively related to the prevalence of multiunit dwellings, even under universal metering. This is because individual apartments are not metered, so that the more there are in a city, the lower the ratio of meters to dwelling units must be. For the 26 cities in question, a regression of M on m yields:

$M = 89.86 - 0.592m$ (0.230)	$R^2 = 0.216$ $F(1,24) = 6.618$ (sig.)

confirming the premise. In this context, the regressions of the three groups displayed above are amenable to the following interpretation: incremental changes in the metering ratio have little effect on water use when the existing metering ratio is high (low percentage of population in multiunit dwellings and high proportion of services metered) or low (high percentage in multiunit dwellings and low proportion of services metered). In the first case, most of the dwelling units would be already metered and further increases in metering could have little effect. In the second case, most of the dwelling units would be apartments, for which water use is insensitive to metering, because of the lack of dispensable outdoor water uses and the fact that individual apartments are not metered or billed for water use. Again, incremental changes in metering would have little effect. Only in intermediate situations would changes in the metering ratio affect residential water use.

Grouping cities by their unemployment rate produced the expressions below:

all cities:	$Q = 91.60 - 0.424M$ (0.180)	$R^2 = 0.188$ $F(1,24) = 5.556$ (sig.)
low unemployment:	$Q - 150.0 - 1.17M$ (0.15)	$R^2 = 0.941$ $F(1,4) = 64.212$ (sig.)

mid. unemployment:	$Q = 63.07 - 0.074M$ (0.228)	$R^2 = 0.011$ $F(1,9) = 0.104$ (not sig.)
high unemployment:	$Q = 58.29 - 0.058M$ (0.354)	$R^2 = 0.0038$ $F(1,7) = 0.027$ (not sig.)

As in the previous case, the relationship for all cities is dominated by a highly significant relationship in only one group. This suggests that water-saving practices pursuant to metering - repair of domestic and municipal leaks, installation of water-conserving plumbing fixtures, etc. - can only be implemented in a full-employment economy; otherwise the necessary financial resources (personal as well as governmental) are lacking.

Finally, grouping the cities according to their average annual precipitation produced the following:

all cities:	$Q = 91.60 - 0.424M$ (0.180)	$R^2 = 0.188$ $F(1,24) = 5.556$ (sig.)
low precip.:	$Q = 132.3 - 1.060M$ (0.386)	$R^2 = 0.518$ $F(1,7) = 7.527$ (sig.)
mid. precip.:	$Q = 61.30 - 0.004M$ (0.204)	$R^2 = 0.000049$ $F(1,9) = 0.000$ (not sig.)
high precip.:	$Q = 72.42 - 0.199M$ (0.239)	$R^2 = 0.147$ $F(1,4) = 0.691$ (not sig.)

Here also the aggregated relationship is dominated by a significant expression in only one group. This result is explained by the much greater importance of outdoor uses such as lawn sprinkling in domestic water use in arid climates. Outdoor uses were found by Howe, et al., and other investigators to be much more responsive to metering than inhouse uses such as cooking, washing, etc., which are substantially the same in metered and nonmetered areas. It follows that residential water use would be more responsive to metering in dry areas than in comparatively moist climates, where lawn sprinkling would be a much smaller proportion of total residential annual demand.

3. Application of Findings

New York City is characterized by 80 percent of its population living in structures of two or more units, an unemployment rate hovering around ten percent with little prospect of falling in the near future, and comparatively high average precipitation that is well distributed over the course of the year. Both theory and experience elsewhere predict that water use in multiunit dwellings is not responsive to metering, and the finding of this study with regard to percent of population in multiunit dwellings is consistent with this. Therefore, one would expect that, in New York City, only water use by one or two-unit building residents would be responsive to metering, because of expendable outdoor water uses.

Part A of this chapter, Water Use and the Nature of Housing in N. Y. C., presented evidence that such residents are more sensitive to water use than apartment dwellers, and in fact use only about half as much water per capita. It was inferred from the latter finding that outdoor uses of water are not important even for detached housing in New York City. This conclusion is strengthened by the effect of New York's relatively abundant rainfall. The impact of metering in New York, therefore, will be minor.

The findings of this study permit estimation of an upper limit on water savings from metering. Conceptually, New York can be thought of as two coterminous sub-cities, one with all multiunit housing and one with no multiunit housing. It is clear from the findings that metering will be effective, at best, only in the latter sub-city. If it is assumed for the moment that other conditions are such as to permit a maximum response to metering (i.e., low unemployment rate and low average annual precipitation), it is possible to estimate the probable water use reduction. The unrealistically optimistic assumptions for the no-multiunit sub-city may be considered to balance the possibly pessimistic assumption of no response in the all-multiunit sub-city.

Based on New York City housing data for 1974 (see Table II-E-4 on p. II-E-17), the metering ratio in the no-multiunit sub-city in a condition of universal metering, expressed as a percent, would be 73.2. The expression for the greatest effect of the metering ratio on per capita use, among cities categorized by percent of population in multiunit housing, was

$$Q = 141 - 1.06M,$$

which says that $Q = 141$ if $M = 0$ and $Q = 63$ if $M = 73.2$. The proportional reduction caused by going from $M = 0$ to $M = 73.2$ is

$$1 - \frac{63}{141} = 1 - 0.45 = 0.55$$

Per capita use in the no-multiunit sub-city was 64.4 gpcd in 1974. The reduction would be (0.55)(64.4) = 35.4 gpcd. Since this sub-city comprises 38 percent of the population of New York City, and since it has been assumed that there would be no reduction in the all-multiunit sub-city, the City-wide reduction in per capita use would be

$$(0.38)(35.4) + (0.62)(0) = 13.5 \text{ gpcd.}$$

This corresponds to a total use reduction of 107 mgd.

This reduction of 107 mgd is 12.1 percent of total 1974 residential use. It can be assumed as an approximation that the metering saving will be the same constant percent of residential water use in future years, and that the 1974 proportion of residential use to total water use in New York City (61.3 percent) will likewise remain unchanged. Based on revised NEWS Study projections of future water demand in New York City, then, it can be concluded that metering could save not more than 111 mgd in the year 2000, and 116 mgd in 2020.

It must be emphasized that these figures are an absolute upper limit that would be impossible to realize in practice. They implicitly assume that the unemployment rate in New York is less than four percent, when in fact it is around ten percent; they assume that New York's average annual precipitation is less than 25 inches, when in fact it is over 42 inches. The statistical analysis performed in this study indicates that actual conditions in New York City militate strongly against the potential water saving being realized.

4. Summary and Conclusions

Statistical analysis of water use and metering by the Temporary State Commission was reviewed and found to contain data of questionable quality. With revised data and expanded analysis, it was found that, over the entire 26-city sample, per capita residential water use has a significant negative relationship with the metering ratio. The explanatory power of this relationship was low, however. Better statistical expressions were obtained by breaking the total sample into groups based on percent of population in multiunit structures, unemployment rate, and average annual precipitation. The results indicate that metering has the least impact in areas with the greatest proportion in multiunit structures, the highest unemployment rate, and the most rainfall.

To apply the analytical findings to New York City, the city was conceptually divided into all-multiunit and no-multiunit sub-cities. Consideration of the findings and the relevant characteristics of New York led to the conclusion that the all-multiunit sub-city would have no reduction in water use with universal metering, and the no-multiunit sub-city would have a maximum reduction of 35.4 gpcd, given extreme favorable assumptions. This would correspond to a City-wide reduction of 13.5 gpcd, or 107 mgd, for 1974 water use levels, 111 mgd for 2000 use levels, and 116 mgd for 2020. The required favorable assumptions, however, do not correspond to New York City's actual characteristics, and under realistic circumstances there is little a priori reason to expect the potential savings to be realized. Consequently, based upon consideration of this matter by State and local representatives, an estimate of 50 mgd was assumed for planning purposes.

This implies that universal metering would be better justified on grounds other than water use savings. Metering would promote equity and efficiency of water supply system operation, by requiring all customers to pay in direct proportion to their use, and by providing a management tool for accounting for water use patterns. It could possibly be useful as an adjunct to leakage control in the water supply distribution system, by identifying areas of anomalously high water use. It would also provide a marginal revenue increase to the city, since flat-rate residential customers pay an effective "price" for water that is, on the average, about 60 percent of the metered rate. (Conversely, of course, residential water bills would increase about 75% on the average.) Finally, it is important as a symbolic affirmation of the conservation ethic.

These benefits are, however, difficult to quantify, and are of little relevance to the development of the physical requirements and costs of a metering program, for which a particular water supply saving is needed. Considering the uncertainty surrounding the amount of such a saving, it is appropriate to use alternative levels of 50, 100, and 125 mgd to evaluate metering program costs.

C. A RESIDENTIAL METERING PROGRAM FOR NEW YORK CITY

A comprehensive program for universal metering of all New York City residences was prepared in October 1964 by Armand D'Angelo, then Commissioner of the Department of Water Supply, Gas and Electricity. Tables II-E-7 through II-E-10 summarize the physical requirements and estimated costs of that program.

This program can be updated in two respects: accounting for the increase in the number of buildings to be metered over 1964-1974, and the increased level of costs over the same period.

TABLE II-E-7

1964 Report on Universal Metering

UNIVERSAL METERING: NUMBER OF BUILDINGS AND REQUIRED METER SIZES

Buildings By Families	Required Meter Size	Manhattan	Bronx	Brooklyn	Queens	Richmond	Total
1 & 2	3/4"	2,260	36,300	161,800	103,400	32,300	336,060
1 & 2 *	1"	-	12,000	16,800	22,100	3,000	53,900
3 & 4	1"	4,640	8,800	44,700	3,466	425	62,031
5 - 20	1½"	20,279	5,430	22,400	6,900	140	55,149
21 - 50	2"	4,909	4,990	3,420	4,150	25	17,494
51 -120 (COMPOUND)	3"	1,637	1,879	1,620	600	10	5,746
121 -300 (COMPOUND)	4"	655	191	185	230	8	1,269
Over 300 (COMPOUND)	6"	103	10	10	4		127
TOTALS		34,483	69,600	250,935	140,850	35,908	531,776

* With flushometers.

TABLE II-E-8

1964 Report on Universal Metering

UNIVERSAL METERING: COST OF METERS & INSTALLATION*

Meters to be Purchased by City - Installation by Contract

Meter Size	Quantity	Installation Cost	Total
3/4"	336,060	$ 75.00	$25,204,500.00
1"	115,931	100.00	11,593,100.00
1½"	55,149	200.00	11,029,800.00
2"	17,494	265.00	4,635,910.00
COMPOUND 3"	5,746	750.00	4,311,500.00
COMPOUND 4"	1,269	1,125.00	1,427,625.00
COMPOUND 6"	127	2,135.00	271,145.00
		GRAND TOTAL....	$58,473,580.00

* See Breakdown of Costs.

TABLE II-E-9

1964 Report on Universal Metering

UNIVERSAL METERING: BREAKDOWN OF ESTIMATED COST TO CITY FOR METERS & INSTALLATION

Meter Size	Meter Cost	Labor Cost	Material Cost*	Total Cost
3/4"	$ 40.00	$ 20.00 (1½ hrs.)	$ 15.00	$ 75.00
1"	60.00	20.00 (1½ hrs.)	20.00	100.00
1½"	110.00	60.00 (3 hrs.)	30.00	200.00
2"	165.00	60.00 (3 hrs.)	40.00	265.00
COMPOUND 3"	440.00	120.00 (6 hrs.)	190.00	750.00
COMPOUND 4"	735.00	120.00 (6 hrs.)	270.00	1,125.00
COMPOUND 6"	1,560.00	120.00 (6 hrs.)	455.00	2,135.00

* Includes: 20% for Overhead and Profit, Meter Test Fee, and By-Pass for Compound Meters.

TABLE II-E-10

1964 Report on Universal Metering

UNIVERSAL METERING: ADDITIONAL PERSONNEL & EQUIPMENT

	Manhattan	Bronx	Brooklyn	Queens	Richmond	Meter Test	Total
Inspectors	7	16	45	32	6	8	114
Clerks	3	8	21	17	2	2	53
Laborers	-	-	-	-	-	2	2

114 Inspectors	@ $5,450 per annum	$621,300.00
53 Clerks	@ $3,500 per annum	185,500.00
2 Laborers	@ $5,360 per annum	10,720.00
TOTAL ANNUAL COST - ADDITIONAL PERSONNEL		$817,520.00
ESTIMATED COST FOR NEW METER TESTING STATION & EQUIPMENT		$150,000.00

Table II-E-11 presents the housing inventory in New York in 1974, as extracted from the Department of Buildings Annual Report for that year. To obtain an updated estimate of the number of meters required, it was assumed that the growth within each overall building size category (i.e., one-and-two-unit, and multiunit) was uniform, so that the required number of meters of the various sizes would have increased in the same proportion as the number of buildings in the overall categories. This leads to the following estimate of the number of meters required:

buildings by unit	required meter size	1964 estimate	growth factor	1974 estimate
1 and 2	3/4"	336,060	1.5734	528,770
1 and 2*	1"	53,900	1.5734	84,808
3 and 4	1"	62,031	0.8956	55,558
5-20	1½"	55,149	0.8956	49,394
21-50	2"	17,494	0.8956	15,669
51-120	3"**	5,746	0.8956	5,146
121-300	4"**	1,269	0.8956	1,136
over 300	6"**	127	0.8956	114
		531,776		740,597

* with flushometers
** compound meters

The 1974 items may not sum up to the total due to rounding. It is to be noted that the housing mix has shifted toward one-and-two-unit structures, with an absolute decrease in the number of multi-unit buildings.

The increase in costs may be most simply approximated by the change in the Engineering News Record (ENR) Skilled Labor Cost Index for New York City. This is applied to the purchase cost of the meters as well as to their installation labor cost for lack of a more specifically appropriate index, and because the meters are built with skilled labor. This index, for which 1967 = 100, stood at 85 in December 1964 and 179 in December 1974, corresponding to a growth factor of 2.106. This produces the following estimated 1974 installation costs, assuming large-lot purchase of meters by the city and installation by contract, as in the D'Angelo report. (See page II-E-44.)

TABLE II-E-11

HOUSING INVENTORY - 1974

Buildings

	1-unit	(%)	2-unit	(%)	multi-unit	(%)	TOTAL	(%)
Bx	30895	40.8	25838	34.2	18877	25.0	75610	100
Bk	92660	35.7	104363	40.3	62199	24.0	259222	100
Mh	8909	24.9	923	2.6	25919	72.5	35751	100
Qu	203755	67.6	78738	26.1	19138	6.3	301631	100
Rd	53098	77.6	14400	21.1	885	1.3	68383	100
NYC	389317	52.5	224262	30.3	127018	17.2	740597	100

Dwelling Units

Bx	30895	6.1	51676	10.2	423611	83.7	506182	100
Bk	92660	10.2	208726	23.1	602751	66.7	904137	100
Mh	8909	1.3	1846	0.3	684334	98.4	695089	100
Qu	203755	30.0	157476	23.2	318931	46.8	680162	100
Rd	53098	54.1	28800	29.3	16317	16.6	98215	100
NYC	389317	13.5	448524	15.6	2045944	70.9	2883785	100

Source: NYC Dept. of Bldgs. Annual Report

Meter Size	Quantity	Installation Cost	Total Cost
3/4"	528,770	$ 158	$ 83,515,000
1"	140,366	211	29,559,000
1½"	49,394	421	20,804,000
2"	15,669	558	8,744,000
3"*	5,146	1579	8,128,000
4"*	1,136	2369	2,691,000
6"*	114	4496	513,000
TOTAL	740,597		$153,954,000

* compound

In addition, the D'Angelo report stated that a new meter testing shop would be required, along with associated equipment, to handle the maintenance of the vastly increased number of meters. The 1964 capital cost of this shop was estimated to be $150,000. The ENR Construction Cost Index for New York City was 91 in December 1964 and 185 in December 1974, a growth factor of 2.033. Applying this to the $150,000 cost of the testing shop gives an estimated 1974 capital cost of $305,000.

The capital cost of the universal metering program would therefore be $154,259,000 at December 1974 cost levels. This corresponds to a capital cost per mgd of $3,085,180 at an assumed yield of 50 mgd, $1,542,590 per mgd at a yield of 100 mgd, and $1,234,072 at a 125 mgd yield.

Annual program costs consist essentially of debt service, and personnel costs for meter reading and maintenance. Debt service is computed under the assumptions of: (1) a 35-year payback period with equal annual amortization, and (2) an interest rate of 6.14 percent (an average 1974 municipal bond rate derived from the Bond Buyer's Index of municipal bonds). In addition, annual costs are computed at 8.5 and 10 percent, to reflect current conditions in the regional financial markets, for purposes of comparison.

Personnel costs in Table II-E-10 are updated by application of the ENR Skilled Labor Cost Index, as previously described.

Annual program costs at December 1974 cost levels are therefore as follows:

	at 6.14% per year	at 8.5% per year	at 10% per year
debt service	$10,815,000	$13,913,000	$15,995,000
personnel	1,722,000	1,722,000	1,722,000
TOTAL	$12,537,000	$15,635,000	$17,717,000
cost per million gallons:			
at 50 mgd	$688	$858	$970
at 100 mgd	$344	$429	$485
at 125 mgd	$275	$343	$388

The analysis in the previous sections of this chapter led to the conclusion that the impact of metering on water use would be limited to one and two-unit residential structures, although equity requires that multiunit buildings be metered as well. One and two-unit buildings comprise 83 percent of the residential structures (and, therefore, new metering connections) in the city. It is suggested that metering proceed concurrently in each borough, with the extent of effort proportioned according to the number of one and two-unit structures in each. The order of resource allocation for metering would therefore be: Queens, Brooklyn, Richmond, the Bronx, and Manhattan. Within each borough, priority should be given to metering single-unit structures, followed by two-unit and then multiunit structures. The program should be scheduled for completion within a ten-year period, requiring about 74,100 new meter connections per year.

It should be noted that the City Administrative Code provides for metering of multiple dwellings by resolution of the Board of Estimate. Metering of one and two unit structures, however, would evidently require amendment of the Code. Such action, and any other necessary legal or administrative changes, would therefore be of first priority.

It was estimated by the Temporary State Commission that 92 percent of the water use in the New York part of the NYMA outside New York City is already metered. The water saved by metering the remainder would be of little magnitude in regional terms. However, metering can be justified (non-quantitatively) in terms of benefits of equity and managerial efficiency in each water system. Accordingly, it is believed advisable that universal metering be required to be undertaken by any municipality or utility using water supplied from either the New York City system or any regional project that may be built.

CHAPTER 3. CONTROL OF DISTRIBUTION SYSTEM LEAKAGE IN N.Y.C.

A. INTRODUCTION

For the past several years, New York City has not had a regular work force to systematically survey its water distribution system for leaks. Such a force did exist in the past, with varying levels of manpower and geographical scope. It has been suggested throughout the literature that the City's water consumption could be materially reduced by a full-scale resumption of this effort. The Temporary State Commission on the Water Supply Needs of Southeastern New York, which made the most current analysis of this question, concluded that total distribution system leakage was approximately 6 percent of total consumption, or 84 mgd in 1970, of which 3 percent, or 42 mgd, was deemed controllable. However, neither the level of effort nor costs for such a program were estimated.

The actual total amount of leakage in New York cannot be determined, since leaks are detected only when they manifest themselves visibly. It seems likely that many leaks from pipes of 8 inches diameter or less, which comprise 56 percent of the total mileage of water mains, would not surface, but would be absorbed by the natural hydrologic system underlying the city. This supposition is reinforced by data from annual reports of the Department of Water Supply, Gas and Electricity (now the Department of Water Resources), indicating that, in general, approximately as much waste from leakage was discovered by systematic survey as was discovered by citizen complaints.

In the past, other investigators have attempted to estimate the potential water savings from a systematic, city-wide leakage detection and control effort by referring to the experience of other cities. The 1951 report Future Water Sources of the City of New York, for example, compared New York to Chicago and Detroit.

However, the water distribution systems of large cities differ greatly in age, size, physical characteristics, natural hydrology and climate, and efforts to control leakage have had widely varying degrees of success. Because of these fundamental differences, it is considered more meaningful in this investigation to extrapolate on previous experience in New York City.

B. PREVIOUS EFFORTS IN NEW YORK CITY

In mid-1953, systematic leakage control surveys were expanded from coverage of Manhattan and the Bronx to include all five boroughs. In 1954, the first full year of such work, sixteen work gangs were operating on survey and complaint work:

five in Manhattan, four in Brooklyn, three each in the Bronx and Queens, and one in Richmond. Each gang averaged five workers. The personnel roster included:

1	Civil Engineer
1	Assistant Engineer
5	Junior Engineers
5	Foremen
7	Caulkers
17	Auto-Enginemen
47	Laborers
1	Clerk

Approximately 75 percent of the force's time was given over to survey work, consisting of aquaphone investigation of pipelines, hydrants, and service connections. The accomplishments of the force in 1954 are summarized in Table II-E-12.

The assumption that uncorrected leaks would continue for an average of two years is used consistently in the City reports, and is based on the experience that some leaks surface almost immediately, while others can persist for many years before correction. The average leak lifetime was estimated, evidently on a rule-of-thumb basis, to be two years. This assumption is adopted in this analysis for lack of evidence to the contrary.

TABLE II-E-12

CLASSIFICATION OF LEAKS STOPPED (1954)

Source: N.Y.C. D.W.S.G.E. - Underground Leakage Control Surveys Ann. Reprt.

Type	No. of Leaks	%	Amount of Leakage Located & Stopped (1000 GPD)	%
Live Services	160	14.06	8931	14.25
Abandoned Services	23	2.02	1521	2.43
Inside Plumbing	93	8.17	923	1.47
Joints on Main	292	25.68	39459	62.99
Broken Mains	10	.87	5439	8.67
Gates	125	10.98	1222	1.95
Hydrants	399	35.06	408	.67
Miscellaneous	36	3.16	4758	7.57
TOTALS	1138	100.00%	62671	100.00%

TABLE II-E-12 CONT'D

Total amount of leakage located and stopped (GPD)	62,671,000
Number of leaks located and repaired	1,138
Number of street openings made	527
Average size of leaks stopped (GPD)	56,000

COST

Salaries and wages	$317,216.00
Transportation and Compressor	27,300.00
Supplies (Estimated)	2,400.00
Total Cost	$346,916.00

Economic Value of Water Saved. Assuming that the leaks stopped would otherwise have continued for an average of two years: $9,150,000.00

Cost of Saving a Million Gallons. Assuming that the leaks stopped would otherwise have continued for an average of two years: $7.81

C. A LEAKAGE CONTROL PROGRAM FOR NEW YORK CITY

This actual performance may be related to present potential performance by taking into account the expansion of the city's distribution system in the intervening years, and the general increase in costs over the same period. In the first case, it can be assumed as a working hypothesis that average leakage per mile of main is a constant. It can further be assumed that the average efficiency of leak detection has increased to some degree, although probable improvements in techniques are balanced against the lack of experienced workers to apply them. It follows that as a first approximation, potential productivity of a leak detection force has increased in about the same proportion as the total mileage in the system. On the basis of annual reports, this mileage was about 5,400 in 1954, and 6,100 in 1974. The current potential yield of a leak detection program, as of 1974, would therefore be:

$$(62.7 \text{ mgd}) \times \frac{6100}{5400} = 70.8 \text{ mgd.}$$

The annual cost of this effort can be updated on the basis of Engineering News Record (ENR) cost indices. The Skilled Labor Index for New York City was 52 as of December 1954, and 179 as of December 1974. (These indices are based on 1967 = 100.) The Common Labor Index went from 43 to 180 over the same twenty-year interval. The cost of skilled labor therefore increased by a

factor of 3.44, and the cost of common labor by a factor of 4.19. Since common labor represented about 60 percent of the total, the weighted average cost increase factor was 3.89. Since no readily available index exists for the cost of the equipment and supplies used, this increase factor was applied to all of the cost items, yielding an annual cost of $1.35 million. Adopting the assumption used in the past, that leaks discovered would otherwise continue for an average of two years before their eventual correction, this total cost of $1.35 million to arrest 70.8 mgd of leakage is equivalent to $19,061 per mgd, or $26.11 per million gallons.

These calculations, it should be noted, apply to the first year of operation of a city-wide leakage control force. Whether this level of performance would be consistent over time is difficult to judge. On the one hand, increasing experience and proficiency of the workers over time could improve the overall efficiency of the operation; on the other hand, the most significant existing leaks would probably be among the first to be detected, leaving only those comparatively minor leaks that crop up consistently, and unavoidably, over time. (In this sense, an eventual fall-off in the total volume of leaks corrected would be a positive indication of the force's performance.) The level of residual annual leakage was estimated by the Temporary State Commission to be half of the total. Discussion with State and City officials indicated that, other things being equal, the volume of leakage corrected annually would decline over time to a residual level of about 25 mgd. Considering the efficiency of the previous leakage control efforts, it can reasonably be assumed that this equilibrium level would be reached in the third year of operation.

For future savings from leakage control, it could be assumed that the volume of leakage corrected would be proportional to the total mileage of mains in the distribution system. There is, however, little prospect for further growth of system mileage, and technological improvements in leak detection and in the mains themselves - such as the recent use of rubber-jointed ductile iron pipe - may well reduce the leakage per mile. Accordingly, it is assumed that the equilibrium leakage control saving of about 25 mgd will remain constant in the future.

Universal metering of all residences could possibly aid a leakage control effort by identifying areas of unusually high water use. In particular, if master meters are also put on the mains (which is not a part of any recently proposed metering program), comparison of the volume of water entering a district with the volume of water used, perhaps by computer analysis of customer bills, could narrow the area of search for suspected

leaks, and improve the efficiency of the effort. However, this could involve pressure losses to customers, and the added logistical and cost problems of obtaining timely and accurate data and analysis from several hundred thousand service and master meters. While a comparative cost analysis has not been done, and would be highly speculative in any case, it may turn out to be simpler and cheaper to hunt for distribution system leaks by the more traditional systematic search procedures.

To summarize, analysis and updating of information on a previous city-wide effort to detect and control leaks indicates that such an effort, if undertaken now, could reduce total water use by about 71 mgd in the first year, declining in the third year to 25 mgd. Slower growth in the distribution system and improved technology would hold this level of saving constant through 2020. At December 1974 cost levels, the first year would cost $1.35 million, or about $26 per million gallons saved. If the program were begun in 1976, then by 1978 the cost per million gallons would be about $74 at December 1974 cost levels. (If skilled labor costs in the New York area continue their present 5.4 percent rate of annual increase, however, the 1978 cost per million gallons would be about $85 at 1978 cost levels.)

Since leakage control is cost-effective for almost any reasonable valuation placed on the water saved, it is apparent that a city-wide program of leakage surveys and correction should be undertaken, with an organization and at a level of effort at least commensurate with similar programs pursued twenty years ago. This would comprise a force of about 80 persons, with associated equipment and supplies.

Although detailed analysis has not been performed on leakage control for areas outside of New York City, it is highly probable that such efforts would be similarly beneficial. It is therefore suggested that an ongoing leakage control program be required to be initiated by any municipality or utility that uses water supplied from either the New York City system or any regional project that may be built.

CHAPTER 4. PRICING AND WATER DEMANDS IN NEW YORK CITY

A. INTRODUCTION

Using the price of water to help reduce water demand must be evaluated as part of a potential water conservation program for the NYMA. The general theoretical arguments have been explored and the available literature reviewed. The theory indicates that the effect of a price increase on domestic use would be minor and the literature reviewed supports this conclusion. However, before applying this result to New York City it was necessary to estimate the potential consumer response to a price change (price elasticity of demand). This estimation involved an attempt to apply a widely acceptable model of domestic demand to the New York City area - the Howe and Linaweaver model. Subsequently, attempts were made to estimate price elasticity for New York City. Finally, the implications of utilizing pricing as a water conservation policy were evaluated.

B. THEORY OF CONSUMER BEHAVIOR

In principle, water can be treated like any other commodity for the purpose of analyzing the response of consumption patterns to changes in price. A brief description of some key concepts will provide some context for the empirical work described below.

A consumer's response to a change in the price of a commodity, all other things being equal, consists of an income effect and a substitution effect. If the price goes up, for instance, he will have less income at his disposal and will consume less of everything; at the same time he will try to switch his consumption away from the commodity whose price has risen, toward other commodities that can substitute for it. (One such "substitute," of course, is simply doing without the item in question.) How much the pattern of consumption changes, then, depends on two critical factors: how important the commodity is in the consumer's total budget (the strength of the income effect), and whether reasonable substitutes exist for that commodity. The consumer's response to a given price change is greater over the long term than it is in the short run, because he can modify his lifestyle more and more as time passes. These considerations apply equally as well to a business firm as to an individual consumer or a family.

The response of consumption to a change in income or commodity price is measured by its elasticity. The price elasticity of consumption is defined as the percent change in consumption resulting from a given percent change in price, or

$$\varepsilon = \frac{\Delta Q/Q}{\Delta P/P}$$

Income elasticity is defined in a similar way.

Since price and demand move in opposite directions, price elasticity is a negative (and dimensionless) number that can vary from zero to minus infinity. If elasticity is between 0 and -1, consumption is said to be inelastic, because a change in price causes a less-than-proportional change in quantity demanded. Similarly, an elasticity with a larger negative number than 1 (such as -2) means that a change in price causes more-than-proportional change in quantity demanded, and such demand is said to be elastic. Income elasticities are perfectly analogous, except that they are usually positive numbers (since income and consumption usually move in the same direction).

A number of studies have been conducted to determine whether domestic water use follows the predictions of the theory of consumer choice briefly described above. The studies reviewed were representative of various locational characteristics and present a reasonably complete picture of the results.

The studies reviewed indicate several major conclusions:

1. Domestic in-house water use is not sensitive, to any great extent, to changes in the price of water over a reasonable range.

2. Apartment dwellers, whose apartments are not individually metered, are not responsive to any size price change.

3. There are major questions of equity associated with very large price changes.

Furthermore, the question arises as to the applicability to New York City of the various estimates of price elasticity found in the literature.

Several problems arise in considering the results of these studies, because the real world is vastly more complex than the idealized realm of theory.

The theory of consumer behavior usually assumes "all other things being equal" - that is, that all factors capable of influencing consumer behavior, other than the price of one commodity, are assumed not to change. But these other factors, which can include the family's income, its personal tastes, the prices of other goods and services, the age and nature of its

housing, the status of the local and national economy, climate, and many others, all can vary over time and place. A great deal of care is required, in the structuring of a study and in the interpretation of its results, in order to isolate the effect of one factor with any confidence.

Theory also assumes that the consumer will act as if he has perfect knowledge of the consequences of all of his actions, and will always act in accordance with his own short run and long run best interests. In fact, the real consumer operates in uncertainty; he can be taken by surprise and exhibit temporary "shock" or "novelty" reactions that are not economically justified; and he can act in ways that do not correspond to his (economic) best interests - indeed, he may not be consciously aware of what his best interests are. If large enough numbers of people are considered, however, the individual idiosyncrasies average out, and the remaining systematic differences from the ideal situation can be identified and accounted for.

It must also be emphasized that the limitations particular to each analysis must be recognized before their results can be meaningfully interpreted and applied to any one city such as New York. One problem lies in the reliability of measuring, or even estimating, the relevant variables. Lawn sprinkling requirements, for example, depend on effective precipitation and potential evapotranspiration, which are usually not directly measured, but must be deduced from theory and indirect data. Home value, another important variable, is itself only a proxy for general economic status, and involves problems of comparability from place to place. Another problem is that any particular city has unique characteristics, and a relationship that may be completely appropriate for the nation, or a region as a whole, may not be literally correct for a given city. A house of given market value in New York City, for instance, generally has a much smaller lawn area to be watered than a similarly-valued house in the suburbs, and other water use factors may be expected to differ as well. Related to this is the fact that definitions may vary from place to place - in data compiled by New York City, "nonindustrial consumption" does not include commercial use, whereas in data compiled by most other cities it does, and it usually also includes a proportion representing municipal and institutional use and leakage that varies in size from city to city.

The point is that the reliability of using theoretical and empirical results to predict the consequences of price changes in a new situation depends on the sophistication of the model used, the availability and quality of the data, and careful attention to local idiosyncrasies that could distort the results obtained from the use of any general model.

The problem of deciding whether a price elasticity for water, developed for another area with its own set of underlying parameters (i.e., income levels, population density, climate, percent of population in multiple dwelling units, etc.) is applicable for New York is compounded by the wide range of possible values for this price elasticity. The range of estimates for various cities is detailed in Table II-E-14 and varies from -0.12 to -1.24. Consequently, a series of investigations was carried out to determine if the price elasticity of water could be estimated for New York City.

C. METHODS OF ANALYSIS

The initial work involved an attempt to apply to New York City the basic equations which Howe and Linaweaver (H&L) found to have significance for explaining water use per dwelling unit. The focus of the present analysis was on domestic consumption as opposed to commercial and industrial use. There are several reasons for this:

a. Domestic use in New York City is approximately 60 percent of the total use.

b. Exempt uses (i.e., municipal and institutional), underregistration of meters, and leakage comprise about 20 percent of the total use.

c. Commercial and industrial use, comprising about 20 percent of total use, is already metered in New York and there is strong evidence to indicate that the water use for these establishments is not price elastic. In the late 1960's the water rate to commercial and industrial users was increased from $200/million gallons to $700/million gallons with no appreciable reduction in use. This is due to the fact that the commercial and industrial use is primarily employee-related water use and freshwater used for processing. This type of use is difficult to restrict.

The H&L Model is a linear model. It is a cross-sectional model (not time variable) of the following form:

$$Q = A + BX_1 + CX_2 + \ldots$$

$X_1, X_2, \ldots, X_m$ are the independent variables and consist of recorded data. Q, the dependent variable in the equation, is the water use per dwelling unit and is also data. A, B, C, ... are the coefficients to be estimated. In carrying out the analysis, two tests of statistical significance are made. The

t-test measures the significance of the estimated coefficients and the F-test is a measure of the significance of the relationship portrayed by the estimating equation.

A t value of 2 or more usually indicates that the coefficient is significant at the 5% level. This implies that there is only a 5% chance the estimated value is not equal to the true value. The F-test has different levels which imply significance depending upon the number of variables in the equation and the number of observations.

1. Procedures

The initial item of work was the collection of data. Data was collected for each of the five boroughs in the City of New York for the Census years 1950, 1960, 1970. The following variables were those for which the information was collected:

1. Qa d = Domestic water use per dwelling unit (gals/day)
2. T = July-Aug. avg. temperature (degree F)
3. a = Percent of dwelling units less than 10 yrs old
4. dp = Average persons per dwelling unit
5. t = Time dummy variable (1950=1, 1960=2, 1970=3)
6. p = Marginal water cost (cents/1000 gals, 1970 dollars
7. Cdu = Non-metered water cost per d.u. ($/d.u./yr., 1970 dollars)
8. Cw = Non-metered average water cost (cents/1000 gals, 1970 dollars)
9. Vo = Median owner-occupied d.u. value ($1000, 1970 dollars)
10. Vr = Median renter-occ gross rent ($, 1970 dollars)
11. rp = Previous year precipitation (in.)
12. rc = Current year precipitation (in.)
13. dr = % of d.u.'s renter occupied
14. u = Unemployment rate
15. fl = Percent low income families

After the data were assembled, the estimating equation which H&L found to give the best results as an explanation of water use per dwelling unit for unmetered, flat rate areas,

$$Qad = 28.9 + 4.39V + 33.6dp,$$

did not give results which were of statistical significance. (The F test indicated that the results obtained were not significantly different from a random chance occurrence.)

Subsequently, an attempt was made to modify the H&L equation to reflect the housing mix in New York City. The V variable

was divided into its owner-occupied and renter occupied components. This equation was fitted for all of New York City for 1950, 1960, 1970 and for a combination of all 3 years. The following is a summary of the estimates obtained and their significance:

Let Qad = average daily domestic demand per dwelling unit
V = average dwelling unit value
Vo = median owner-occupied dwelling unit value
Vr = median renter-occupied dwelling unit gross rent

t = time (1950=1, 1960=2, 1970=3)

Then:

Howe & Linaweaver best fit	F	R^2	Std. Err.
Qad = 28.9 + 4.39V + 33.6dp (0.558) (8.46)	42.127	.946	23.3
NYC 1970 Qad = 843 - 4.54Vo - 1.26Vr - 92.4dp (0.121) (o.052) (4.19)	1025.847 (sig. at 5% level)	.99984	1.63
NYC 1960 Qad = 2220 - 17.4Vo - 501dp (3.46) (106)	12.624	.963	26.2
NYC 1950 Qad = 6470 - 75.2Vo - 6.74Vr - 1330dp (14.0) (2.33) (254)	9.879	.984	22.7
NYC 50+60+70 Qad = 872 - 7.35Vo - 171dp + 46.9t (3.21) (104) (29.8)	3.155	.680	48.0

It can be noted by reference to the F values, that only the second of the above equations can be, with a 5% possibility of error, considered to give reliable estimates of average water use per dwelling unit. An analysis was then made as to why the New York City 1970 equation was significant and the others were not. The reason for this lies in the nature of regression analysis. The Q variable is considered to be the dependent variable. The V's and t are the independent variables. Independent variables should have a minimum level of intercorrelation - they should not exhibit any relationship between each other. The measure of the degree of intercorrelation is the correlation coefficient. A correlation coefficient of over .60 indicates a high degree of intercorrelation and consequently the independent variables are not truly independent. This is what has happened in the

case of the New York City 1970 data. Consequently, the estimating equation developed from the H&L Model cannot be relied on as the actual one. (See Attachment II-E-2 for a summary of those independent variables which possess a high degree of intercorrelation - above .60.)

Because the relationships established were not statistically valid, the model approach had to be extended beyond what H&L considered. Variables were developed to attempt to include economic conditions and time in the analysis. The data was manipulated in several ways: 1) grouped by all three years, 2) New York City as a whole and 3) each borough was considered separately. However, in the case of five boroughs considered separately the limited number of observations made regressing more than one independent variable impossible.

Table II-E-13 summarizes the results of the statistical analysis. Only those relationships which were statistically significant are included in the table. (See Attachment II-E-2 for a table summarizing all the equations tested.) The variable numbers correspond to the list of variables on page II-E-57.

TABLE II-E-13

SIGNIFICANT ESTIMATING EQUATIONS

Independent Variable	Significant Variables	Level of Significance of the Equation	R^2	Standard Error
1970 Data				
4, 9, 10	4, 9, 10	at 5% level	.999	1.617
2, 9	2, 9	at 5% level	.961	12.47
Grouped Data				
4,5,7,8,9,10	7, 8	at 1% level	.874	27.20
5,7,8,9,10	7, 8	at 1% level	.864	26.66
5,7,8,9	7, 8	at 1% level	.857	25.88
4,7,8,9	7, 8	at 1% level	.858	25.84
4,5,7,8	7, 8	at 1% level	.853	26.29
5,7,8	7, 8	at 1% level	.850	25.27
7,8,9	7, 8	at 1% level	.855	24.86
7,8	7, 8	at 1% level	.850	24.22

Based upon an analysis of the information found in Table II-E-13 the relationships with the most statistical significance and the highest explanatory power are:

(1) 1970 Data:

$$Qa\ d = 843 - \underset{(4.19)}{92.4dp} - \underset{(0.12)}{4.54Vo} - \underset{(0.06)}{1.26Vr}$$

$R^2 = 0.99968$
$F(3,1) = 1025.847$
std. err. of est. = 1.617

(2) Grouped Data:

$$Qa\ d = 266 + \underset{(1.3)}{10.8Cdu} - \underset{(1.3)}{10.5\ Cw}$$

$R^2 = 0.85043$
$F(2,12) = 34.116$
std. err. of est. = 24.223

Considering equation (1), water use per dwelling unit varies inversely with persons per dwelling unit and with the two measures of dwelling unit value. This is exactly the opposite result that should be expected and as that obtained by Howe and Linaweaver. The result suggests that the underlying assumptions made by those investigators may not apply in New York City. In particular, it was assumed that dwelling unit value and family economic status would be closely related. This does not seem to be unambiguously true in New York, where purely locational factors make housing in Manhattan, which has a relatively high proportion of low-income families, more costly than newer housing elsewhere. Also, rent control for older units and steeply rising construction costs for new units cause housing prices to be higher in Queens and Richmond than they might be for comparable dwellings in the Bronx or Brooklyn. A further complication is a high degree of intercorrelation between dp and Vo. Based on 1970 data alone, the computed relationship cannot be relied upon.

Equation (2) is more illuminating. Water use per dwelling unit is seen to vary directly with average nonmetered cost per dwelling unit. This is to be expected, since nonmetered cost per dwelling unit is a function of frontage per dwelling unit and other factors which would vary positively with income. For an apartment dwelling, this cost would be comparatively low; in a private, single unit dwelling, which would use water for sprinkling and other outdoor uses in addition to inhouse uses, this cost would be relatively high. Nonmetered water cost per thousand gallons, however, varies inversely with water use per dwelling unit. It is tempting to identify this as a cause-and-effect, price-demand relationship, but to do so would be misleading. Apartment dwellers are not directly billed for their water use, and individual homeowners pay a single annual bill that does not vary with the quantity they use, so that this measure is not really a "price" in the usual behavioral sense. Moreover, it is very highly correlated with the water cost variable. What has been arrived at, then, is an aggregated,

purely statistical relationship that cannot meaningfully be interpreted in behavioral terms.

Based on the statistical analysis performed on New York City data, two conclusions have therefore been adduced: that the data available for New York City is not analytically comparable to data used in other analyses elsewhere; and that analysis of this data does not yield defensible conclusions about the response of water use in New York City to changes in water price.

This series of attempts to extend the H&L Model did not produce statistically significant equations. There are several reasons for this:

1. The number of data points is small, only three years: 1950, 1960 and 1970.

2. There is a high degree of correlation among many of the independent variables. (See Attachment II-E-2 for a summary of the levels of intercorrelation and a potential explanation.)

From the results of the regression analysis obtained in trying to extend the H&L Model and the analysis of the correlation among variables, it is clear that a direct extension of the H&L Model does not provide a solution to the problem.

A third approach to estimating the price elasticity of water use involves statistical analysis of price elasticities found by other investigators. Twenty-six such findings are summarized in Table II-E-14. These twenty-six elasticities have a mean value of -0.58 and a standard error of the mean of 0.07. There is, therefore, a 95 percent probability that the mean price elasticity of water use for this sample is between -0.45 and -0.71.

But this itself is a weighted average of inhouse and sprinkling uses of water. What is the price elasticity of water for inhouse uses alone, which is more pertinent to New York City? This can be estimated by making two assumptions: that outdoor water uses have a price elasticity of -1.5, and that outdoor uses are equal to indoor uses but only exist for one-third of each year - i.e., that outdoor uses comprise one-fourth of total annual domestic use. (These assumptions are consistent with the findings of Howe, et al., and others, and their precision does not materially affect the results.) In that case,

$$1/4\ (-1.5) + 3/4\ (x) = -0.58$$

TABLE II-E-14

ESTIMATED ELASTICITIES OF DEMAND FOR WATER

Investigator	Year	Type of Analysis	Price Elasticity
Gottlieb	1952	68 Kansas cities	-1.02
	1952	19 Kansas cities	-1.24
	1957	84 Kansas cities	-0.69
	1957	24 Kansas cities	-0.68
	1958	24 Kansas cities	-0.66
	1963	Kansas Cross-Sectional	-0.95 (mean)
Seidel and Baumann	1957	American cities Cross Sectional @ .45/1000 g.	-0.12
Renshaw	1958	36 Water Service Systems Cross-Sectional	-0.45
Fourt	1958	34 American cities Cross-Sectional	-0.39
Wong, et al.	1963	Northeastern Ill. Cross-Sectional	-0.31 (mean)
Heaver and Winter	1963	Ontario cities	-0.254
Hedges and Moore	1963	Northern Calif. Irrigation	-0.19
Howe and Linaweaver	1963-1965	21 Residential Domestic Public Sewers	-0.23
Gardner and Schick	1964	42 Northern Utah Water Systems Cross-Sectional	-0.77
Flack	1965	54 Western cities Cross-Sectional @ .45/1000 g.	-0.12
		All cities @ .45/1000 g.	-0.65
Ware and North	1965	634 Georgia Residences	-0.67

TABLE II-E-14 CONT'D - P. 2

Investigator	Year	Type of Analysis	Price Elasticity
Bain, Caves, and Margolis	1966	41 Northern California Cities Irrigation	-1.10 -0.64
	1966	41 California Cities Cross-Sectional	-1.099
Conley	1967	24 S. California Communities Cross-Sectional	-0.625 (mean)
Turnovsky	1969	19 Massachusetts Towns Cross-Sectional	-0.225 (mean)
Bruner	1969	Phoenix	-0.3
Grima	1970	91 Observations Cross-Sectional	-0.93
	1972	Ontario Cities Winter	-0.75
Wong	1970	Chicago, 1951-61 Time Series	-0.15 (mean)
		Four Community Size Groups Cross-Sectional	-0.54 (mean)

where x is the elasticity of inhouse water uses. Solving for x yields an elasticity of -0.27, which says that for every 10 percent increase in the price of water, inhouse water use will decrease by a little less than 3 percent.

To determine whether an elasticity of -0.27 would be appropriate for New York City, certain comparisons were made with Chicago, the city closest in size.

Studies done on the City of Chicago have indicated a price elasticity for water of about -0.15. As can be seen from Table II-E-15 the major areal characteristics and how they relate to price elasticity indicate that a comparison is viable. For example, as the percent of multiunit structures increases we would expect price elasticity to decrease. New York has a greater percent of its population in multiunit structures, so that we would expect New York's price elasticity to be lower. This is also true for median value of owner occupied dwelling units, percent of employment in manufacturing, and average annual precipitation. Consequently, while -0.27 has been calculated from our sample, it is considered an upper limit on the range of probable price elasticities for New York. The mean price elasticity in New York should, based on the above, be estimated as, at best, no greater than the -0.15 for Chicago, though it is probably smaller.

TABLE II-E-15

COMPARISON BETWEEN NEW YORK CITY AND CHICAGO

	New York City		Chicago	
	1960	1970	1960	1970
Population	7,781,984	7,894,851	3,550,404	3,362,825
% in multiunit structures	86.7	88.1	75.9	76.5
unemployment rate (%)	5.2	4.2	5.4	4.4
precipitation (in./yr.)	42.37	42.37	33.18	33.18
median fam. income ($)	6,091	9,673	6,738	10,239
% emp. in mfg.	24.9	20.6	32.3	32.0
median value owner occupied dwelling units ($)	$17,000	$25,864	$18,000	$21,290

Source: U.S. Census County and City Data Book, 1972.

D. SUMMARY AND CONCLUSION

To summarize, attempts were made to find in the literature an estimate of price elasticity which could be applied to New York City. Then the Howe and Linaweaver models were applied to New York City data, and expanded in an attempt to improve their applicability. Both of these efforts failed to yield reliable conclusions about the responsiveness of water use in this area to price changes. Accordingly, it was decided to analyze water price elasticities calculated for other areas to obtain an approximate estimate for New York. This work indicated that inhouse water uses respond poorly to changes in water price, with an elasticity of about -0.27. Further comparison of similarities between New York and Chicago indicate that an elasticity of -0.15 is a better maximum estimate for the former city.

The conclusion of this analysis is that pricing would not be an effective technique for demand reduction in New York City, which comprises a substantial portion of the water used in the NYMA. The metered water rate in New York City of 70.1 cents per 1000 gallons is already high relative to the nation as a whole and the rest of the NYMA as well. Because most City residents are apartment dwellers (in 1970, 76.4% of all occupied residences in New York City were rented), the ultimate users of water would not directly bear the brunt of price increases, so that even the low elasticity estimated above would probably not be realized in fact. Consequently, to have a sizable impact, the price of water would need to be increased in multiples of current levels to levels believed impractical to achieve.

CHAPTER 5. INDUSTRIAL CONSERVATION

A. INTRODUCTION

Another major element in a water conservation program for the New York Metropolitan Area is industrial conservation. It has been estimated that industrial withdrawal from public systems in the New York Metropolitan Area (the New York State portion only) will account for about 110 mgd in the year 2000. Therefore, a conservation program developed for this area must consider the role of industrial use.

The degree of reduction in fresh water withdrawal for industrial use results from two types of changes in industrial processes. One is a change in the technology of production (T), and the other is a change in the technology of reuse of a resource after it has been initially used in the productive process (R). The approach used was to project R and T separately and then combine the influence of both of these changes into a recirculation-technological change (RxT) factor, and apply this to projected use to get an estimated impact on the need for future withdrawals due to this type of conservation. This would allow for a comparison to the existing data on recirculation and enable the projected value to be analyzed.

The influences which determine rates of technological change that occur within the productive process are varied. These influences include: resource costs and availability; the government's position on the need for technological change (e.g., the provision of tax subsidies for research and development work); the impact of foreign competition; and the degree of competitiveness in the market. The second area of consideration is the changes that will occur in the technology of reusing resources which have already been utilized in the productive process. There are many different variables which affect this. However, the major impetus for changes in this area resides not with market factors, but with the express position that government has taken in regard to industrial discharges. The Water Resources Council, in its summary Water Use Price/Cost Sensitivity Technical Committee Report, 19 September 1975, has stated: "In the area of manufacturing water use, it was concluded that no significant reductions in water use over and above that caused by effluent controls could be achieved with any reasonable level of water price increase." A conclusion that market factors in general will not play a significant role in the rate of technological change in the area of reuse of resources appears to be reasonable.

Consequently, in developing an estimate of the recirculation-technological change factor for the New York State portion

of the NYMA the emphasis has been on consideration of the potential for increasing the R factor through government policy and/or law. Even though the market factors that determine technological change (T) have not been analyzed in detail, the implication is not that these factors will be of little value in a conservation program, but that the greatest water savings can be accomplished by altering the R factor through government policy.

1. T - Technological Change in the Productive Process

The development of an industrial water conservation program must consider the way in which water is used in production. Production techniques are primarily affected by market conditions, trends in capital formation, the age of the existing capital stock, the availability of water, and trends in industrial location.

Table II-E-16 provides the estimated T values for the New York State portion of the NYMA.

TABLE II-E-16

T FACTORS FOR NYS IN NYMA

	1980	2000	2020
FOOD	1.05	1.15	1.26
TEXTILE	1.05	1.15	1.26
PAPER	1.07	1.20	1.34
CHEMICALS	1.12	1.36	1.60
PETROLEUM	1.09	1.26	1.43
PRIMARY METALS	1.05	1.15	1.26

For example, a T of 1.05 in 1980 in the Food industry means that the water required to produce one dollar of output in this industry would be 5% less than the 1975 requirements.

As can be seen, the greatest changes are predicted to occur in paper, chemicals and petroleum. The food and textile industries use essentially fresh water for turning out finished products. The other industries have productive processes which require large amounts of cooling and/or process water in which the potential for saving is much greater. Great advances are not anticipated for the technology for reducing the amount of water used to prepare foods or textiles. Industries such as paper, chemicals and petroleum, which have experienced the greatest public pressure to recycle, require much larger amounts of water

and are projected to have the greatest rates of growth for water-saving technology.

2. R - Recirculation in Industry

The following table (Table II-E-17) summarizes the R factors which have been derived for the New York portion of the NYMA. Achieving this level of recirculation, it must be emphasized, would only be achieved by efficient implementation of Federal and state laws and/or standards regulating discharges. The level and effectiveness of these laws will depend upon the willingness and ability of the responsible agencies to enforce them. An inherent assumption in estimating the change in the R factor in New York State as a consequence of these laws and/or regulations is that the State be successful in vigorous enforcement of such laws and regulations. This assumption is based on the State's strong advocacy position on conservation, combined with the role of industrial activity in the economy of the New York State portion of the NYMA. This would result in the highest levels of recirculation occurring in the New York State portion of the NYMA.

TABLE II-E-17

R FACTORS FOR NYS IN NYMA

	1980	2000	2020
FOOD	1.09	1.43	1.71
TEXTILE	1.19	1.88	2.46
PAPER	1.10	1.53	1.87
CHEMICALS	1.53	3.38	5.02
PETROLEUM	1.35	2.58	3.66
PRIMARY METALS	1.19	1.88	2.46

B. ESTIMATED FUTURE RECIRCULATION

The combined impact of the R and T factors on water use is shown in Table II-E-18 below.

The development of a projection of future industrial demand and the impact of the RT factors in the need for publicly supplied fresh water should be considered.

TABLE II-E-18

RT FACTORS FOR NYS IN NYMA

	1980	2000	2020
FOOD	1.14	1.64	2.15
TEXTILE	1.25	2.16	3.10
PAPER	1.18	1.84	2.50
CHEMICALS	1.71	4.60	8.03
PETROLEUM	1.47	3.25	5.23
PRIMARY METALS	1.25	2.16	3.10

The projection of future industrial needs for water involved a two step procedure. Initially, based upon OBERS Series E estimates of industrial activity in FEA 14, an estimate for the amount of water necessary to sustain the projected output levels at the current technology of production and recirculation was developed. Next, this amount of water had to be allocated among potential sources of water available in the future: i.e., self-supplied or publicly supplied. Increases in R and T would allow economic activity at projected levels, with smaller inputs of fresh water used in a manner equivalent to the water needed to sustain projected development if there were no change in R and T from current levels. In effect, the need for increases in future industrial withdrawals could be reduced through R and T developments. Table II-E-19 summarizes the projected relationships between gross industrial water use, recirculation (R and T), and fresh water withdrawals from public and self-supplied sources for the New York portion of the NYMA.

The potential for reducing the rate of increase of withdrawals through industrial reuse provides the State with an opportunity to exercise considerable influence on the demand for water in the future. However, it also presents the State with a considerable enforcement responsibility if the projected levels of saving are to be met. Other local governmental units are also involved in this effort. The responsibility for regulating and monitoring industrial discharges currently resides in the New York State Department of Environmental Conservation and in the Environmental Protection Administration in New York City. These agencies are expected to continue to monitor and enforce the existing legislation.

As can be seen from Table II-E-19, the estimated increase in industrial withdrawals from public systems is about 80 percent between 1970 and 2000 even with the increases assumed in R and T over the period. (Note that further increases assumed in R and T will reduce withdrawal by an equivalent percent: e.g., a 10

TABLE II-E-19

SOURCES OF INDUSTRIAL FRESH WATER USE

	1970				2000				2020			
			fresh water withdrawal				fresh water withdrawal				fresh water withdrawal	
	gross use	recir.	pub. sup.	self sup.	gross use	recir.	pub. sup.	self sup.	gross use	recir.	pub. sup.	self sup.
NYC	489	198	44	246	836	575	30	231	1,210	966	20	224
Dutchess	3	1	--	2	13	7	3	3	28	17	6	5
Nassau	71	34	4	33	190	141	14	35	347	281	31	35
Orange	31	24	1	6	88	78	4	6	165	151	8	6
Putnam	0	0	0	0	0	0	0	0	0	0	0	0
Rockland	92	55	4	33	294	243	13	38	596	513	45	38
Suffolk	64	49	2	14	553	497	39	17	1,161	1,091	50	20
Ulster	0	0	0	0	0	0	0	0	0	0	0	0
Westchester	118	64	6	48	242	189	7	46	408	349	13	46
TOTAL	868	475	61	382	2,216	1,730	110	376	3,915	3,368	173	374

"----" less than 0.5

percent increase will reduce withdrawal about 11 MGD.) The role of R and T is crucial in keeping the increase in withdrawal to this level. Consequently the viability of the RT estimate was analyzed. The subsequent portions of this chapter provide the results of this analysis.

C. DATA ANALYSIS

Several steps were employed to determine an appropriate rate of industrial recirculation for the New York portion of the NYMA. Initially, the literature in the area of industrial recirculation was reviewed. Then an analysis was made of the trends found in the Census of Manufactures volume, Water Use in Manufacturing. Finally, the historical trends for New York were compared to those for the nation in order to estimate the rate of increase for industrial recirculation in New York State. As noted above, the rate of change for industrial recirculation is highly related to the level of enforcement imposed by the state.

The Census Bureau compiles and publishes a Census of Manufactures at five-year intervals. Part of this census is a collection of water use data by a variety of categories (e.g., geographic areas, sources, use, level of recirculation). The census provides information covering the period 1954-73. It should be noted that the earlier census volumes for 1954 and 1958 had serious data collection problems and, particularly for the State data, there were numerous disclosure problems - that is, the publication of the data would reflect on an individual firm. Thus, the data for the years 1963-73 only are used in the analysis of the trends in the New York State portion of the NYMA. The data collection and analysis consisted of two phases.

Data items collected for the United States by the six major water-using manufacturing industries for 1963-73 were: Gross Use (including recirculation), Brackish Use, Total Fresh and Total Use (See Attachment II-E-3, Table II-E-37). Data was assembled for these 6 major industries for the Delaware-Hudson water use region (the NYMA falls in this water use region) for these and two additional categories - Process Water and Water from Public Systems. The latter two were not available for the United States as a whole. Then, an analysis was made of the relative change in the use of fresh water and fresh water from public systems.

The conclusions of this analysis were:

1. For this area, fresh water use is probably growing more rapidly than total use for most of the six industries (see Table II-E-20).

TABLE II-E-20

PERCENT CHANGE IN WATER USE IN DELAWARE-HUDSON REGION

Type of Industry	Year	Gross	Total Fresh	Total Use
FOOD	1963-68	22%	36.2%	17.6%
	68-73	57.1%	11.9%	15.5%
	Over Period	91.6%	52.5%	35.9%
TEXTILE	1963-68	-612.6%	-84.2%	-84.2%
	68-73	120.7%	69.7%	69.7%
	Over Period	-69.0%	-7.8%	-7.8%
PAPER	1963-68	.9%	35%	33.3%
	68-73	74.4%	D*	33.2%
	Over Period	76%	D*	50%
CHEMICAL	1963-68	23.7%	33.9%	22%
	68-73	86.2%	37.8%	33%
	Over Period	130.3%	84.6%	63%
PETROLEUM	1963-68	13%	4.0%	-6.4%
	68-73	17.2%	.4%	10.0%
	Over Period	2.2%	3.5%	3.0%
PRIMARY METALS	1963-68	6.8%	1.4%	-1.1%
	68-73	108.7%	19.6%	102%
	Over Period	123%	21.3%	39.8%

* D = Disclosure Problem

2. The proportion of fresh water coming from public systems has increased for all but one of the industries. (See Table II-E-21.)

These two trends indicate that the industries locating in the area will rely more and more on publicly supplied fresh water for carrying on production. Since publicly supplied fresh water in general is more costly to industry than self-supplied water, the reliance on public supply coupled with the lack of new sources for self-supply will increase costs of production with current technology. This will increase the economic incentive for technological change and would lead to the conclusion that

the trend for technological change which would reduce water use per unit of output in productive processes is continuing in the NYMA.

TABLE II-E-21

PERCENT $\frac{\text{PUBLIC SYSTEMS}}{\text{TOTAL FRESH}}$ AND CHANGE IN PERCENT IN DELAWARE-HUDSON REGION

Type of Industry	Year	Percent	Change	Percentage Change
FOOD	1963	42.5		
	68	49.0	6.5	15.3
	73	46.2	-2.8	-5.7
	Over Period		3.7	8.7
TEXTILE	1963	7.1		
	68	17.1	10.0	135
	73	12.9	-4.2	-24.6
	Over Period		5.8	81.6
PAPER	1963	2.5		
	68	5.6	+3.1	124.0
	73	D		
	Over Period			
CHEMICAL	1963	25		
	68	11.4	-13.6	-54.4
	73	14.1	3.7	23.6
	Over Period		-10.9	-43.6
PETROLEUM	1963	3.1		
	68	3.9	0.8	25.8
	73	5.0	1.1	28.2
	Over Period		1.9	61.3
PRIMARY METALS	1963	5.1		
	68	6.0	.9	17.6
	73	7.9	1.9	32.0
	Over Period		2.8	55.0

The gross recirculation coefficients for the industries analyzed were then derived by dividing $\frac{\text{GROSS USE}}{\text{TOTAL USE}}$ and $\frac{\text{GROSS USE}}{\text{FRESH USE}}$ for both the United States and the Delaware-Hudson Region (Table II-E-22). These results were plotted by industry. (See

Figure II-E-1.) In most cases the observed trend for recirculation $\left(\frac{\text{GROSS}}{\text{FRESH}}\right)$ for the nation is above that observed for the Delaware-Hudson Region.

TABLE II-E-22

RECIRCULATION RATES, U.S.

Type of Industry	Year	GROSS WATER / TOTAL FRESH	GROSS WATER / TOTAL USE
FOOD	1954	2.37	2.14
	58	2.34	2.08
	63	1.75	1.57
	68	1.82	1.66
	73	2.52	1.96
TEXTILE	1954	1.49	1.20
	58	1.59	1.31
	63	1.72	1.44
	68	2.03	1.73
	73	D*	2.40
PAPER	1954	2.57	2.38
	59	3.16	3.12
	63	3.11	2.66
	68	3.95	3.34
	73	3.54	3.34
CHEMICAL	1954	1.97	1.60
	58	2.51	1.61
	63	3.03	1.98
	68	3.19	2.10
	73	3.79	2.66
PETROLEUM	1954	6.52	3.33
	58	8.04	4.38
	63	8.68	4.41
	68	8.89	5.08
	73	18.33	9.13
PRIMARY METALS	1954	1.37	1.29
	58	1.67	1.53
	63	1.61	1.46
	68	1.73	1.55
	73	2.01	1.79

TABLE II-E-22 CONT'D

Type of Industry	Year	GROSS WATER / TOTAL FRESH	GROSS WATER / TOTAL USE
Recirculation Rates for Delaware-Hudson Region			
FOOD	1963	2.12	1.47
	68	1.90	1.52
	73	2.67	2.07
TEXTILE	1964	4.43	4.43
	68	1.14	1.14
	73	1.49	1.49
PAPER	1963	2.54	2.54
	68	3.92	3.84
	73	D*	2.98
CHEMICAL	1963	2.51	1.54
	68	2.32	1.56
	73	3.13	2.18
PETROLEUM	1963	6.61	2.33
	68	5.54	2.18
	73	6.52	2.32
PRIMARY METALS	1963	1.39	1.28
	68	1.46	1.38
	73	2.55	1.43

* D = Disclosure Problem

FIGURE II-E-1
RATIO OF GROSS WATER USE
TO TOTAL FRESH WATER WITHDRAWAL,
U.S. AND DELAWARE-HUDSON REGION

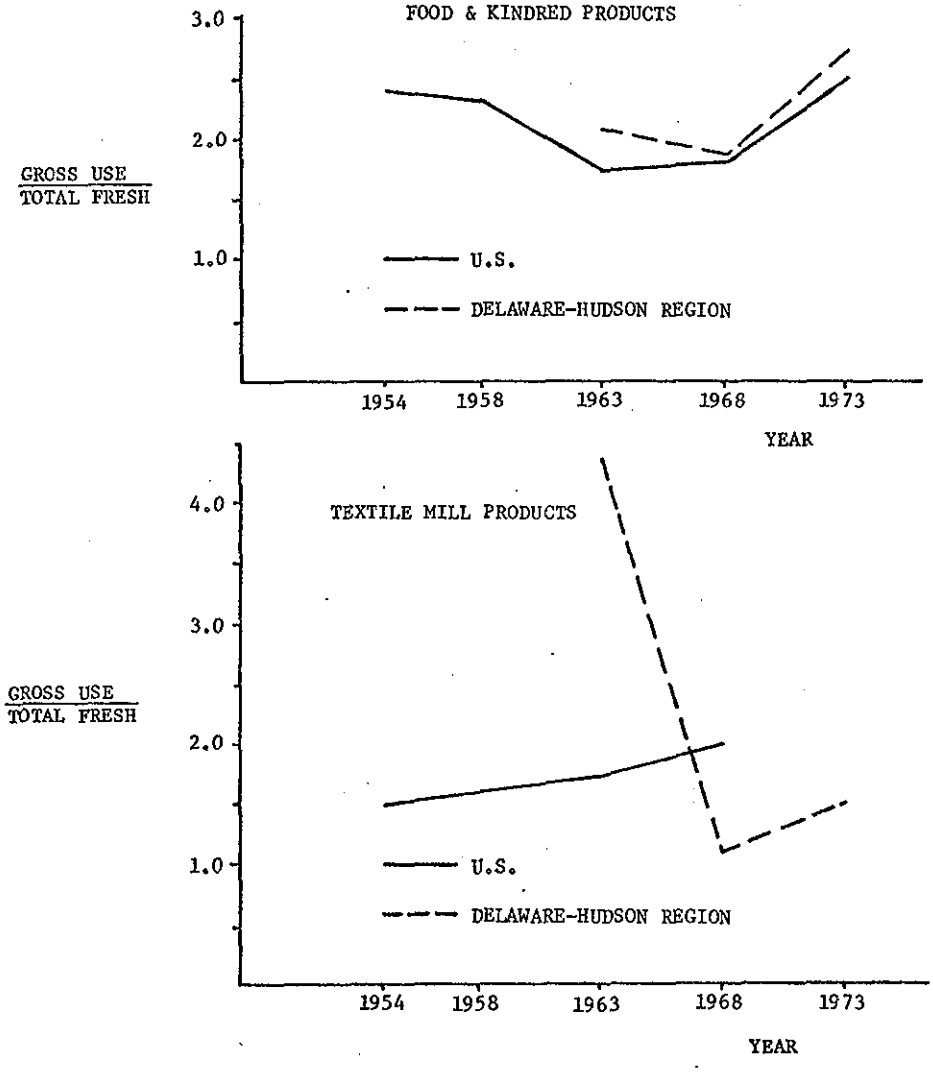
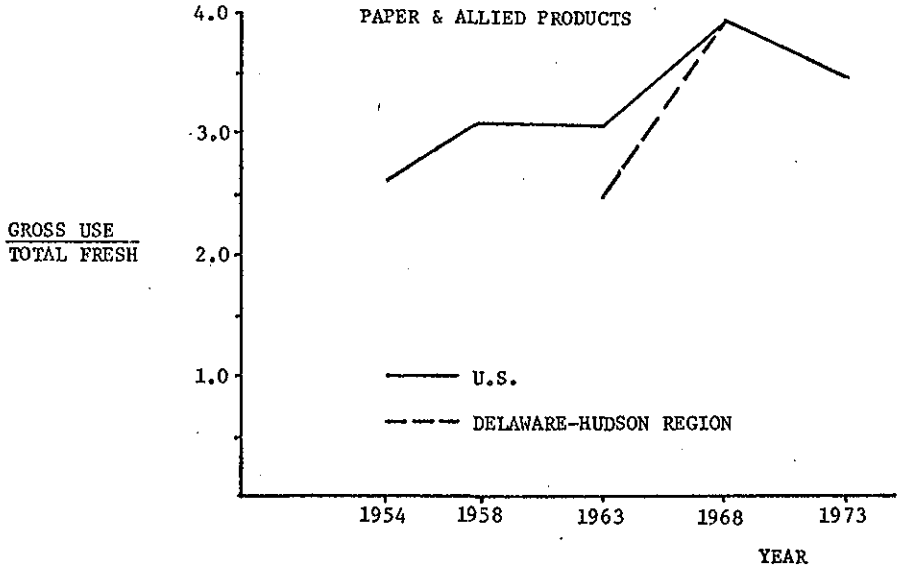
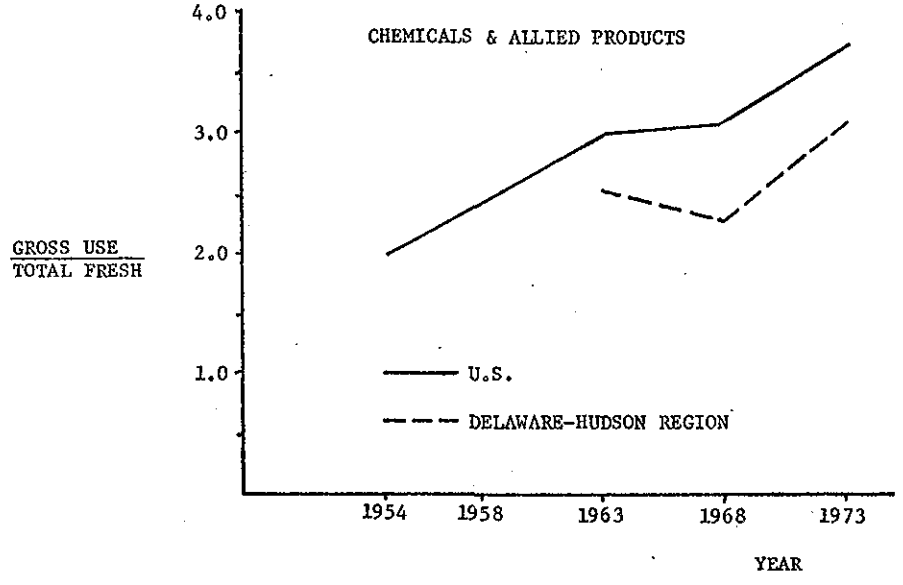
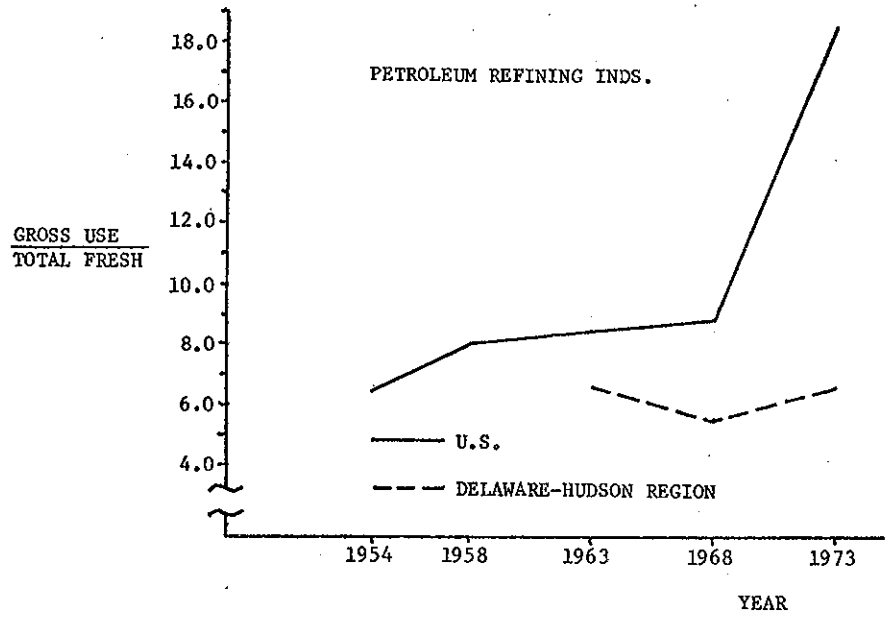
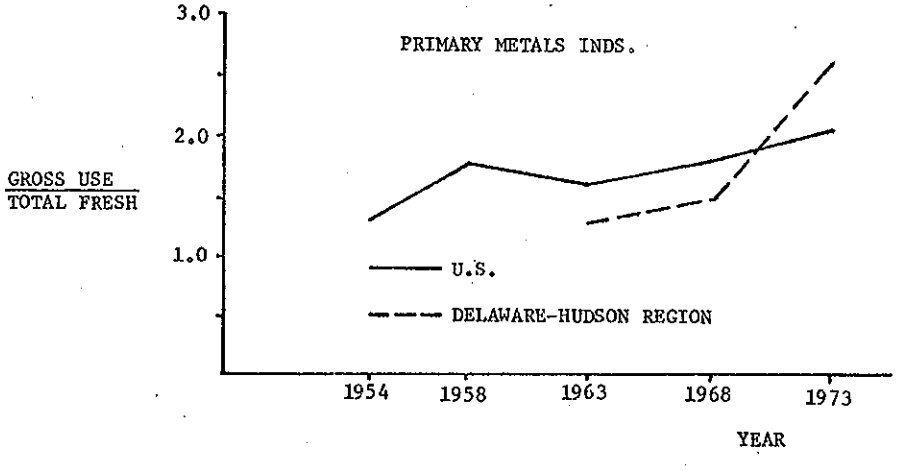


FIGURE II-E-1 CONT'D - P.2






PETROLEUM REFINING INDS.
GROSS USE / TOTAL FRESH
18.0
16.0
14.0
12.0
10.0
8.0
6.0
4.0
U.S.
DELAWARE-HUDSON REGION
1954
1958
1963
1968
1973
YEAR


PRIMARY METALS INDS.
GROSS USE / TOTAL FRESH
3.0
2.0
1.0
U.S.
DELAWARE-HUDSON REGION
1954
1958
1963
1968
1973
YEAR

Prior to considering the differences in the rate of growth of recirculation between the U.S. and the NYMA and what goal might be reasonable for New York State to achieve, two observations can be made:

1. The recirculation coefficient that NEWS is projecting is concerned only with fresh water reuse. The brackish and saline components should be netted out and a "new" recirculation coefficient estimated.

2. If the data will allow, New York State should be the geographic area of breakdown, not the Delaware-Hudson Region.

The recirculation coefficients were recalculated for the nation and for the Delaware-Hudson region with brackish water netted out. The procedure was $\frac{\text{GROSS USE - BRACKISH}}{\text{TOTAL FRESH}}$. This assumes that brackish use is not a process use, but is, in fact, mainly a cooling use which is used only once, rather than recirculated. This allows the netting out without introducing the problem of overstating the recirculation coefficients. (See Table II-E-23 for US and Delaware-Hudson values.)

Again the data indicates that this area (the Delaware-Hudson Region) is below the national averages.

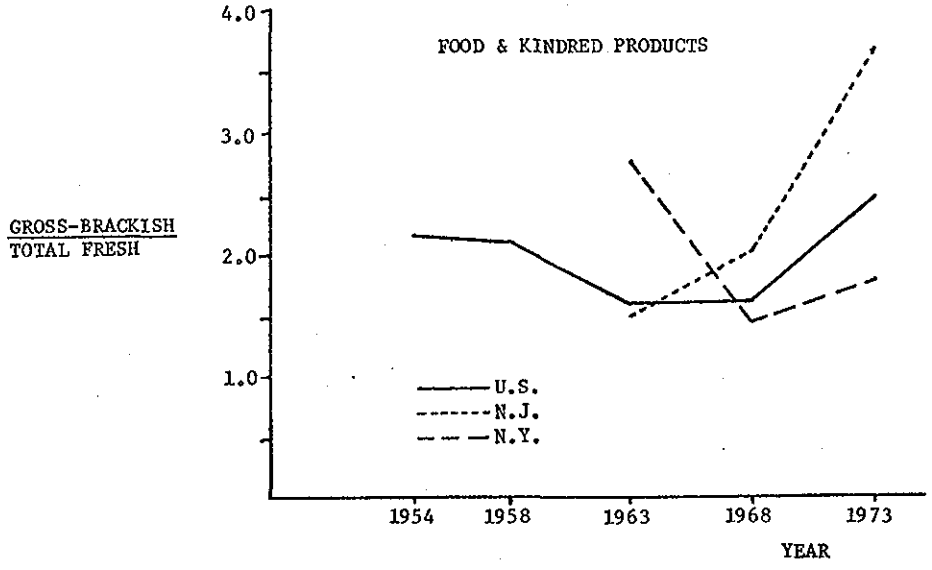
The second major adjustment was to utilize data in New York State itself. (For comparison, New Jersey was included.) The early census publications, 1954, 1958, were not useful in compilation of data as there were too many disclosure problems. However, the 1963, '68, and '73 Census did provide some interesting insights into the nature of water use and industrial recirculation in New York State and New Jersey. (See Tables II-E-39 and II-E-40, Attachment II-E-3, for the current use of water by the six major water using industries for each state.) Figure II-E-2 presents a graphic comparison between recirculation levels in the U.S., New Jersey and New York. As can be observed, the trend in New York State has been much below the national average and, for all but one industry, below that of New Jersey. Several reasons for this can be postulated. Water in New York State has been relatively abundant and as a result easier to acquire. The cost of acquiring fresh water in New Jersey is relatively more expensive. New Jersey also has more chemical and petroleum producing industries than New York. The pressure on these industries to recycle has been greatest since they use large amounts of water and are easily identified sources of pollution. Consequently, industries in New Jersey have been forced to recycle water to a greater degree than in New York. However, as public pressure rises and water sources become unavailable, this, coupled with the existing legislative

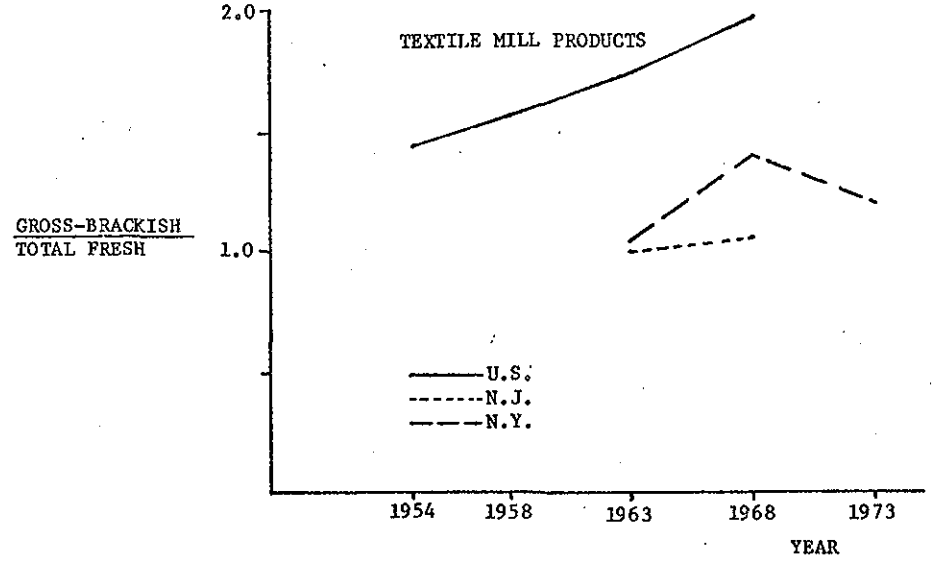
TABLE II-E-23

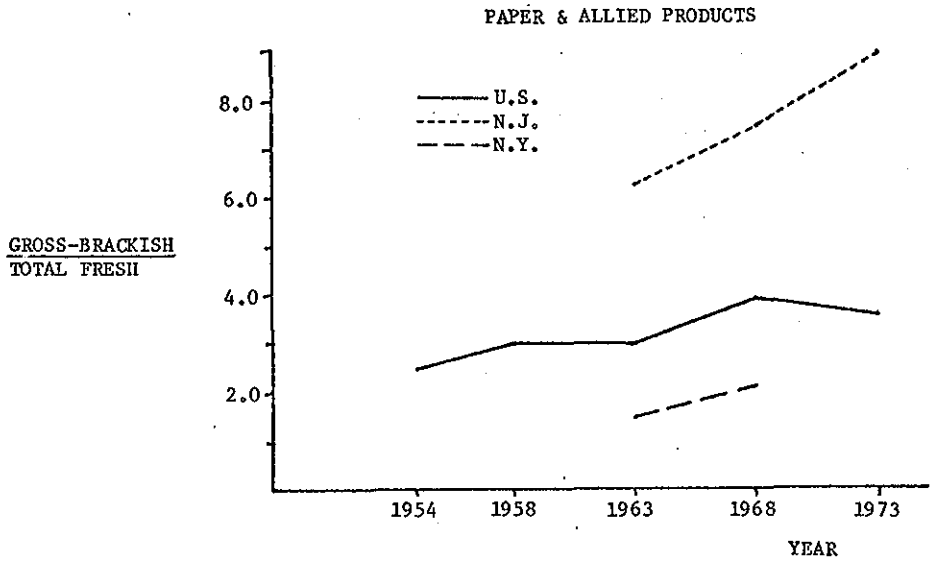
RECIRCULATION RATES

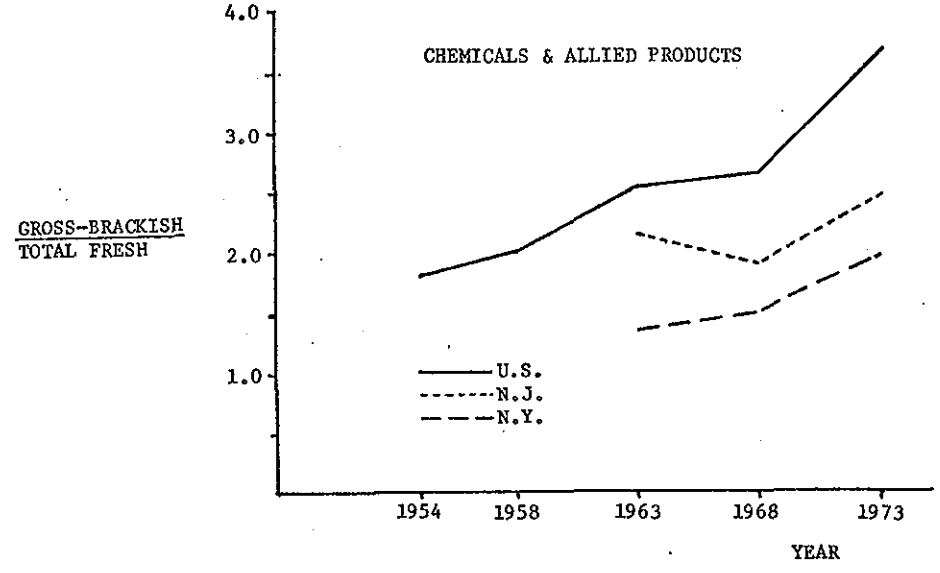
Type of Industry	Year	U.S.	Delaware-Hudson
FOOD	1954	2.26	
	58	2.21	
	63	1.63	1.73
	68	1.72	1.66
	73	2.41	2.46
TEXTILE	1954	1.47	
	58	1.58	
	63	1.71	4.43
	68	2.01	1.14
	73	D	1.49
PAPER	1954	2.49	
	58	3.07	
	63	3.02	2.95
	68	3.85	3.90
	73	3.51	-
CHEMICALS	1954	1.74	
	58	1.95	
	63	2.50	1.90
	68	2.67	1.99
	73	3.63	D
PETROLEUM	1954	5.56	
	58	7.20	
	63	7.71	5.46
	68	8.14	4.38
	73	17.61	-
PRIMARY METALS	1954	1.31	
	58	1.58	
	63	1.51	1.32
	68	1.62	1.40
	73	1.89	2.47

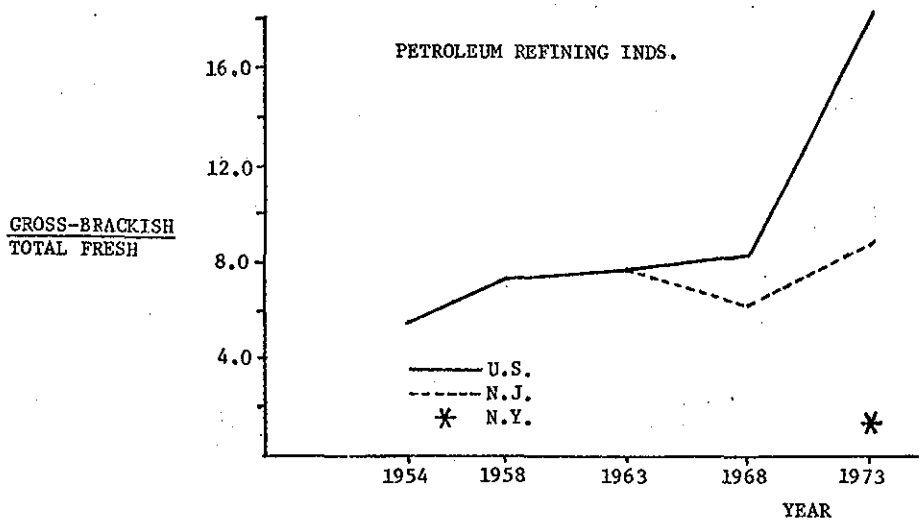
FIGURE II-E-2
RATIO OF GROSS (NET OF BRACKISH)
WATER USE TO TOTAL FRESH WATER
WITHDRAWAL, U.S., N.J. AND N.Y.

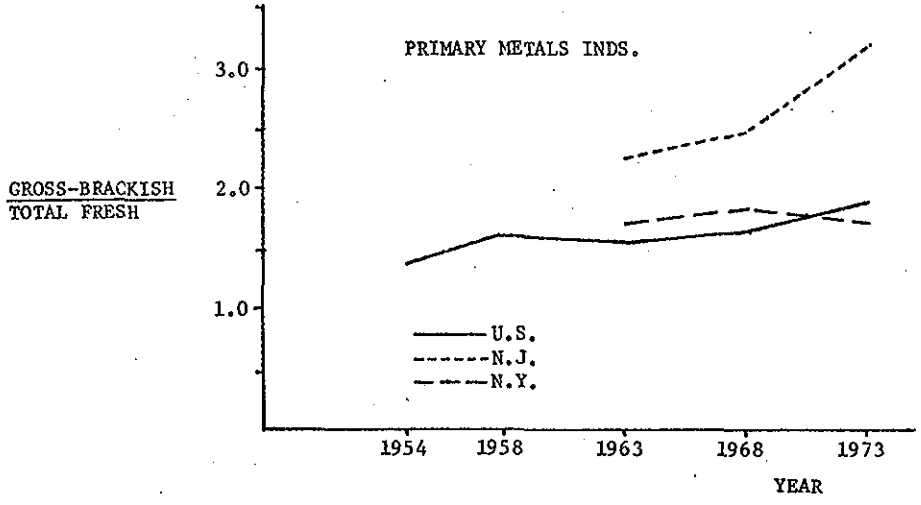





PAPER & ALLIED PRODUCTS
U.S.
N.J.
N.Y.
8.0
6.0
4.0
2.0
GROSS-BRACKISH
TOTAL FRESH
1954
1958
1963
1968
1973
YEAR


CHEMICALS & ALLIED PRODUCTS
4.0
3.0
2.0
1.0
GROSS-BRACKISH
TOTAL FRESH
U.S.
N.J.
N.Y.
1954
1958
1963
1968
1973
YEAR


PETROLEUM REFINING INDS.
GROSS-BRACKISH / TOTAL FRESH
16.0
12.0
8.0
4.0
U.S.
N.J.
N.Y.
1954
1958
1963
1968
1973
YEAR


PRIMARY METALS INDS.
GROSS-BRACKISH / TOTAL FRESH
3.0
2.0
1.0
U.S.
N.J.
N.Y.
1954
1958
1963
1968
1973
YEAR

requirements, will cause increases in recirculation in New York State. On this basis we would expect the New York State portion to experience a relatively more rapid rate of growth of recirculation than in New Jersey. (See Table II-E-24 for percent change in recirculation rate for New York and New Jersey.)

TABLE II-E-24

PERCENTAGE CHANGES IN RT

Type of Industry	Year	New York % Change	New Jersey % Change
FOOD	1963-68	-48.9	44.5
	68-73	21.7	74.4
	Over Period	-37.8	152.1
TEXTILE	1963-68	30.8	4
	68-73	-13.3	D*
	Over Period	15.4	D*
PAPER	1963-68	32.2	17.9
	68-73	D*	20.8
	Over Period	D*	42.4
CHEMICAL	1963-68	9.6	-13.1
	68-73	29.7	30.8
	Over Period	42.2	13.6
PETROLEUM	1963-68	D*	-22.8
	68-73	D*	45.1
	Over Period	D*	12.0
PRIMARY METALS	1963-68	10.3	7.9
	68-73	-7.1	30.2
	Over Period	2.4	40.5

* D = Disclosure Problems

In order for New York State to reach the current national average for each industry by the year 2020 recirculation would have to increase by the following annual percentage amounts for each industry:

1. Food - 3/4% per year
2. Textile - 0
3. Paper - 0

4. Chemicals - 1-1/2% per year
5. Petroleum - 5-3/4% per year
6. Primary Metals - 1/4% per year.

This makes the assumption that the historical forces which have caused the increase in recirculation in this area will extend enough influence to bring New York State recirculation to the current national averages by 2020. This, however, ignores the impact of the increased anti-pollution statutes and can be viewed as a lower limit of what could be achieved - that is, with little or no State involvement.

An alternative to this is to assume that the recirculation of water in New York State will not only overtake the current national average but will in fact catch up with the rest of the nation by the year 2020. To achieve this an estimate of what the national averages will be in 2020 was developed. The growth rates for the nation for the period 1954-73 were calculated for each of the six industries. These included:

1. Food - 1/3% per year
2. Textile - 2-5/8% per year
3. Paper - 1-3/4% per year
4. Chemicals - 3-3/4% per year
5. Petroleum - 5-5/8% per year
6. Primary Metals - 1-7/8% per year.

They were then applied to the 1973 recirculation rates for the Nation and estimates of future recirculation were derived. (It should be noted that for Petroleum an upper limit to recirculation was imposed based upon a 5% consumptive loss, since the calculated coefficient was about 230, well beyond what could be expected.) Having calculated this recirculation value, the rate of growth necessary for New York State to reach these levels by 2020 was developed. This led to the following growth rates:

1. Food - 1-1/16% per year
2. Textile - 2-3/4% per year
3. Paper - --
4. Chemicals - 5-1/4% per year
5. Petroleum - 6-1/8% per year
6. Primary Metals - 2-1/16% per year

This can be viewed as the highest increases in recirculation that the area could achieve.

The growth rates for recirculation that are being used for estimating future demand for the NYMA are within this upper and lower limit range with the exception of the Petroleum industry. All of the rates, with the exception of the Petroleum industry,

lie closer to the maximum than the minimum levels. This was assumed to reflect the conservation ethic and thrust that New York State has exhibited. The growth rate for Petroleum was below even the minimum rate assumed. This was assumed to be true because Petroleum products at the two digit SIC level include a whole gamut of industrial processes. Some of these processes use large quantities of water, while others do not. Petroleum refining - the major type of water user in this group - is not primarily a New York State activity. Therefore, improvements in the Petroleum area will not be as great or as rapid in New York State as in the remainder of the nation.

CHAPTER 6. A PROGRAM TO REDUCE WATER DEMAND IN THE NEW YORK METROPOLITAN AREA THROUGH THE INSTALLATION OF DOMESTIC CONSERVATION DEVICES

A. INTRODUCTION

One approach to reduce domestic water consumption is through the use of plumbing fixtures and household appliances which are designed to accomplish their required tasks by using less water than models commonly found in homes today. Widespread use of a device should be implemented by public policy, such as local plumbing codes, rather than by voluntary actions of the public (which should be dealt with as part of a public education campaign). While a large number of domestic conservation devices and appliances are available, those selected for a domestic conservation program should be chosen according to the following criteria:

- The devices should be capable of saving a significant amount of water.
- The devices should be technologically and economically feasible.
- There must be a practicable means to insure their widespread acceptance and use.

In the following sections the various types of domestic conservation devices and appliances are described and evaluated in terms of the above criteria. Those which meet the criteria have been selected for the domestic conservation program. An implementation schedule is outlined and the amount of water that could be saved by the program is estimated.

B. WATER SAVING DEVICES AND APPLIANCES

Water is used in the home for a variety of purposes, including drinking, cooking, bathing and other personal uses, laundry, washing dishes, and toilet flushing. Water is consumed for these purposes through the use of various devices and appliances, such as faucets, showers, washing machines, dishwashers, and toilets. The prospects for saving water by installing more efficient devices and appliances are discussed below.

1. Toilets

Water-saving devices on flush toilets range in complexity from placing a brick in the toilet reservoir to installing a vacuum system, which uses only 10% of the water required by a standard flush toilet. (1)

a. Displacement of Water in Toilet Reservoir - Bricks and other objects have been used to save water in flush toilets that are designed to use more water than is necessary for adequate flushing. If an ordinary brick is placed in the toilet reservoir, the water it displaces (a little over 1 quart) is saved each time the toilet is flushed. A plastic bottle filled with water could be substituted for a brick. When the toilet is flushed the plastic bottle displaces the volume of water it contains. Toilet reservoir volume reducers are available commercially and are designed to fit most toilets. These devices reduce the volume of water in the toilet reservoir by walling off a section of the reservoir.

b. Improved Float Assemblies - Water is saved by adjusting specially designed float assemblies to maintain a lower water level in the toilet reservoirs. Flushing efficiency is not impaired when water levels are lowered using one of these devices.

c. Shallow Trap Toilets - This type of toilet has a smaller water reservoir than that of a conventional toilet, using only about 3-1/2 gallons per flush as compared to an average of 5 to 6 gallons for a standard toilet. Available models range from 3.2 to 8 gallons or more per flush. Shallow trap toilets are operated the same way as conventional toilets.

d. Flush Valves - Flush valves, which are widely used in commercial buildings and in some apartments do not require a reservoir as do conventional toilets. The flush valve automatically delivers the required volume of water to flush the toilet and the water flow ceases when flushing is completed. Flush valves are especially adapted to installation as a two cycle system in which two volumes of water are utilized for flushing, one for feces and a smaller one for urine. This is made possible by installing two valves in the water line. A disadvantage of flush valves is that they require larger water supply lines than are standard in most homes; however, this would not preclude their use in the future.

e. Siphon - Jet Toilets - Siphon - Jet toilets are so called because when flushed, water is siphoned from the toilet reservoir rather than emptied by gravity flow. Such a design permits smaller volumes of water to be utilized in flushing the toilet bowl. Toilets of this type have been used in Britain for many years and are now available in this country. Water use of U.S. models is reported by the manufacturer to be one-third of that for his conventional models. (2) An improvement to this toilet that is finding wide acceptance in Britain is the two cycle siphon-jet toilet. The difference between this toilet and the standard siphon toilet is that there are two separate flush cycles, one for urine and one for feces. The solid waste

flush cycle uses 2.5 gallons per flush. The flush cycles are initiated by a short, sharp pull on the flush handle for the smaller amount of water, and a longer more persistent pull for the larger amount of water. Compared to the 5 to 6 gallons of water used to flush standard toilets, siphon-jet toilets could save large amounts of water if widely installed. However, these toilets are not yet being manufactured in the United States.

f. Vacuum System - In this system a vacuum pump removes wastes from the toilet and transports them to a holding tank from which they are fed into the sewer line. Such a system uses a mere 10 percent of the water required by the standard flush toilet. This type of system is too expensive for installation in individual homes but it appears to be attractive where many toilets can be joined to a central vacuum system as in hotels or housing developments. The effects that vacuum systems will have on conventional sewage treatment facilities is not known. (3)

g. Recycling Wastewater - Recent studies have shown that wastewater from sinks, bathtubs, and laundry drains is satisfactory for reuse in toilet flushing without treatment other than simple filtering. (4) Wastewater from these drains can be stored in a tank connected to the toilet reservoir. This method can save most of the water usually required for toilet flushing. However, staining agents and bacteria may cause discolored or murky water and may be objectionable to some people.

h. Incinerator Toilets - Incinerator systems use a colorless, odorless, nontoxic oil in place of water in toilet bowls. When the toilet is flushed, the oil-sewage mixture flows into a holding tank where the oil separates from the urine and solid materials. The waste flows into an incinerator where it is burned at temperatures exceeding 1200°F, while the oil is chlorinated, filtered and returned to the toilet to be used again. Wastes are reduced to a sterile ash and a small amount of gas released to the outside air, which does not contribute to air pollution. (5)

2. Showers

a. Flow Control Devices - Flow control devices on showerheads, which restrict the passage of water without greatly affecting the quality of the shower, are commercially available. These devices usually limit flows to 3 gallons per minute compared to a flow from standard heads ranging from 5 to 15 gallons per minute. Water savings of 50 to 70 percent are claimed for flow-limiting showerheads. (6)

b. Thermostatic Mixing Valve - This type of valve permits mixing of hot and cold water to preset temperatures. Water flows from the tap at this temperature. This reduces or eliminates the amount of water wasted while the temperature is being adjusted by manipulating the hot and cold water faucets in showers and sinks.

3. Faucets

a. Faucet Aerators - By mixing water with air, these devices reduce the amount of water flowing from a faucet and reduce splashing while providing an even flow. Air is added to the water as it leaves the faucet, giving the illusion that more water is flowing from the tap than the actual volume released. It has been estimated that aerators, which are widely used today, will save .25 gallons per capita per day (gpcd) for each faucet. (7)

b. Spray Taps - These taps are actually mini-showers desgined for use in lavatory sinks and wash basins. Water is sprayed from the tap rather than issuing forth in a single stream as is the case with conventional faucets. The spray allows for faster washing and rinsing with less water use as a consequence. When such devices are combined with the thermostatic mixing valves water saving of up to 90 percent are possible.

c. Flow Control Devices - These devices are similar to those on showers. On faucets, flow is usually limited to 2.5 gallons per minute and water use is reduced up to 50%. (9)

4. Clotheswashers

Currently available automatic home washers exhibit a range of water use from 32 to 59 gallons per 8 pound load. (See Table II-E-25.) The average consumption for the models listed in the table is 46 gallons. The "water-saving" group (Maytag A 206, Whirlpool, Sears Kenmore 29500) averages 35 gallons per load, a 24% reduction over the average consumption. (10)

A special suds-saving system is available on a few models for use in areas where water conservation is of special concern. This feature has had limited reception because of the need for water storage tubs and the lowering of performance by using "soiled water."

TABLE II-E-25

WATER USED BY VARIOUS CLOTHESWASHER MODELS

	TYPE	Total Water per 8 lb load (gallons)		TYPE	Total Water per 8 lb load (gallons)
1)	Maytag A606	40	8)	Wards Sig. 6329	54
2)	Westinghouse LAJ550	50	9)	G.E. WA740E	42
3)	Wizard 2734	55	10)	Sears Kenmore 48500	51
4)	Maytag A206	32	11)	Hoover 0710	46
5)	Hamilton WA769	41	12)	Blackstone BA620	48
6)	Kelvinator W421C	59	13)	Whirlpool LTA6700	34
7)	Norge AWK1820	56	14)	Sears Kenmore 29500	39
				Average	46

Source: Consumers Report, August 1969, p. 436.

5. Dishwashers

Normal home-size dishwashers consume between 12.5 and 16.5 gallons per cycle, while small, apartment-size models use 7-8 gallons per cycle. Replacement of the normal-size washers with the smaller models will not necessarily save water because two cycles may be necessary to handle a normal family load. (11)

C. EVALUATION OF WATER SAVING DEVICES AND APPLIANCES

The selection of water saving devices and appliances for a water conservation program should be based on the three criteria discussed earlier: (1) widespread use of a device should be implementable; (2) it should save a significant amount of water; and (3) it should be technologically and economically feasible.

1. Toilets

Displacement of water in toilet reservoirs by the placing of bricks or other objects in the tank, while technologically and economically feasible, would be difficult to implement by public policy. Savings would also be minimal, approximately, 1 quart out of 5 to 6 gallons. Improved float assemblies serve a similar function by reducing the amount of water in an oversized tank. It is appropriate to encourage the use of such devices through a public education campaign, rather than to require their installation as part of a mandatory program.

Flush valves, which are widely used in commercial buildings, would be difficult to install domestically because these valves require larger water supply lines than are standard in most homes. While this would not preclude their use in some dwellings, especially in large multi-unit structures where they are commonly used, flush valves are not as widely adaptable as other types of toilet devices.

Although vacuum system toilets, incinerator toilets, and recycling domestic wastewater may be feasible in areas with chronic or imminent water shortages, these devices are generally too expensive and not readily adaptable to most homes.

While two cycle siphon-jet toilets are not yet manufactured in the United States, it is possible that this model will gain acceptance here, as it has in Britain. The single cycle model which is manufactured in the United States, is capable of saving more than 50% of the water used for a standard toilet. The siphon-jet toilet appears to be adaptable to the plumbing systems found in most homes.

Shallow trap toilets also save a significant amount of water, and are operated and installed the same as conventional toilets. Thus, they are readily adaptable to most homes.

In summary, shallow trap and siphon-jet toilets are the only toilet devices that are used as part of this domestic water conservation program. Other devices save little, are too expensive, difficult to install, or not implementable through public policy actions.

Howe et al. (12) estimated that water-saving models (primarily shallow-trap toilets) use approximately 60% as much water as ordinary toilets, and since water for toilet use constitutes about 45% of total in-house use, the savings would amount to about 18% of total in-house uses.

2. Showers

Flow control devices on showers are readily adaptable to most homes and are capable of saving significant amounts of water. Howe estimated that water-restricting showerheads use about 50% as much water as the types of showerheads commonly used. Since water used for showers constitutes about 18% of total in-house use, the savings would be approximately 9% of total in-house uses. (13) Such devices could be implemented through public policies such as plumbing codes. Thermostatic mixing valves could also be required, but the amount of water saved is probably negligible and difficult to estimate. While thermostatic devices are included as part of the conservation program, flow control devices only are used to estimate the savings attributable to showers.

3. Faucets

Aerators, spray taps, and flow control devices on faucets are all capable of reducing the amount of water flowing from the tap and all are adaptable to standard plumbing systems found in most homes. If flow from the tap is limited to 2.5 gallons per minute through the use of one or any combination of these devices, 50% of faucet water could be saved. Howe estimated that water used for personal uses other than showers constitutes about 12% of total domestic in-house uses. (14) Thus, a 50% reduction would amount to 6% of total in-house uses.

4. Clotheswashers

Clotheswashers are not considered as part of the domestic conservation program for the following reasons:

(i) Water saving models would save only about 5% of domestic in-house water use. (15)

(ii) Washing machines are not as common as faucets, toilets, and showers. Only 19% of the population in the NYMA had clotheswashers in 1970, ranging from a low of 3% in Queens to a high of 43.6% in Nassau County. If the annual percent increase in population with clotheswashers continues at 1% (as assumed in the NYMA Study's demand projections) the percentage of the population with dishwashers will increase to only 21% by 2000 and 23% by 2020. Although the amount that could be saved by more efficient clotheswashers would be greater in areas where much of the population has such appliances, total savings throughout the study area would be only about 1% of domestic in-house water use by

2020. (5% saving X 23% of population with water saving models.)

(iii) It would be difficult to implement the use of water saving models by local governments because clothes-washers are not generally covered by plumbing codes. However, it is possible that state or federal regulatory agencies could establish standards that would require manufacturers to limit water consumption of washing machines to less than 40 gallons per 8 pound load.

5. Dishwashers

Dishwashers are not considered as part of the domestic conservation program because water saving models as such do not exist, other than small, "apartment size" models which require two cycles for a normal family size load. (16)

6. Water Saving Devices Selected for the Program

Based on the evaluation of the various water saving devices and appliances discussed above, toilets, showers, and faucets have been selected as the water-using implements that could be most significantly affected by a domestic conservation program.

D. EFFECT OF WATER CONSERVATION DEVICES ON DOMESTIC IN-HOUSE CONSUMPTION

Water used for various in-house purposes has been estimated as follows: drinking and cooking, 5%; showers, 18%; other personal uses, 12%; laundry and dishes, 20%; and toilet flushing, 45%. (17) Water conserved by water saving toilets, showers and faucets could amount to as much as 33% of total domestic in-house use (18% for toilets, 9% for showers, 6% for faucets), assuming that (1) the estimates of savings per device are accurate and (2) such devices will be installed as a result of public policy actions. Total in-house use is estimated by Howe to be 80 gallons per capita per day (gpcd). Thus, savings from more efficient toilets, showers and faucets could be as high as 26.4 gpcd. Table II-E-26 summarizes the savings that could be realized under optimal conditions.

The savings listed in Table II-E-26 that could be attributable to more efficient toilets, showers, and faucets are considered to be the upper range of possible savings. The amount saved per device is based largely upon the work of Howe, which has been widely quoted. The actual amount of water used in homes for various purposes probably varies widely because individual water use practices are undoubtedly not uniform.

Thus, the savings attributable to a water conserving device should be determined not only by the mechanical property of the device, but also by the way such a device is used. It is possible that a showerhead designed to restrict flow to 3 gallons per minute will cause some individuals to perceive a deterioration in the quality of the shower, resulting in longer showers, thus reducing or negating the savings attributable to the showerhead's mechanical properties. Thus the savings presented in Table II-E-26 represent what is possible, but not likely, given the variation in human behavior and water use habits. It is also critical to note that this table assumes these devices are installed in all homes at the same time. This is virtually impossible.

TABLE II-E-26

DOMESTIC CONSUMPTION WITH AND WITHOUT WATER CONSERVING DEVICES

	Domestic in-house use without water-saving devices		Water conserved by water-saving devices		Domestic in-house use with water-saving devices
	gpcd	%	gpcd	%	gpcd
drinking, cooking	4	5	0	0	4
personal, other than showers	9.6	12	4.8	6	4.8
showers	14.4	18	7.2	9	7.2
laundry, dishes	16	20	0	0	16
toilet flushing	36	45	14.4	18	21.6
TOTAL	80	100	26.4	33	53.6

One study (18) estimated that reductions in water consumption due to more efficient toilets, showers and faucets range from 12% to 30%, with 20% to 25% considered the normal range. This study has chosen 15% as a mid-range figure for estimating overall savings attributable in the NYMA to the implementation of water saving devices through an amended plumbing code. The overall savings estimated for the NYMA is discussed below in the section "Effect of a Domestic Conservation Program on NYMA Water Demands."

E. A PROGRAM TO OBTAIN USE OF DOMESTIC CONSERVATION DEVICES

The difference between an educational program for water conservation and a program based on the installation of domestic conservation devices is that the former would seek to achieve its ends through the voluntary cooperation of the public while the latter would require compliance through legal means. The legal means available to implement a domestic conservation program include actions by state agencies and amendments to local plumbing codes.

Although state agencies traditionally have little control over local plumbing codes, certain agencies which regulate or fund local government functions should require, as conditions for granting approval or financial aid to localities, that local plumbing codes be amended to require the installation of water saving devices.

Local plumbing codes should be amended as follows:

- limit toilets to 3.5 gallons per flush by requiring the installation of shallow trap toilets or siphon jet toilets.
- limit the flow of showers to 3 gallons per minute through the installation of flow control devices.
- limit the flow of faucets to 2.5 gallons per minute through the installation of aerators, spray taps, or other flow control devices.

F. IMPLEMENTATION SCHEDULE FOR A DOMESTIC CONSERVATION PROGRAM

Immediate replacement of existing toilets with water-conserving models would be costly and difficult to achieve on a large scale in the NYMA. Immediate replacement would be cost effective only if the value of the water saved exceeded the cost of replacement. For example, Howe estimated in 1971 that immediate replacement would be cost effective only if the price of water exceeded 80 cents per thousand gallons in 1971 prices (19), which is higher than current water rates in most of the NYMA. Thus, there would be no economic incentive for homeowners and owners of apartment buildings to install water-conserving toilets. The economic incentive is non-existent in non-metered homes, of which there are many in New York City.

Although immediate replacement of conventional showerheads with water-saving models would have become economical in 1971 at a water price above 10 cents per thousand gallons, according to Howe (20), it is questionable whether the financial incentive would be large enough to warrant immediate replacement. (21) Immediate replacement of conventional faucets is not considered

feasible for the same reason.

A more appropriate strategy would be to require, through local plumbing codes, the installation of water saving toilets, showers and faucets in new or renovated dwellings. The rate at which these devices could be installed depends on: the ability of local governments to implement amended plumbing codes; and the replacement and renovation rates of existing dwelling units. In order to estimate the savings that could result from the installation of domestic conservation devices, the following implementation schedule has been assumed:

- Plumbing codes will be amended throughout the NYMA by 1980 so that new and renovated dwelling units will be equipped with water-saving toilets, showerheads, and faucets.
- Existing dwelling units will be replaced or renovated at a rate of 2% per year.

If the domestic conservation program is implemented uniformly throughout the study area according to the assumptions listed above, nearly 50% of the population in the NYMA will live in housing equipped with water-saving toilets, showers, and faucets, by 2000, and nearly 85% will inhabit dwellings with these models by 2020. Table II-E-27 presents the population served by water-saving devices for the entire study area and selected subareas.

TABLE II-E-27

POPULATION USING WATER-SAVING TOILETS, SHOWERS AND FAUCETS

Subarea	2000		2020	
	Population (in 000's)	% of subarea	Population (in 000's)	% of subarea
N.Y. State (including NYC)	7,099.4	47.8	13,950.8	84.4
NYC only	3,644.4	43.2	7,196.8	81.9
New Jersey	3,488.8	50.3	6,760.6	85.5
Connecticut	1,058.8	49.3	2,088.6	85.2
ENTIRE STUDY AREA	11,647.0	48.6	22,800.0	84.8

G. EFFECT OF A DOMESTIC CONSERVATION PROGRAM ON NYMA WATER DEMANDS

The total amount of water that could be saved by a program to install water-saving toilets, showers and faucets is calculated by multiplying the population using such models times the amount saved per person (gpcd). Table II-E-26 lists the maximum savings that could result from the installation of water-saving devices - 26.4 gpcd, which represents a 33 percent reduction in domestic in-house use. However, this percentage is most unlikely since it assumes an almost complete turnaround in people's habits. Mid-range and low estimates of per capita savings are necessary in order to calculate a range of potential savings for the entire NYMA. A 15 percent reduction was considered to be the mid-range estimate of reduced water consumption due to water-saving devices on toilets, showers and faucets. A reduction of 5 percent was considered the low estimate. Table II-E-28 lists the potential savings for the entire NYMA which could result from domestic in-house savings of 33 percent, 15 percent and 5 percent, respectively.

TABLE II-E-28

TOTAL WATER SAVED BY DOMESTIC CONSERVATION DEVICES: HIGH, MID-RANGE, AND LOW ESTIMATES (MGD)

	NYS (including NYC)	NYC only	N.J.	CONN.	NYMA TOTAL
2000					
High	187	96	92	28	307
Mid-Range	85	44	42	13	140
Low	28	15	14	4	47
2020					
High	368	190	178	55	601
Mid-Range	168	86	81	25	273
Low	56	29	27	8	91

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(1) William Sharpe, Water Conservation and Wasteflow Reduction in the Home, Pennsylvania State University, p. 3.

(2) Ibid., p. 8.

(3) Ibid., p. 8.

(4) Ibid., p. 8.

(5) Coffin & Richardson, Water Demand Study - Eastern Massachusetts Region, May 1974, p. B-22.

(6) Sharpe, op. cit., p. 5.

(7) Ibid., p. 5.

(8) Ibid., p. 5.

(9) Ibid., p. 5.

(10) Coffin & Richardson, op. cit., p. B-14.

(11) Ibid., p. B-18.

(12) Howe, et al., Future Water Demands, March 1971, p. 9.

(13) Ibid., p. 10.

(14) Ibid., p. 9.

(15) Ibid., p. 12.

(16) Coffin & Richardson, op. cit., p. B-7.

(17) Howe, et al., op. cit., p. 7.

(18) Metropolitan Washington Council of Governments, Report on the Use of Regional Plumbing Codes to Effect Water Conservation, June 1973, p. 3.

(19) Howe, et al., op. cit., p. 9.

(20) Ibid., p. 10.

(21) Coffin & Richardson, op. cit., p. B-13.

CHAPTER 7. AN EDUCATIONAL PROGRAM FOR WATER CONSERVATION IN NEW YORK CITY

A. INTRODUCTION

Reduced domestic water consumption could be achieved through an educational campaign designed to influence, and ultimately change, individual attitudes and water use habits. Such a campaign could be conducted during a drought, when the public is generally aware of the immediate need to reduce water consumption, or a campaign could be conducted during normal "wet" years when the value of water conservation is not so obvious. A drought-oriented campaign is generally an intensive, short term program which emphasizes the potential crisis of a water shortage. During such a campaign, people may be asked to temporarily relinquish certain water-related conveniences. For example, during the drought of 1949-50, New York City water consumers were requested to reduce their water use to a minimum on "Dry Friday" and men were asked to forego shaving. On the other hand, a long run, less intensive campaign conducted during non-drought years should attempt to make the public aware of wasteful water practices that can be reduced or eliminated without any effect on the standard of living. While a crisis-oriented campaign during a drought attempts to bring about an immediate but temporary reduction in water use, an educational program such as the one considered in this paper should be oriented toward a gradual, but permanent change in water consumption attitudes and practices.

B. CHOICE OF NEW YORK CITY FOR A LONG RUN EDUCATIONAL PROGRAM

While it would be desirable to conduct a long run educational program throughout the New York Metropolitan Area (NYMA), a program that focuses on New York City may help to determine the effectiveness of a campaign conducted during non-drought years without incurring the costs of a larger scale, regional effort. New York City, as opposed to another city or region within the NYMA, has been selected as the focus of a program for the following reasons:

- A large number of people live in a relatively small geographic area, thus facilitating the dissemination of public information materials.

- New York City consumes a large amount of water (approximately 50% of total demand in the NYMA in 1970). Thus, the potential effectiveness of an educational campaign on total consumption would probably be greater in New York City than a campaign in an area with less people.

- New York City contains a large variety of housing types, both metered and unmetered, and its population represents numerous socio-economic characteristics. Thus, a program in New York City may determine whether or not water use attitudes and practices vary according to housing type and socio-economic characteristics.

C. PHASES OF AN EDUCATIONAL PROGRAM IN NEW YORK CITY

Water is one of the most abundant and cheapest natural resources. Only a twist of the wrist is required to bring forth a seemingly endless flow from the tap. As a result, large quantities of water are probably wasted each day due to ingrained attitudes and habits. Such attitudes and habits cannot be easily changes. While a long run objective of an educational campaign would be to change wasteful water use habits so that water consumption is reduced, a more immediate objective would be to determine whether or not attitudes and habits can be significantly changed by an educational campaign. Although public educational efforts in New York City during the drought of the 1960's had a significant effect on reducing consumption, it is not necessarily true that a campaign conducted during non-drought years would be effective. While individuals may be willing to temporarily forego certain water-related conveniences during a water shortage, it is unrealistic to expect them to behave similarly over long time periods when rainfall is abundant.

An implicit assumption is that individuals waste water by using more than they need. Although the drought indicated that consumption can be reduced without causing major hardships, insufficient information exists about the specific ways that individuals restricted their use of water. In order to structure a meaningful conservation program - the purpose of which is to reduce consumption during non-drought years - it is necessary to develop information about personal water use habits during periods when rainfall is plentiful. This information would be used to identify wasteful uses, which would then be the basis for developing the methods and techniques designed to change wasteful habits.

Given the limited information about water consumption habits, it is more feasible to conduct an educational campaign in several carefully designed phases than to launch a comprehensive, expensive effort that could prove ineffective. These phases are:

1. Identify existing water use attitudes and habits and develop methods and techniques to change those habits which appear to be wasteful.

2. Conduct a pilot program which focuses on a small but representative sample of the City's population and evaluate the effectiveness of this pilot program.

3. If the pilot program is successful, conduct a city-wide educational campaign.

Phases 2 and 3 can be neither designed nor conducted until Phase 1 is completed. Consequently, this chapter describes in detail the tasks associated with Phase 1 but only outlines the basic concepts of Phases 2 and 3.

1. Phase 1

During this phase, information about existing water use attitudes and habits is collected and analyzed, and strategies are developed for Phase 2, the pilot program. Phase 1 consists of 7 tasks, which are described below:

a. Task 1 - The purpose of this task is to develop a conceptual framework on which to base the selection of a number of sample neighborhoods which are representative of New York City as a whole. This task requires an analysis of the socio-economic characteristics of the City's population, the selection of indicators which reflect those characteristics, and an analysis of the various types of housing found in the City. The socio-economic and housing data are then cross-classified, resulting in a description of typical neighborhoods in New York City.

For example, suppose that the following U.S. Census classifications are selected as socio-economic indicators.

- Percentage of families less than the poverty level.
- Percentage of families with median family income of $15,000 or more.

Suppose, too, that the City's housing units are grouped into the following classifications:

- Co-ops
- Apartments (rental)
- Single family
- Two family

Cross-classifying the above socio-economic and housing characteristics yields the following types of neighborhoods:

- Co-op, large percentage of families with median family income $15,000 or above.

- Apartment, large percentage of families with median family income $15,000 or above.

- Apartment, moderate percentage (city-wide average) of families with median family income $15,000 or above.

- Apartment, large percentage of families with income less than the poverty level.

- Single family, large percentage of families with median family income $15,000 or above.

- Single family, moderate percentage of families with median family income $15,000 or above.

- Two family, moderate percentage of families with median family income $15,000 or above.

It may be useful to further classify the single family and two-family categories according to whether the housing units are metered or unmetered. Thus, the single and two family categories would be expanded into 6 types of neighborhoods, making a total of 10 neighborhood types. The actual number and types of neighborhoods identified in Task 1 would depend on the results of the socio-economic and housing analyses.

b. Task 2 - The purpose of this task is to identify and select actual neighborhoods in New York City which closely resemble the characteristics of the typical neighborhoods specified in Task 1. These neighborhoods would be selected by analyzing U.S. Census data for Census tracts and blocks. Two neighborhoods - one "control group" and one "subject group" - would then be selected for each of the neighborhood types identified in Task 1. For example, if 10 types were identified in Task 1, then 20 actual neighborhoods - 10 control and 10 subject - would be selected for Phase 2 of the program. Control and non-control groups would be selected to improve the reliability of the survey data to be collected, as specified in Task 4.

c. Task 3 - The purpose of this task is to develop a methodology to determine existing water use attitudes and habits. This methodology could include the distribution of a written questionnaire, a telephone survey, or face-to-face interviews.

d. Task 4 - The purpose of this task is to implement the methodology of Task 3, that is, to conduct a survey of existing water use attitudes and habits in each of the subject group and control group neighborhoods. For each neighborhood type, the survey of the subject group would be analyzed and compared with the survey of the corresponding control group in order to

test the hypothesis that the attitudes and habits of each subject group closely resemble those of the corresponding control group. If the hypothesis is validated, then it can be assumed that the non-control group accurately represents the characteristics of its particular neighborhood type. If the hypothesis is not validated, then it may be necessary to survey a larger sample of neighborhoods.

An analysis of the survey should indicate the "baseline" water use attitudes and habits, which will be the basis for determining the educational techniques to be used during Phase 2. The baseline will also be used to evaluate the effectiveness of Phase 2. Another survey will be conducted at the end of Phase 2 and the results will be compared with the baseline survey to determine whether or not the pilot program caused any changes in water use attitudes and habits.

e. Task 5 - The purpose of this task is to determine the techniques, based on the results of the baseline survey, which are most appropriate to educate each subject group neighborhood about water conservation. The control group neighborhoods are excluded from further study - the purpose of the control group is to improve the reliability of the baseline survey by providing a basis of comparison.

The particular characteristics of each neighborhood should determine the specific educational techniques to be used. While some techniques and messages will most likely be applicable to all neighborhoods, it is possible that the special characteristics of some neighborhoods will require techniques or messages unique to those neighborhoods. For example, a campaign to reduce the opening of fire hydrants by children may be more applicable in low-income, inner city neighborhoods where alternative recreational facilities are limited. A spray cap campaign was conducted in such neighborhoods during the summer of 1975. Such a campaign might not be needed in middle-income neighborhoods with a predominance of single family homes where more abundant recreational opportunities exist.

In general, the educational techniques and materials used should focus on special neighborhoods rather than on the city as a whole. Thus, expensive mass media techniques such as advertising in the subways, television, or radio would not be feasible in a pilot program. More appropriate techniques would include articles in community newsletters, posters on specific, local bus routes, and the dissemination of information through local civic associations, block groups, tenant associations, and local public schools.

f. Task 6 - The purpose of this task is to identify and

contact various groups in each neighborhood in order to ask for their assistance in disseminating educational materials. Determining the willingness of such groups to participate in an educational campaign is necessary in order to estimate the potential effectiveness of certain techniques, such as circulars or pamphlets.

g. Task 7 - The purpose of this task is to develop cost estimates for Phase 2. The following information, at a minimum, would be needed to develop accurate estimates:

- the number of neighborhoods and the approximate number of people in each neighborhood.
- the type of techniques to be used so that the necessary posters, circulars, pamphlets, etc. could be designed and printed.
- the manpower requirements (for design, printing, dissemination of information).
- the cost of a second attitude survey, similar to the baseline survey.

Reliable cost estimates for Phase 2 could not be developed until Phase 1 - the detailed design of the pilot program - were completed. A more detailed discussion of cost is presented in a later section.

2. Phases 2 and 3

During Phase 2, the pilot program would be conducted according to the strategies mapped out in Phase 1. At the end of Phase 2, a survey of water use attitudes and habits - similar to the baseline survey of Phase 1 - would be taken to measure whether or not the pilot program had an effect on water use attitudes and habits. Based on this evaluation, it would be decided whether or not the pilot program should be expanded to a city-wide campaign, or extended to specific neighborhoods which, based on the results of the pilot program, would be most likely to respond to a public educational effort for water conversation.

3. Appropriate Agencies for Implementing An Educational Program for Water Conservation

The Public Information Office of the Environmental Protection Administration of the City of New York is the agency which has the most familiarity with public service educational campaigns in New York City. This agency has conducted anti-litter

campaigns as well as programs designed to encourage the use of spray caps on fire hydrants. The staff members of the Public Information Office are familiar with various educational techniques, have dealt with advertising and public relations firms, and might well be selected to implement the type of program described in this paper. The New York State Department of Environmental Conservation, which has expressed great interest in the development of an educational program for water conservation, is another agency which might appropriately conduct or participate in such a campaign in New York City.

4. Implementation Schedule

Depending upon the number of experienced staff available, Phase 1 could be completed in 2-3 months. Phase 2 (the pilot program) should be conducted over a period of about one year in order to address water use habits which may vary according to seasons. For example, lawn sprinkling or the opening of fire hydrants are most likely to occur during warm months. Phase 3 should begin after Phase 2 has been evaluated. The time frame of this phase could range from several months to a continuous, on-going program.

5. Cost Elements of an Educational Campaign

The cost of an educational campaign for water conservation is dependent on many factors, including the level of effort required, the techniques, used, and the urgency for conserving water. During the drought of the 1960's, for example, the cost of an intensive, crisis-oriented campaign was minimal compared to the required level of effort because the mass media helped to publicize the campaign as a public service. Also, much of the work was done in-house by City agencies, funded out of operating budgets. During the summer of 1975, the Public Information Office of the New York City Environmental Protection Administration conducted (in-house) a spray cap campaign. Other recent in-house campaigns included the city-wide distribution of anti-littering and "Curb Your Dog" posters.

Although it is difficult, if not impossible, to estimate the overall cost of a long run educational program for water conservation until Phase 1 is in progress, various cost elements which would be included in a campaign can be discussed.

Tasks 1, 2 and 6 of Phase 1 - analysis of socio-economic characteristics, selection of sample neighborhoods, and identification of neighborhood groups, respectively - could be accomplished in-house by the City agency that conducts the campaign. Tasks 3 and 4, the development and implementation of a methodology to determine existing water use attitudes and habits,

would require the services of a professional public opinion research organization. The costs of such services could not be estimated until the actual number and type of sample neighborhoods are selected. Task 5, the concept and design of educational techniques, would require the services of a professional advertising agency or public relations firm. The cost of this task could not be determined until Tasks 1-4 were completed.

Educational techniques used during Phase 2 could include posters in buses or subways and pamphlets and circulars. In addition to the cost of design, expenses for posters include printing costs and upcharges - the cost of mounting posters in subway cars and buses. Printing could be done in-house by the Public Information Office of the New York City Environmental Protection Administration, which has access to the Department of Sanitation's sign shop. Upcharges are $1.00 per poster in subways and $.50 for each interior bus poster. (Large posters on the outside surface of buses are more expensive.) Total upcharges for subway posters are $6,600 for a full run - two posters in every subway car - and $1,640 for a quarter run - two posters in one of every four cars.

Various information materials are currently available from the New York City Environmental Protection Agency, including:

Booklet: "The Water We Use In New York"

Fact Sheet on Water Supply (with map)

Posters and Flyers (in English and Spanish):
"Spray Caps Save Lives"

The American Water Works Association has published a pamphlet entitled: "Water Conservation at Home --- Why To - Where To - How To." The cost per pamphlet ranges from 7.5 cents for less than 100,000 copies, 6 cents each 100,000 to 200,000 and 5 cents each for 500,000 or more.

CHAPTER 8. DROUGHT CONTINGENCY PLAN FOR NEW YORK CITY

A. INTRODUCTION

During the droughts of 1949-1950 and 1961-1966, the volume of water in New York City's reservoirs was well below normal. Official responses to the water shortage consisted of two types of actions: (1) those which temporarily increased supplies by tapping previously unused sources; and (2) those which reduced consumption through mandatory and voluntary restrictions on water use. By implementing these drought contingency measures, New York City avoided severe social and economic hardships. These measures, which are described in the following sections, are a basis for the drought contingency plan that is outlined in this chapter. (Much of the information for this chapter was supplied by the City's Bureau of Water Supply Annual Reports.)

B. CONTINGENCY MEASURES USED DURING PREVIOUS DROUGHTS

Although some actions were taken to temporarily augment supplies, the basic response to the droughts of 1949-1950 and 1961-1966 was a campaign to reduce consumption. This campaign included temporary mandatory restrictions on certain water using activities as well as appeals urging the public to voluntarily reduce water consumption. The specific responses to each of these droughts is described below.

1. Drought of 1949-1950

Beginning in June 1949, rainfall was less than average while consumption rose to over 1200 mgd during the summer months. Under these conditions, storage began to fall rapidly until by October 1, the reservoirs held only about 56% of capacity. The depletion of Kensico Reservoir, which had a surface elevation of 333 feet on October 1, became critical during this period. It was estimated that if the elevation fell below 325 feet, or 37% of capacity, it would be difficult to maintain a flow of 800 million gallons per day (MGD) to Hillview Reservoir.

As Kensico's elevation continued to fall, the Mayor of New York City initiated a series of measures designed to reduce water consumption. On October 14th, the Mayor appealed to the public to conserve water and ordered city departments to curtail their use of water. Such measures included turning off park fountains and eliminating the use of fire hydrants for street flushing. The conservation campaign was publicized through the press, radio and television; posters indicating ways to save water were displayed in subway cars; and circulars with a similar message were widely distributed.

However, the public responded poorly to the Mayor's appeals, and, as a consequence, Kensico Reservoir continued to drop, reaching an elevation of only 329 feet, or 44% of capacity, on October 29th. Additional measures, both voluntary and mandatory, were subsequently initiated to further reduce consumption. Voluntary measures included the designation of "dry days" during which consumers were requested to reduce water use to a minimum and men were asked to forego shaving. On "Dry Friday" (December 16, 1949), consumption dropped to 802 mgd, the lowest since 1927. In order to constantly remind people to save water, every Thursday, beginning on January 12, 1950 and ending on June 15, 1950, was designated as "Dry Thursday." Due to increased reservoir storage and continued reduced consumption, "Dry Thursday" was observed only once a month after June 15, ending on September 14, 1950.

In addition to appeals for voluntary reduction of water use, the following mandatory restrictive measures were initiated:

- December 8, 1949 - automobile washing banned.
- December 22, 1949 - use of water or steam to clean the outside of buildings was prohibited.
- December 30, 1949 - new regulations for air conditioning and refrigeration required that units of three tons or more must be equipped with recirculation devices.
- January 6, 1950 - the following restrictions were ordered:

    1. Prohibiting the use of hose, spout and similar pressure bathing apparatus; also the maintenance of constant flow from showers or similar apparatus.
    2. Prohibiting the operation of swimming pools except those designed and used exclusively for medical treatment.
    3. Prohibiting the operation of automatic plumbing flush fixtures using a constant or fixed periodic flow.
    4. Prohibiting the bleeding of water lines on docks, other structures, or in any building for the purpose of maintaining a constant flow to prevent freezing.

5. Prohibiting the operation of skating rinks requiring the use of water for ice purposes with the exception of those skating rinks where the water can be reused.

- March 23, 1950 - hoses, sprinklers or other means to water lawns, gardens or sidewalks were banned.

On June 15, 1950, many of the restrictive measures were suspended for a trial period of 30 days, with the exception of the new rules governing refrigeration and air conditioning, which were made permanent. Due to continued reduced consumption and favorable storage in the reservoirs, all temporary restrictions were permanently suspended on September 15, 1950. The effectiveness of the conservation campaign, both voluntary and mandatory measures, is illustrated in Table II-E-29, which enumerates the average daily consumption by month for the years 1948 through 1950.

TABLE II-E-29

AVERAGE WATER CONSUMPTION IN NEW YORK CITY, 1948-1950
(MGD)

MONTH	1948	1949	1950
January	1,158	1,160	872
February	1,197	1,143	878
March	1,155	1,152	896
April	1,128	1,127	890
May	1,100	1,120	894
June	1,159	1,265	969
July	1,193	1,256	966
August	1,198	1,257	987
September	1,202	1,211	988
October	1,145	1,173	990
November	1,135	1,136	976
December	1,150	935	994
Average for Year	1,160	1,161	942

From the table it can be seen that consumption was low during the first five months of 1950, but, as soon as some of the restrictive measures were relaxed in June, consumption for that month showed a marked increase over consumption for the preceeding months. It should also be noted that the use of water in December, 1950, was 59 mgd higher than in December 1949. This was due to the permanent suspension of the restric-

tive measures.

In addition to the measures taken to reduce consumption, clouds were seeded with dry ice and silver iodide smoke to test the feasibility of increasing rainfall by artificial stimulation. This program occurred from February 1950 to February 1951.

2. Drought of 1961-1966

The unprecedented drought, which began in 1961, culminated with a severe water shortage in 1965. By then, the deficiency in precipitation from the beginning of the drought amounted to a loss of about 1 year of rainfall. On January 1, 1965, reservoirs were only at 26% of capacity compared to a normal level for January of nearly 75%. The drought persisted and rainfall from January 1 to April 1 was 16% below normal.

As a result, the Mayor directed all City agencies on April 7, 1965 to strictly conserve water. The directive included the following:

- Lawn sprinkling in municipal parks and golf courses was stopped.
- Street flushing operations were suspended (in some instances, chlorinated river water was used).
- Fire hydrant harnesses were installed and laws against illegal hydrant openings were more strictly enforced.
- An educational campaign began in the City's schools.
- Water used for cleaning subway cars and buses was reduced.

Beginning on April 19th, the following water use restrictions were imposed on the public:

- Watering lawns and gardens was restricted to certain hours of the day, the use of hoses was banned, and filling private pools was prohibited. (On June 16, watering lawns and gardens was banned entirely.)
- Ornamental fountains were shut down.
- Restrictions were placed on car washing.
- The use of water for cleaning buildings or other structures was banned.

- Water used by air conditioning units of 2 tons or more was limited and the number of hours during which air conditioners could operate was limited.

In addition to the above mandatory restrictions, an intensive educational campaign was initiated through the press, radio, and television. Posters and leaflets were distributed and publicized in order to make the public aware of the seriousness of the situation so that individuals would make efforts to conserve water. The importance of the public education campaign was indicated in the 1965 Report of the Board of Water Supply:

> The appeal to the public was undoubtedly the most important part of the campaign, for without their voluntary cooperation the campaign would falter. Although restrictions were imposed on water usage, this type of restriction is difficult to enforce in a City the size of New York. The success of the campaign depended on the public's voluntary cooperation.

Industrial and commercial establishments using large quantities of water were also requested to reduce their water usage. These included barbers, hairdressers, bottling plants, department stores, laundries, breweries, the photograph processing industry, landscapers, general contractors, hotels and motels, the food industry, restaurants and many others. Suggestions were made to these commercial establishments on the various methods that could be employed in saving water which would specifically apply to their own operation.

The intense conservation campaign, both the voluntary and mandatory aspects, was continued in 1966, but due to increasing storages in the late Spring of 1966, some of the restrictions were relaxed.

The long run effect of the conservation campaign is indicated in Table II-E-30. While average daily consumption for 1965 was more than 12% less than the 1964 level, the drop in consumption for the second half of the year - when the conservation campaign was in full force - was 19% compared to the similar period of the previous year. While there were complaints about the campaign, especially from businesses whose livelihood depended on water use, the willingness of a well-informed public to cooperate in a water saving effort was amply demonstrated.

TABLE II-E-30

AVERAGE WATER CONSUMPTION IN NEW YORK CITY, 1960-1967
(MGD)

	MGD	Percent Change from Previous Years
1960	1147.3	-0.4
1961	1167.2	+1.7
1962	1151.0	-1.4
1963	1158.0	+0.7
1964	1131.0	-2.
1965	994.0	-12.1
1966	987.3	-0.7
1967	1078.3	+9.2

In addition to the intensive conservation campaign, which reduced consumption as shown above, measures were taken to supplement the reservoir system by reactivating the Ridgewood System on Long Island and by withdrawing water from the Hudson River at Chelsea. The Ridgewood System, which had not been used since 1958, was reactivated in 1965, delivering a total of 4.5 billion gallons into the City system in 1966. As an emergency measure, the Hudson River pumping station at Chelsea, which ties into the Delaware Aqueduct, was reconstructed to a capacity of 100 mgd. This station was first constructed in 1950 to alleviate the water shortage during that drought, but was dismantled in 1957. Beginning in March 1966, the Chelsea Station delivered 24 to 100 mgd of Hudson River water into the City system, totaling 20.3 billion gallons by the end of 1966.

C. A CONTINGENCY PLAN FOR FUTURE DROUGHTS

While the basic intent of the NYMA Water Supply Study is to insure that the metropolitan area has enough water to meet demands during a recurrence of the most severe drought on record, it is possible that a drought could occur before the existing deficit is eliminated. This deficit could be eliminated by increasing supplies, reducing demands, or a combination of both. If a future water shortage is as severe as the droughts of 1949-1950 and 1961-1966, it will again be necessary to take similar actions is additional sources are not developed. Even if they are, in the event of a water shortage more severe than anything yet experienced, it may be necessary to consider alternative ways to cope with an emergency situation.

The drought contingency plan consists of three successive phases:

- Phase 1 - Conservation campaign such as conducted during previous droughts.
- Phase 2 - Tap sources not normally used for water supply to augment the City system.
- Phase 3 - Severe, mandatory water use restrictions in the event of a water emergency.

The purpose of Phase 1 is to reduce consumption, largely through the voluntary cooperation of the public, so that the City's reservoirs are not depleted to dangerously low levels during periods of abnormally low precipitation. If reservoir levels were to continue to drop, it would be necessary to initiate Phase 2 in addition to Phase 1. During the drought of the 1960's, for example, the water conservation campaign was supplemented by tapping the Hudson River and the Ridgewood System. If the reservoirs were to be depleted such that an emergency situation existed, Phase 3 would have to be implemented. Each of these phases is described in more detail below.

1. Phase 1

Although the conservation campaigns conducted during the droughts of 1949-1950 and 1961-1966 included mandatory restrictions on water use, the success of these campaigns was largely attributable to the public's efforts to conserve water. Many of the restrictions were difficult to enforce and the estimated amount of water saved from some restrictive measures was minimal. For example, the water saved by lawn sprinkling in parks and golf courses during the 1960's drought was estimated by an official in the City's Department of Water Resources to be 10 mgd and savings attributable to closing fountains was even less. (1) The primary effect of the water use restrictions was psychological in that their imposition demonstrated to the public the seriousness of the drought. In addition to the restrictions, the public was persuaded to conserve water through an intensive educational campaign. Thus, the following restrictive measures, in combination with appeals for the public to voluntarily use less water, are recommended as the initial drought contingency measures:

- Curtail lawn sprinkling in municipal parks and golf courses and, if necessary, extend to private lawns and gardens.

- Substitute chlorinated river water for city water for street flushing operations.

- Install harnesses or spray caps on fire hydrants and strictly enforce laws against illegal hydrant openings.

- Reduce the amount of water used for cleaning subway cars and buses.

- Shut down ornamental fountains.

- Ban the use of water and steam for cleaning the exterior of buildings.

- Prohibit the filling of public and private swimming pools.

- Place restrictions on car washing.

- Prohibit the operation of automatic plumbing flush fixtures.

- Curtail the operation of skating rinks.

- Restrict the bleeding of water lines for the purpose of maintaining a constant flow to prevent freezing.

Various combinations of the above measures can be imposed, depending on the severity of a water shortage. Also, certain measures apply only to hot weather, such as restriction on swimming pools, while others pertain to winter, such as the prohibition of water line bleeding.

Because many of the water use restrictions are difficult to enforce in an area as large as New York City, the success of such measures is largely determined by the public's willingness to cooperate. In addition to complying with restrictions, the public should be encouraged to save water by eliminating wasteful uses in the home. An intensive public educational campaign, in conjunction with restrictive measures, might be necessary in order to significantly reduce consumption.

The purpose of an educational campaign would be to convince the public that reduced consumption during a drought is necessary to avert a severe water shortage. Techniques to inform the public about ways to save water could include:

- Mass media (the press, radio, television).
- Posters in subways, buses and other public places.
- The distribution of pamphlets and circulars.

Designating "dry days," during which the public is asked to save as much water as possible, is a technique which proved successful during the drought of 1949-1950.

As shown in Tables II-E-29 and II-E-30, past water conservation campaigns resulted in significant savings. During a 6 month period in 1950, when a campaign was fully operational, water consumption was 22% less than consumption for a similar period in 1949. During a 6 month period in 1965, consumption was reduced by 19% compared to a similar period during the previous year. But after the use restrictions and the educational campaigns were phased out - when the droughts of 1949-1950 and 1961-1966 ended - consumption increased to pre-drought levels.

Whether or not a conservation campaign conducted during a future drought will cause a 20% reduction in demand depends on several factors, including:

- the severity of the drought.
- the ability of public officials to convince the public of the need to conserve water.
- the willingness of the public to make a conscious attempt to reduce water consumption.
- the frequency with which the public is called on to conserve water as a drought contingency measure.

2. Phase 2

If new sources designed to increase the City system's safe yield are not developed, it may be necessary during a drought to modify release schedules in the Delaware watershed and to tap sources not normally used for water supply.

Methods that could be used to bolster the City system during a drought include:

- Modification of release schedules in the Delaware River watershed.
- Reactivating the Byram River Watershed.
- Reactivating the Ridgewood System on Long Island.
- Withdrawals from the Hudson River at Chelsea.
- Cloud Seeding.

a. Modification of Release Schedules in the Delaware Watershed - The Delaware River is an interstate stream which flows from New York State into Pennsylvania, New Jersey and Delaware. The interbasin transfer (from the Delaware River Basin into the Hudson River Basin) was challenged by the downstream states, since the transfer resulted in a subsequent loss of water for the downstream users. This issue was brought to the Supreme Court and rulings were issued in 1931 and 1954. The 1954 decree, which replaced the earlier one, requires that water be released from the three New York City reservoirs located in the Delaware River Basin. The downstream release requirements are of two kinds. The first one requires that a minimum flow of 1750 cubic feet per second (cfs) be maintained at Montague, New Jersey (compensating releases). The other, so called "excess release," requires a certain quantity of "excess water" to be released from the three reservoirs.

The decree also authorized New York City to divert an equivalent of 800 mgd in such a manner that at no time during any twelve-month period commencing June 1, shall the aggregate total quantity diverted, divided by the number of days elapsed since the preceding May 31, exceed the permitted rate of diversion.

Since downstream states are entitled to a flow of 1750 cfs at Montague while New York City is authorized 800 mgd, conflicting claims for Delaware water may arise during a drought when flows are not sufficient to provide both parties with their alloted amount of water. In 1965, for example, the flow rate at Montague was reduced to 1200 cfs, without apparent adverse effects on water supply systems downstream. The Philadelphia Water Department, which draws heavily from the Delaware, operated throughout the 1960's drought without restrictions or loss of capacity although encroachment of salt water into the estuary was a matter of concern. Elimination of excess releases and reduction of compensating releases could increase New York's share of Delaware water during extreme droughts. (2)

b. Byram River Watershed - Although the City abandoned its diversion of Byram Lake and 9 square miles of the Byram River watershed in 1955 because of increased pollution, this source could be considered during a severe drought. However, the total dependable yield of this source, combined with the Bronx River watershed, which drains into Kensico Reservoir, is only 10 mgd.

c. Ridgewood System - Much of this groundwater system on Long Island was built prior to 1900 to serve Brooklyn. Most of the system was dismantled by 1958, but it was reactivated during the drought of the 1960's, yielding less than 20 mgd on the

average. The system's water quality is below State standards. Average manganese and iron concentrations are 4 times and 2 times above permitted levels, respectively. The iron and manganese are oxidized when mixed with air or chlorine, producing a bronze color in the Ridgewood water, even after blending with water from the City's upstate reservoirs. The water was unpopular in the area where it was distributed during the drought of the 1960's. (3)

d. Hudson River - A 100 mgd emergency pumping station, located on the Hudson River near Chelsea, was operated to augment the City's water supply in 1966. Water may be drawn from the river and discharged into the Delaware Aqueduct at Shaft 6 only when flows are sufficient to keep the salt front below Chelsea. This limits the operating period to about 6 months of the year during a prolonged drought. In addition, the Health Departments supervising the operation required during the 1960's drought that the Hudson River water be diluted by not less than four parts of additional water from Rondout Reservoir. Therefore, at the pumping station design rate, 500 mgd is required from the Rondout Delaware System. This quantity may not be available, or may imbalance storage among the three supplies. The dependable yield from the Chelsea station is estimated at no more than 50 mgd on an annual average basis.

New York City pumped 21.4 billion gallons from the Hudson River between March 21, 1966 and January 13, 1967. The water was heavily chlorinated and treated with alum at the pumping station in order to induce subsequent coagulation and purification in West Branch Reservoir. A chlorine residual was maintained below West Branch. Although these precautions permitted safe use of Hudson River water during the 1960's drought, the Chelsea pumping station is considered to be an emergency facility - not a regular source of supply.

e. Cloud Seeding - This technique has been used to increase rainfall, with mixed results. Although it is possible that rainfall can be increased, seeding may decrease rainfall under some conditions and have no effect under others. Scientists are still unable to determine optimum cloud conditions and seeding techniques, or to accurately predict the results of seeding. Cloud seeding is impractical under severe drought conditions when the humidity is low and clouds are lacking. However, temporary disruptions of drought conditions may occur when there may be sufficient clouds to support rainfall. Under these conditions, seeding might produce positive results. In addition to potentially reducing rainfall, improper seeding could intensify the rainfall rates of storms that are naturally of moderate to heavy intensity, thereby increasing erosion and sedimentation. Given the risks of failure and detrimental effects, cloud seeding could be used

as an emergency measure to augment supplies. (4)

In summary, there are certain risks associated with each of the alternatives for supplementing the City's supplies during a drought. Water quality problems and small reliable yields decrease the feasibility of drawing water from the Byram watershed and the Ridgewood system. Increasing rainfall by cloud seeding, thus providing some relief from a drought, is subject to many uncertainties and potential yield is impossible to estimate. In the absence of long range alternatives designed to provide an adequate supply of water during a drought, an emergency pumping station on the Hudson River at Chelsea appears to be a more feasible supplementary source. Modification of required releases in the Delaware watershed could have provided increased yields during the 1960's drought. However, the decision to make such modification during future droughts rests with the Delaware River Basin Commission, the River Master and the courts and would be dependent upon flow conditions in the Delaware River.

3. Phase 3

If the actions outlined in Phases 1 and 2 of this drought contingency plan are inadequate to prevent a severe water shortage, it may be necessary to impose the additional measures outlined below, either singly or in various combinations. Implicit in the choice of emergency measures is an assessment of the severity of the shortage, a determination of water use priorities, and an assessment of the potential adverse impacts of each measure.

- Curtail or shut down water consuming businesses and industries.

- Cut off water supplies to buildings, including residences, for several hours each day, on a rotating schedule by geographic area.

- Turn off water mains for several hours each day on a rotating schedule by geographic area, if a way could be found to handle fire emergencies in such areas during temporary dry periods.

- Mass shipments of drinking water to the City if the quantity or quality of water from the tap is insufficient for drinking and cooking purposes.

a. Curtail or shut down water consuming businesses and industries - Commercial and industrial establishments use about 20% of total water consumed in New York City. Depending on the severity of the shortage and the potential adverse economic impacts, some or all of these establishments could be closed,

saving a significant amount of water.

b. Cut off supplies to buildings - Although enforcement would be difficult, the City could require (or request) building owners to shut off the water supply for several hours each day, on a rotating schedule by geographic area. For example, neighborhood A could be asked to cut off supplies from 8:00 A.M. to noon on one day, from noon to 4:00 P.M. the next day, etc. A rotating schedule would impose a hardship in an equitable manner.

c. Turn off water mains - If the measure discussed above is not effective, it may be necessary to turn off water mains in parts of the City on a rotating basis so that the hardship is equitably distributed. However, this measure increases the risks of fire damages in those areas where water pressure in mains is inadequate for fire fighting purposes. The risks of fire should be carefully weighed against the risks of further decreasing reservoir storages before this contingency measure is imposed.

d. Mass shipments of water - If water pressure becomes inadequate to draw water from the tap or if water quality deteriorates below potable standards due to polluted emergency sources, it may be necessary to procure mass shipments of bottled water for cooking and drinking purposes. It has been estimated that water for cooking and drinking amounts to 4 gpcd. (5) Thus, about 32 mgd of bottled water would have to be delivered to New York City to meet these basic needs. Given the large wholesale and retail food system within the City, it is likely that the necessary amount of bottled water could be transported to the City and distributed through supermarkets.

If a water shortage requiring drastic measures such as those discussed above were to occur, New York City would probably be eligible for emergency disaster assistance from the State and Federal governments, and numerous private organizations, such as the Red Cross, would inevitably take measures to mitigate the effects of a severe water shortage.

NOTES - CHAPTER 8

(1) Telephone conversation with Abraham Groopman, Chief Engineer, New York City Department of Water Resources, Nov. 1975.

(2) Comprehensive Public Water Supply Study for NYC and Westchester County, August 1967, p. 171.

(3) Ibid., p. 59.

(4) Engineering Feasibility Report On Alternative Regional Water Supply Plans (Joint Venture), November 1971, p. 6-14.

(5) Howe, et al., Future Water Demands, March 1971, p. 7.

ATTACHMENT II-E-1

CONSUMER BEHAVIOR AND METERING

A. THEORY

In principle, water can be treated like any other commodity in order to analyze the response of consumption patterns to outside influences. But it is important to bear in mind that metering as such has only the passive purpose of identifying and quantifying the distribution of water use. This information, once acquired, can be put to more active uses, such as (1) accounting for the total level of unsold water in the system, (2) identification of specific distribution system leaks, (3) identification of unusually large consumer in-house consumption due to possible waste and leakage and (4) water demand modification through pricing policy. Almost all of the theoretical discussion of metering has been concerned with the significance of the last application, with the unspoken assumption that the other uses are obvious and automatic.

The theory of consumer demand has been extensively developed elsewhere by a very large number of analysts, and only a few salient points will be reviewed here. A consumer's response to a change in the price of a commodity, all other things being equal, consists of an income effect and a substitution effect. If the price goes up, for instance, he will have less income at his disposal and will consume less of everything; at the same time he will try to switch his consumption away from the commodity whose price has risen, toward other commodities that can substitute for it. (One such "substitute," of course, is simply doing without the item in question.) How much the pattern of consumption changes, then, depends on two critical factors: how important the commodity is in the consumer's total budget (the strength of the income effect), and whether reasonable substitutes exist for that commodity. The consumer's response to a given price change is greater over the long term than it is in the short run, because he can modify his lifestyle more and more as time passes. These considerations apply equally as well to a business firm as to an individual consumer or a family.

In the case of water, one would expect the income effect of a price increase on domestic consumption to be minor, since water costs the average family less than a hundred dollars a year, and a change in its price would have to be very large to have a noticeable effect on day-to-day water use. As for substitutes, including simple non-use, it must be considered that water has a number of domestic uses, which can be broadly categorized as in-house (drinking, cooking, hygiene, etc.) or

outdoor (lawn sprinkling, car washing, etc.). Water has no good substitutes for its in-house uses, particularly in the short run. Over time, inefficient or leaky plumbing fixtures and appliances could be replaced with water-conserving models, if the water savings would be great enough to compensate for greater cost and inconvenience. But in general, economic theory leads one to expect in-house water uses to be relatively insensitive to the price of water within the usual range of water costs (i.e., up to $1.00 per 1000 gallons, and averaging $.40 per 1000 gallons).

Outdoor uses are another matter, however. Car washing can be completely foregone, or greatly reduced, with the loss only of the psychic "income" of having an outwardly clean car. Lawn sprinkling is intended to compensate for lack of natural rainfall during dry spells, and in a naturally wet climate like that of the northeastern United States, such dry spells are usually brief enough to permit the reduction of sprinkling to a great degree without lasting damage to lawns and shrubbery. This is a short run adjustment; in the long run, lawns can be reduced in size or reseeded with grasses resistant to dryness, if such measures would be cost-effective. In general, then, one would expect outdoor water uses to be comparatively responsive to changes in water costs.

The successful use of water pricing policy to constrain water demand depends, first, on knowing with confidence how much water each household consumes, and second, on charging each household an amount proportional to its use. Water meters accomplish the first condition simply by their nature, but only if every family has a meter that is accurately read and properly maintained. Metering can permit the second condition to be met, because nonmetered customers of a public system are charged a flat rate for unlimited use (so that the "price" of using an extra gallon of water is zero), while metered customers pay on a per-gallon basis. Metering by itself cannot be expected to be a panacea for controlling water demand: it must be accompanied by a pricing policy that elicits the greatest degree of the potential response in consumption, as discussed above.

B. EMPIRICAL RESULTS

A number of studies have been conducted to determine whether domestic water use follows the predictions of the theory of consumer choice briefly described above. Several problems arise in considering the results of these studies, because the real world is vastly more complex than the idealized realm of theory.

The preceding section assumed "all other things being equal" - that is, that all factors capable of influencing

consumer behavior, other than the price of one commodity, are assumed not to change. But these other factors, which can include the family's income, its personal tastes, the prices of other goods and services, the age and nature of its housing, the status of the local and national economy, climate, and many others, all can vary over time and place. A great deal of care is required, in the structuring of a study and in the interpretation of its results, in order to isolate the effect of one factor with any confidence.

Theory also assumes that the consumer will act as if he has perfect knowledge of the consequences of all of his actions, and will always act in accordance with his own short run and long run best interests. In fact, the real consumer operates in uncertainty; he can be taken by surprise and exhibit temporary "shock" or "novelty" reactions that are not economically justified; and he can act in ways that do not correspond to his (economic) best interests - indeed, he may not be consciously aware of what his best interests are. If large enough numbers of people are considered, however, the individual idiosyncrasies average out, and the remaining systematic differences from the ideal situation can be identified and accounted for.

The most comprehensive and rigorous analysis of residential water use in this country is contained in a series of studies published over a ten-year period by Charles W. Howe, F. P. Linaweaver, Jr., Jerome B. Wolff, et al. (1) (2) (3) (4) (5) (6). This work is of particular value because of the detail of data collection, the number of variables analyzed, and the length of observation of each study area (2-1/2 to 3 years in all cases). Sample populations were structured on the bases of eastern United States versus western United States (to account for climate), metered versus flat-rate supply, and public sewers versus septic tanks. Study areas corresponding to different combinations of these characteristics were analyzed for the relationship between water use and such factors as economic level (measured by dwelling unit value), number of persons per dwelling unit, age of the dwelling unit, water pressure, water cost and billing practices, the regional price index, the irrigable area per dwelling unit, precipitation and potential evapotranspiration. Most of these variables were found to be statistically insignificant in terms of "explaining" the observed water use behavior. In fact, in-house water use was found to depend only on dwelling unit value and water cost in areas that are metered with public sewers; only on dwelling unit value and persons per dwelling unit in flat-rate and apartment areas with public sewers; and only on persons per dwelling unit in metered areas with septic tanks. (7) In-house water use is insensitive to price, within the observed range, even in metered areas; it is more responsive to dwelling unit value (i.e., economic level).

It should be noted that apartment dwellers are classed with flat-rate users even if the apartment buildings are metered: since individual apartment services are not metered, they are not billed in direct relation to their quantity of use, and in effect are flat-rate consumers. Many investigators have noted this effect. Another key finding is that the level of in-house water use, and the rate of leakage (about 10-15 percent of in-house use), are not significantly different between metered and flat-rate areas, although leakage seems to increase more with the age of the housing in flat-rate areas than in metered areas. (8) Sprinkling demand, however, was found to be responsive to the cost of water in metered areas, especially in the eastern United States (9), and sprinkling use was considerably lower in metered areas than in comparable flat-rate areas. (10) Sprinkling use was also found to be more responsive to economic level than in-house use. (11)

The various case studies found in the data in the long-run effects of metering provide mixed results, depending largely on the unique characteristics of particular cities, whether the data includes industrial and sprinkling demand, etc. Several of the major cities considered experienced short-term reductions but soon returned to the long-run trends. Others experienced reductions which had longer lasting impacts. Depending upon which samples are selected and which data used over which time period, the results can be made to confirm any desired conclusion.

It must be emphasized that the limitations particular to each analysis need to be recognized before their results can be meaningfully interpreted and applied to any one city such as New York. One problem lies in the reliability of measuring, or even estimating, the relevant variables. Lawn sprinkling requirements, for example, depend on effective precipitation and potential evapotranspiration, neither of which can be directly measured; they must be deduced from theory and indirect data. Home value, another important variable, is itself only a proxy for general economic status, and involves problems of comparability from place to place. Another problem is that any particular city has unique characteristics, and a relationship that may be completely appropriate for the nation, or for a region, as a whole, may be inappropriate for any given city in that region. A house of given market value in New York City, for instance, generally has a much smaller lawn area to be watered than a similarly-valued house in the suburbs, and other water use habits may be expected to differ as well. Related to this is the fact that data definitions may vary from place to place - in New York City, "non-industrial consumption" does not include commercial use, whereas in most other cities it does, and it usually also includes a proportion representing municipal

and institutional use and leakage that varies in importance from city to city.

In this context, a report by the American Water Works Association (12) notes wide variations in water use per customer, both for a given utility over time and among utilities, because of changing local conditions. It also notes the practical difficulty in an empirical survey of isolating the effects of one variable, such as metered versus flat-rate service, from other variables that are usually changing at the same time. (13) The empirical models developed by Howe, Linaweaver, et al. are reviewed and commended, but their application is viewed with great caution for the same reasons as described in the preceding paragraph: ". . . extreme care must be used in application of the method . . . it is not practical for estimating particular planning requirements of specific communities that normally have their own unique characteristics, apart from those recognized in the report." (14)

The point is that the reliability of using theoretical and empirical results to predict the consequences of metering in a new situation depends on the sophistication of the model used, the availability and quality of the data, and careful attention to local idiosyncrasies that could undermine any general model.

C. PREVIOUS STUDIES OF METERING IN NEW YORK CITY

A large number of studies have been made of the potential water savings to be realized in New York City through universal metering, leakage control, and conservation practices. The discussion has been going on sporadically for over a century, surfacing whenever New York City has suffered a drought or has contemplated an expansion of its supply system.

One of the earlier analyses of metering and water conservation was performed in 1906 for the Merchants' Association of New York. (15) It set forth certain basic concepts common to subsequent studies of metering. The term "waste" was carefully defined to mean loss by accident or leakage, rather than frivolous or malicious overuse, which was judged to be insignificant. (This distinction has usually been blurred in popular discussions of metering.) Three fundamental reasons for metering were described: (1) equity, by causing water users to pay in proportion to their use; (2) managerial efficiency, improving the planning and operation of the system by generating better information on the level and distribution of water demand; and (3) water conservation, by encouraging control of leaks in customer services. It was considered that the first two reasons were sufficient in themselves, apart from the water saved by conservation. Water lost over the period 1894-1904 was estimated at not more than 15 percent of

total delivery, largely confined to leakage in unmetered services. Leakage from distribution mains was deemed unimportant and too costly to bother repairing. House-to-house inspections were recommended as the immediate means of reducing leakage, followed by metering to encourage permanent control. While the amount of water to be saved was uncertain, it was considered that the ability to delay building the then-planned Catskill system would reduce its interest costs significantly.

The only comprehensive study of water use in New York City was performed in 1939 by the Works Projects Administration. (16) Its uniqueness still makes it a primary source in spite of the age of the data. One of its strongest features was the actual measurement of representative samples of metered and unmetered water consumption, using temporary meters on distribution pipelines and other means, enabling the estimation not only of unmetered residential consumption, but also of exempt municipal consumption, meter slippage, and leakage from water mains. Water consumption, totalling 938 mgd in 1939, was found to have the following distribution:

Water Use Class	MGD	%
residential flat-rate	540	57.5
residential metered	9	0.9
business metered	203	21.7
misc. unmetered	7	0.7
meter slippage	38	4.1
exempt use	72	7.7
leakage from mains	70	7.4
TOTAL	938	100.0

(The sum of water uses by class differs from the total due to rounding.) Exempt users, in order of importance, included the Department of Sanitation, hospitals, schools, the Parks Department, and others (churches, firefighting, other municipal uses, etc.). With regard to residential use, it was found to be higher (per capita) in apartment buildings than in one or two family homes, and varied quite strongly and consistently with the level of rent (a proxy for income). Of greater significance to later metering studies was the finding that flat-rate per capita residential use was higher than metered use, and particularly so in apartment buildings (89 gpcd versus 54 gpcd).

Another significant report was the 1951 Future Water Sources of the City of New York (17), which included a chapter on metering and conservation as a "source" of water. It based its analysis on the findings of the WPA study and reports prepared by New York City agencies in 1947 and 1948, as well as the

experience of other cities with metering and leakage control. On the latter point, it was observed that New York City allocated a much smaller amount of money and manpower to leak detection from its 5300 miles of mains than did other cities (one-sixth as much as Chicago, with 4000 miles of mains). Moreover, the labor force for this purpose operated (at that time) only in Manhattan and the Bronx, and divided its time among more pressing problems of the distribution system than leak detection surveys. It was concluded that an effective, full-scale effort toward leak detection and repair in all five boroughs would save not less than 100 mgd, and possibly as much as 200 mgd. Concerning universal metering, it was noted that, based on experience elsewhere, savings of 39 to 74 gpcd could be expected to result from it. One City report had estimated savings of 220 mgd from universal residential metering, and 166 mgd from metering only multi-unit buildings; another had estimated domestic plumbing leakage to be 200 mgd (based on spot surveys), of which 110 mgd could be eliminated by comprehensive two-year surveys or 80 mgd by four-year surveys. A water conservation campaign in 1949-1950 had reduced per capita domestic use in New York by 25 gpcd, and it was estimated that only half of the 80 gpcd average use was necessary consumption. It was recommended that meters be owned and maintained by the City. The final conclusion was that the City could save 300 mgd, half from control of water main leakage and half from control of domestic leakage and waste.

A sharply different conclusion was drawn by a 1952 report by the New York City Board of Water Supply. (18) Comparing per capita water use among the nine largest cities in the U.S., New York's was the lowest in 1951, and had been the lowest by a large margin for most of the previous sixty years. It was therefore asserted that New York's water use was not excessive. Projections were made of population and total and per capita consumption for the period 1953-1960, with and without metering of multi-unit buildings over a ten-year period, and it was concluded that this measure could reduce water demands by 6 gpcd, or 53 mgd, as of 1960. The key to so small a projected reduction was the observation that metering an apartment building is no guarantee of a reduction in waste, because the individual tenants - the actual consumers - would still be unmetered. Moreover, the annual costs of metering would include not only the amortized initial cost (estimated at $4.9 million per year), but also costs for meter reading and billing, testing, repair, and replacement, estimated at $800,000 annually. This latter sum alone, it was stated, would support a waste detection force that could maintain a permanent saving greater than the 50 mgd projected to be saved by metering.

The 1964 Report on Universal Metering (19) took an intermediate position. It noted the same estimate of 200 mgd lost

through domestic plumbing leakage as was cited in the 1951 report, but estimated that the water conservation campaign of 1949-1950, and slum clearance in the intervening years, had reduced this loss by half. Consideration of the figures in the 1940 WPA report comparing per capita use in metered and unmetered dwellings, and the experience of a number of cities before and after metering, led to the conclusion that 25 mgd of "wasteful personal practices" (mostly in terms of personal consumption and sprinkling in one and two family homes) would be eliminated by metering, in addition to the 100 mgd lost by leakage, for a total saving of 125 mgd. This would be accompanied by increased revenue and a reduced burden on the City's sewer facilities. The City, it was stated, should purchase and install the meters, over a ten-year period, and be reimbursed by the property owners; maintenance would be the City's responsibility. It was noted that the City Administrative Code (Section 734 (4)-1.0) provided for metering of multi-unit buildings by local law or resolution of the Board of Estimate, but universal metering would require amendment of that Section of the code.

A report by the Samuel J. and Ethel Lefrak Foundation (20) highlighted an interesting aspect of water system financing. Water rates more than covered operating expenses, and in fact, put a $20 million excess into the City's general fund annually (as of 1965). But this excess could not be applied to the capital costs of the system; that was recovered through surcharge on the real estate tax rate. The result, it was pointed out, was a double charge for water, whose total level depended on a property's assessed valuation as well as its water use. An increase in water rates would only increase the surplus into the general fund, without reducing the capital charge; moreover, such a financing system introduced a powerful bias toward projects with high capital costs and low operating costs, such as upstream reservoirs. It was noted that evidence existed for a reduction in water use in one or two family homes with metering, but apartment dwellers would not be individually metered, and landlords are motivated to repair leaks for other reasons in any case. It was therefore questioned whether any water could be saved by metering multi-unit dwellings. Metering of the distribution system was recommended as an adjunct to leakage control, and residential metering was recommended to proceed in stages, in order to evaluate its results.

The report of the Temporary State Commission on the Water Supply Needs of Southeastern New York (21), applied to the boroughs of New York City the relationship between metering ratio and non-industrial per capita use that had been statistically derived for a 30-city sample. It was estimated that, City-wide, universal metering would reduce total consumption by 15 percent, or 210 mgd based on 1970 water use. The discussion of this

indicated that this saving was in the area of domestic plumbing leakage and sprinkling; water-conserving devices were examined and it was concluded that these were not important sources of potential saving. Distribution system leakage was estimated at six percent of total delivery, or 84 mgd in 1970. Of this, 56 mgd was judged to be economically avoidable.

D. DISCUSSION

The literature on metering in New York City has several distinctive features. First, hard data on water use in New York City has been gathered in only one or two studies from twenty-five to forty years old. The various estimates of potential water savings have consequently been derived from the same meager data base, supplemented by judgement or guesswork and extrapolation of experience elsewhere (a risky procedure, as was noted in the previous section). This has led to the second feature: the uncertain level of water use savings projected to result from universal metering, from 50 to 300 mgd. Third, in spite of this broad range of expected results, almost all of the studies have concluded by recommending universal metering in New York City, for reasons of equity and managerial efficiency. Fourth, it is assumed in almost all of the studies that water savings from leakage control and conservation practices would follow automatically upon the implementation of metering, with little or no attention given to economic or institutional factors that could prevent this from happening.

E. SUMMARY AND CONCLUSIONS

Economic theory predicts that in-house residential water use would not be responsive to changes in the price of water, at least within the range of prices usually experienced. Residential water use for sprinkling, however, should be sensitive to water costs.

Empirical studies confirm these predictions. The studies by Howe, Linaweaver, et al., revealed that in-house residential use is influenced chiefly by family income, comparatively little by water cost within the usual range (up to $1.00 per 1000 gallons and averaging $.40 per 1000 gallons), and not at all by whether water is delivered on a metered or flat-rate basis. Sprinkling demand does respond to all of these factors, and depends on climate as well. More limited surveys and analyses of metering and its effects in various parts of the country have also confirmed that metering principally affects lawn sprinkling use, and that the in-house effects of new metering (or of observed water rate increases) are minor and temporary. Moreover, application of any analysis to a particular city is a risky procedure, whose results require very cautious interpre-

tation.

Studies of the potential effects of universal metering in New York City have varied greatly in the conclusions reached as to its viability, and the amount of water that could be saved. The estimated savings have ranged from 50 to 300 mgd. The water savings have, with few exceptions, been based on detection and control of leaks in the distribution mains and in customer services. Estimates of leakage actually occurring vary widely. Domestic leakage estimates run from 50 to 200 mgd (6 to 24 percent of domestic use). Distribution system leakage estimates range from insignificant to 150 mgd (about 10 percent of total system use). By comparison, a common engineering rule of thumb is that unaccounted-for water in a distribution system should not exceed 10 to 15 percent of total system yield (22), and Howe, et al., found a similar rate for in-house leakage to be typical. In this context, New York City's probable losses do not seem to be unusually large. (See Chapter 3 for a discussion of distribution system leakage control in New York City.) Few of the studies have attempted to analyze the legal and institutional constraints that could prevent potential metering savings from occurring.

It has been pointed out that the costs of metering would represent an unfair burden on small property owners, unless this cost were subsidized or completely assumed by the City. Estimates of the costs of installing meters have been based on prevailing prices and interest rates that are now grossly out-of-date.

Finally, the City's present financial crisis must be noted, with the observations that the City may not be capable of completely independent fiscal action, and that a major effort such as universal metering could well be beyond the City's financial capabilities in the foreseeable future. Although Federal planning practice requires the assumption of a stable, growing national economy, free of such disruptions as recession or inflation, the possibility of local economic difficulty is admissable. (A comparison can be made to disruptions of nature: no such assumption can be made on the national level, but the possible recurrence of a regional natural disruption - a widespread drought - was the impetus for the creation of the NEWS Study.) In a broader sense, it would be unrealistic to ignore the changing political and financial environment of New York City.

In light of the foregoing, it must be observed that the most pervasive characteristic of the metering question is uncertainty. Estimates of water to be saved have been based on water use data with a wide range, and on comparisons to experience elsewhere. A logical course of action, on the basis of water

conservation, would be for New York City to undertake an experimental and carefully phased approach to this question so as to eliminate this uncertainty and to provide a sound estimate of the cost-effectiveness of metering.

NOTES - ATTACHMENT II-E-1

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(2) Metered Versus Flat Rate. Report II, Phase Two, Residential Water Research Project, Johns Hopkins University, Baltimore, June 1965.

(3) Linaweaver, F. P., Jr., John C. Geyer, Jerome B. Wolff. "Summary Report on the Residential Water Use Research Project," AWWA Journal, March 1967.

(4) Howe, Charles W., F. P. Linaweaver, Jr. "The Impact of Price on Residential Water Demand and Its Relation to System Design and Price Structure," Water Resources Research, 3:1, First Quarter 1967.

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(7) Howe and Linaweaver, op. cit., p. 27.

(8) Linaweaver, et al., A Study of Residential Water Use, op. cit., p. 49.

(9) Howe and Linaweaver, op. cit., p. 28.

(10) Linaweaver, et al., op. cit.

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(12) AWWA Committee Report on Water Use, American Water Works Association, New York, New York, 29 December 1972.

(13) Ibid., pp. 3, 5.

(14) Ibid., p. 15.

(15) Fuertes, James H. Waste of Water and Its Reduction by Meters and Inspection. A Report by James H. Fuertes, C.E.,

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(17) Future Water Sources of the City of New York. Report of Engineering Panel on Water Supply to Mayor's Committee of Management Survey of the City of New York, July 1951.

(18) Report on Metering Multi-Family Dwellings and Leakage and Waste in the City of New York. Research and Development Department, City of New York Board of Water Supply, 10 October 1952.

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(20) Fava, John L., Dr. Herbert J. Ranschburg. Key Issues of Water Metering and Water Financing in New York City. Interim Report of the Samuel J. and Ethel Lefrak Foundation Water Study, 16 September 1965.

(21) Temporary State Commission on the Water Supply Needs of Southeastern New York. Measures to Reduce Water Consumption in Southeastern New York. Albany, New York, November 1973.

(22) Ibid., p. 52.

ATTACHMENT II-E-2

REGRESSION AND CORRELATION ANALYSIS RESULTS

Data was collected for the following variables.

1. Qad = Domestic water use per dwelling unit (gals/day)
2. T = July-Aug. avg. temperature (degrees F)
3. a = Percent of dwelling units less than 10 yrs. old
4. dp = Average persons per dwelling unit
5. t = Time dummy variable (1950=1, 1960=2, 1970=3)
6. p = Marginal water cost (cents/1000 gals, 1970 dollars)
7. Cdu = Non-metered water cost per d.u. ($/d.u./yr., 1970 dollars)
8. Cw = Non-metered average water cost (cents/1000 gals, 1970 dollars)
9. Vo = Median owner-occupied d.u. value ($1000, 1970 dollars)
10. Vr = Median renter-occ gross rent ($, 1970 dollars)
11. rp = Previous year precipitation (in.)
12. rc = Current year precipitation (in.)
13. dr = % of d.u.'s renter occupied
14. u = Unemployment rate
15. fl = Percent low income families

Tabulated below are the results of the multiple regressions that were performed to identify the most important parameters of water use in New York City.

A. 1950 DATA

	Variable	Significant Variable	Significant Relationship	R^2	Standard Error
1.	3, 6, 7	3, 6, 7	-	.967	22.72
2.	6, 7	-	-	.078	85.35
3.	3, 7	-	-	.027	87.69
4.	3, 6	3, 6	-	.693	49.24

B. 1960 DATA

1.	3, 6, 7	3, 6	-	.930	35.97
2.	3, 6	3, 6	-	.926	26.21
3.	3, 7	-	-	.162	88.52
4.	6, 7	-	-	.372	76.66

	Variable	Significant Variable	Significant Relationship	R^2	Standard Error
C.	1970 DATA				
1.	2, 3, 5	2, 3	-	.972	14.86
2.	2, 3, 6	2		.973	14.57
3.	2, 3, 7	2, 3	-	.971	15.24
4.	2, 3	2, 3	-	.969	11.08
5.	2, 3, 4	2, 3	-	.969	15.59
6.	2, 4, 5	4, 5	-	.998	2.93
7.	2, 4, 6	2, 6	-	.983	11.40
8.	2, 4, 7	-	-	.498	63.53
9.	2, 5, 6	2, 6	-	.976	13.81
10.	2, 5, 7	2, 5, 7	-	.980	12.52
11.	2, 6, 7	2, 6, 7	-	.994	6.6
12.	3, 6, 7	3, 6, 7	at 5% level	.999	1.617
13.	2, 3, 8	2, 3	-	.978	13.23
14.	3, 7	-	-	.545	42.76
15.	2	-	-	.336	42.19
16.	3	-	-	.127	48.39
17.	2, 6	2, 6	at 5% level	.961	12.47
18.	2, 4	-	-	.360	50.71
19.	2, 3, 10	2, 3	-	.972	14.85
20.	3, 5	5	-	.782	29.56
21.	3, 4	-	-	.177	57.52
22.	10	-	-	.586	40.82
23.	2, 7	-	-	.409	48.77
24.	3, 6	3, 6	-	.842	25.20
25.	3, 7	-	-	.545	42.76
26.	6, 7	6, 7	-	.841	28.22
D.	GROUPED DATA				
1.	3, 6, 8, 9, 10	6, 8		.565	47.6
2.	3, 5, 6, 8, 9, 10	6, 8		.670	44.0
3.	3, 5, 8, 9 10, 11	5, 8, 11		.670	44.0
4.	3, 5, 8, 10, 11	5, 8, 11		.669	41.6
5.	3, 4, 5, 7, 8, 9, 10	7, 8	1%	.875	28.99
6.	5, 8, 9	5	-	.312	54.24
7.	3, 4, 8, 9 10, 11, 12	11	-	.672	46.89
8.	3, 4, 8, 9, 10	-	-	.279	61.39
9.	4, 5, 9, 10	5, 9	-	.522	47.38
10.	5, 9, 10	5	-	.382	51.42

GROUPED DATA Cont'd

	Variable	Significant Variable	Significant Relationship	R^2	Standard Error
11.	4, 5, 7, 8, 9, 10	7, 8	1%	.874	27.20
12.	4, 5, 8, 9, 10	5	-	.534	49.34
13.	4, 5, 7, 9, 10	9	-	.530	49.55
14.	5, 7, 8, 9, 10	7, 8	1%	.864	26.66
15.	4, 5, 7, 8, 9	7, 8	1%	.865	26.47
16.	5, 7, 8, 9	7, 8	1%	.857	25.88
17.	4, 7, 8, 9	7, 8	1%	.858	25.84
18.	4, 5, 8, 9	5, 9	-	.472	49.83
19.	4, 5, 7, 9	4, 9	-	.482	49.38
20.	4, 5, 7, 8	7, 8	1%	.853	26.29
21.	5, 7, 8	7, 8	1%	.850	25.27
22.	7, 8, 9	7, 8	1%	.855	24.86
23.	7, 8	-	-	.214	55.49
24.	7, 8	7, 8	1%	.850	24.22
25.	4, 9, 10	-	-	.211	58.09
26.	4, 5, 9	4, 5, 9	-	.462	47.96
27.	4, 5, 10	-	-	.245	56.85
28.	5, 9	-	-	.240	54.62
29.	4, 5	-	-	.126	58.55
30.	4, 9	-	-	.126	58.55

E. CORRELATION ANALYSIS

TABLE II-E-31

AREA	VARIABLE
1. Bronx	1. Q a d = Domestic water use per dwelling unit (gal/day)
2. Kings	3. a = Percent of dwelling units less than 10 yrs. old
3. New York	4. dp = Avg. persons per dwelling unit
4. Queens	6. Vo = Median Owner-occ. dwelling unit value
5. Richmond	7. Cdu = Non-metered annual water cost per dwelling unit
	8. Cw = Non-metered unit water cost per 1000 gals.
	10. Vr = Median renter-occ. dwelling unit gross rent
	13. dr = Percent of dwellings renter-occupied
	14. u = Unemployment rate (%)
	15. fl = Percent low-income families

TABLE II-E-32

Analysis of Variable Correlation Matrix (10 variables)

Only variables significantly correlated for 1970 and 1960 are included.

Variables	1970 Value	1960 Value
1+5	-.841	-.888
2+7	.646	.992
2+8	-.815	-.851
2+9	-.856	-.949
2+10	-.762	-.925
3+6	-.881	-.941
3+8	-.772	-.843
3+9	-.684	-.813
7+8	-.732	-.837
7+9	-.774	-.914
7+10	-.956	-.886
8+9	.924	.887
8+10	.900	.916
9+10	.894	.995

TABLE II-E-33

Only variables significantly correlated for 1970 and 1950 are included.

Variables	1970 Value	1960 Value
1+5	-.841	-.729
2+7	.646	.953
2+8	-.815	-.676
2+9	-.856	-.909
2+10	-.762	-.764
3+6	-.881	-.990
3+8	-.772	-.720
7+9	-.774	-.841
8+10	.900	.838
9+10	.894	.804

TABLE II-E-34

Only variables significantly correlated for 1960 and 1950 are included.

Variables	1960 Value	1950 Value
1+5	-.888	-.729
2+4	-.632	-.943
2+7	.992	.953
2+8	-.951	-.676
2+9	-.949	-.909
2+10	-.925	-.764
3+6	-.941	-.990
3+8	-.843	-.720
3+10	-.862	-.847
4+7	-.691	-.838
6+8	.647	.681
6+10	.787	.875
7+9	-.914	-.841
8+10	.916	.838
9+10	.995	.804

TABLE II-E-35

Only variables significantly correlated for 1970, 1960, and 1950 are included.

Variables	1970 Values	1960 Values	1950 Values
1+5	-.841	-.888	-.729
2+7	.646	.992	.953
2+8	-.815	-.851	-.676
2+9	-.856	-.949	-.909
2+10	-.762	-.925	-.746
3+6	-.881	-.941	-.990
3+8	-.772	-.914	-.841
8+10	.900	.916	.838
9+10	.894	.995	.804

TABLE II-E-36

EXPLANATION OF VARIABLES SIGNIFICANTLY CORRELATED OVER TIME

VARIABLES	EXPLANATION
1+5 - Domestic water use per dwelling unit decreases as non-metered unit water cost per 1000 gallons increases.	Howe and Linaweaver showed that domestic in-house use was relatively independent of price (within normal price ranges). That is, a price change would have little effect on consumption. The reverse seems to be true in New York City, although the magnitude of the effect may not be significant. The fact that variable #5 is non-metered unit cost and varies from a water price in the usual sense, may further complicate matters *vis a vis* the Howe and Linaweaver model.
2+7 - As the percent of dwelling units less than 10 years old increases, median rentor occupied dwelling unit gross rent increases (*i.e.*, the more new units, the higher the median rent).	Explanation - This may indicate that many new units are co-op, or condominiums or single or two family houses (such as on Staten Island). This trend seems to be more evident in recent years as the outer parts of Queens plus Staten Island have been developed and huge Co-op projects (such as Co-op City in the Bronx) have been built. It is significant that the correlation is much stronger for 1970 and 1960 (-.815 and -.851, respectively) than 1950 (-.676).
2+8 - As the percent of dwelling units less than 10 years old increases, the percent of dwelling units renter occupied decreases.	
2+9 - As the percent of dwelling units less than 10 years old increases, the unemployment rate decreases.	Explanation - Housing construction is an indicator of the economy's health: the more new housing starts, the healthier the economy. Also the construction industry (of which housing is a major part) employs a significant portion of the City's labor force.

VARIABLES	EXPLANATION
2+10- As the percent of dwelling units less than 10 years old increases, the percent of low income families decreases.	Explanation - New housing is usually the most expensive (as indicated by the correlation of variables 2+7), so the poor can't afford to live in new housing. The correlation of variables 2+10 also supports the saying: "Urban renewal means low income removal."
3+6 - As the average number of persons per dwelling unit decreases, the median owner occupied dwelling unit value increases.	Explanation - While larger families may need more space (which generally costs more), large families in New York City tend to be less well off than smaller families. Assuming a positive correlation between smaller families and higher incomes, they are more likely to have the income necessary to purchase a home, co-op or condominium.
3+8 - As average persons per dwelling unit decreases, the percent of dwelling units renter occupied increases.	Explanation - If the Explanation for variables 3+6 is accurate, the relationship between variables 3+8 appears to contradict 3+6. 3+8 implies that smaller families tend to live in rentor occupied units or that the larger the family, the more likely that people will not live in renter occupied units (i.e., they will purchase their own homes), but 3+6 implied that smaller families are more likely to purchase the most expensive homes. The apparent conflict might be resolved if one notes that many apartments are occupied by single persons of low economic means (students, elderly, etc.)

VARIABLES	EXPLANATION
7+9 - As the unemployment rate increases, the median renter-occupied dwelling unit gross rent decreases.	Explanation - The unemployment rate is an indicator of the economy's health. A high unemployment rate indicates a recession, which in turn implies low incomes and low rates of new construction. The housing therefore tends to be older, and cannot command high rents.
8+10- As the percent of renter-occupied dwellings increases, percent of low income families increases.	Explanation - Few if any low income families in New York City own their homes. They have no choice but to live in renter-occupied units.
9+10- As the unemployment rate increases, the percent of low income families increases.	Explanation - People laid off obviously have less income than those who work, thus increasing the number (and percent) of low income families.

ATTACHMENT II-E-3

INDUSTRIAL RECIRCULATION

NOTE: All tables and data are based upon information found in U.S. Department of Commerce, Department of Census Publications - Water Use in Manufacturing; 1954, 1958, 1963, 1968, 1973.

TABLE II-E-37

WATER USE BY MAJOR INDUSTRIES, U.S., 1954-68

Type of Industry	Year	Gross Water	Brackish	Total Fresh	Total Use
FOOD	1954	1,318	60	556	616
	58	1,298	69	555	624
	63	1,191	79	681	760
	68	1,346	71	740	811
	73	1,579.8	68	628	804
TEXTILE	1954	160	3	107	133
	58	184	1	116	140
	63	217	1	126	151
	68	205	2	101	118
	73	426.4	D*	D*	178
PAPER	1954	4,424	135	1651	1786
	58	6,046	170	1911	1937
	63	5,491	152	1768	2064
	68	6,522	169	1651	2252
	73	8,126.9	76	2295	2415
CHEMICAL	1954	4,293	513	2172	2685
	58	5,225	1157	2083	3240
	63	7,726	1340	2554	3899
	68	9,416	1526	2950	4476
	73	11,098.7	471	2927	4176
PETROLEUM	1954	4,152	608	637	1245
	58	5,780	600	719	1319
	63	6,161	688	710	1398
	68	7,290	615	820	1435
	73	11,710.8	436	639	1283
PRIMARY METALS	1954	4,947	221	3621	3842
	58	5,676	294	3408	3702
	63	6,702	428	4168	4600
	68	7,780	518	4486	5005
	73	8,841.7	545	4396	4941

*D = Disclosure Problems

TABLE II-E-38

WATER USE BY MAJOR INDUSTRIES FOR
DELAWARE - HUDSON REGION

Type of Industry	Year	Process	Public Systems	Brackish	Gross Water	Total ~~Total~~	Total Use
FOOD	1963	12	17	16	85	40	58
	68	20.4	26.7	13.0	103.7	54.5	68.2
	73	25.2	28.2	12.7	162.9	61	78.8
TEXTILE	1963	1.5	1	D*	62	14	14
	68	1.4	1.3	-	8.7	7.6	7.6
	73	9.6	7.9	-	19.2	12.9	12.9
PAPER	1963	51	2	1	307	121	121
	68	47.2	4.4	1.4	309.8	79.1	80.7
	73	D*	D*	D*	540.3	D*	181.3
CHEMICAL	1963	28	40	99	407	162	264
	68	32.8	24.8	61.8	503.5	217	321.9
	73	68.9	42.3	D*	937.6	299.1	429.7
PETROLEUM	1963	19	4	146	839	127	359
	68	26.4	5.2	153.5	732.2	132.1	336.1
	73	8.8	6.6	D*	857.9	131.5	369.9
PRIMARY METALS	1963	21	14	22	384	277	300
	68	36.4	16.8	15.8	410.1	280.9	396.7
	73	99.0	26.4	D*	856.0	335.9	599.6

*D = Disclosure Problems

TABLE II-E-39

NEW YORK STATE WATER USE IN INDUSTRY

Type of Industry	Year	Gross	Total Fresh	Brackish	Total Use
FOOD	1954				
	58	52			42
	63	70	20	14	34
	68	53.1	28.3	12.7	41.0
	73	34.3	13.0	D*	24.7
TEXTILE	1954				
	58	5			4
	63	52	5	D*	5
	68	3.4	2.5	-	2.5
	73	4.8	4.0	-	4.0
PAPER	1954				
	58	279			151
	63	205	132	D*	133
	68	144.2	70.4	.2	70.7
	73	164.4	D*	D*	D*
CHEMICAL	1954				
	58	196			139
	63	166	93	41	135
	68	198.4	133	1.1	134.1
	73	182.2	94.7	-	126.4
PETROLEUM	1954				
	58	D*			
	63	D*	D*	D*	D*
	68	D*	D*	D*	D*
	73	28.6	20.4	-	20.4
PRIMARY METALS	1954				
	58	192			153
	63	351	212	1	213
	68	331.1	180.9	2.8	183.7
	73	288.9	169.8	2.6	172.4

*D = Disclosure Problems

TABLE II-E-40

NEW JERSEY WATER USE IN INDUSTRY

Type of Industry	Year	Gross	Total Fresh	Brackish	Total Use
FOOD	1954				
	58				
	63	23	13	4	16
	68	35.5	16.3	1.1	17.5
	73	57.2	14.8	2.8 (salt & brackish)	17.6
TEXTILE	1954				
	58				
	63	6	6	D*	6
	68	2.2	2.1	-	2.1
	73	4.2	D*	D*	4.1
PAPER	1954				
	58				
	63	155	25	1	25
	68	142.9	19.6	.2	19.7
	73	151.0	17.1	-	17.0
CHEMICAL	1954				
	58				
	63	232	69	85	154
	68	286.5	106	89.1	195.1
	73	342.7	99.1	103.1 (salt & brackish)	202.2
PETROLEUM	1954				
	58				
	63	284	22	113	135
	68	214	21.7	83.9	105.6
	73	271.5	21.2	87.0 (salt)	108.2
PRIMARY METALS	1954				
	58				
	63	33	11	8	16
	68	36.7	9.7	12.9	22.6
	73	45.3	9.6	14.7 (salt)	25.2

*D = Disclosure Problems

TABLE II-E-41

FRESH RECIRCULATION COEFFICIENT FOR DELAWARE-HUDSON

Type of Industry	Year	Gross Water Brackish	Total Fresh	GW-B T.F.
FOOD	1954			
	58			
	63	69	40	1.725
	68	90.7	54.5	1.66
	73	150.2	61	2.46
TEXTILE	1954			
	58			
	63	62	14	4.43
	68	8.7	7.6	1.14
	73	19.2	12.9	1.49
CHEMICAL	1954			
	58			
	63	306	121	2.65
	68	308.4	79.1	3.90
	73	540.3	D*	-
PAPER	1954			
	58			
	63	308	162	1.90
	68	431.7	217	1.99
	73	937.6	-	-
CHEMICAL	1954			
	58			
	63	693	127	5.46
	68	578.7	132.1	4.38
	73	D*	131.5	-
PRIMARY METALS	1954			
	58			
	63	367.2	277	1.32
	68	393.3	280.9	1.40
	73	829.6	335.9	2.47

*D = Disclosure Problems

TABLE II-E-42

PERCENTAGE CHANGE IN DELAWARE-HUDSON

Type of Industry	Year	Process (Percent)	Public Systems (Percent)	Brackish (Percent)
FOOD	1954-58			
	58-63			
	63-68	70	57	-19
	68-73	24	5.6	-2.3
Over Period of Record		110	65.9	-25.9
TEXTILE	1954-58			
	58-63			
	63-68	-6.7	30	0
	68-73	586	508	0
Over Period of Record		540	690	0
PAPER	1954-58			
	58-63			
	63-68	-7.5	120	40
	68-73	D*	D*	D*
Over Period of Record		-7.5	120	40
CHEMICAL	1954-58			
	58-63			
	63-68	17	-38	-38
	68-73	110	71	D
Over Period of Record		146	+5.8	-38
PETROLEUM	1954-58			
	58-63			
	63-68	28	30	5.1
	68-73	-67	27	D
Over Period of Record		-54	65	5.1
PRIMARY METALS	1954-58			
	58-63			
	63-68	73.3	20	-39.2
	68-73	172	57.1	D*
Over Period of Record		371	88.6	D*

*D = Disclosure Problems

TABLE II-E-43

GROWTH RATE IN FRESHWATER RECIRCULATION - NYS
(1964-1973)

	Rate %
Food	Negative rate
Textile	1-7/16
Paper	-
Chemical	3-1/2
Petro	-
Metals	23/96

TABLE II-E-44

GROWTH RATES NECESSARY FOR 1973 NY RT
FACTOR TO REACH 2020 PROJECTED LEVELS

	2020			1973	Implied Growth
	R(1)	T(2)	RT	RT	Rate (%)
Food	1.71	1.26	2.15	1.24	23/48
Textile	2.46	1.26	3.10	2.58	2-1/8
Paper	1.87	1.34	2.51	D	-
Chemical	5.02	1.60	8.03	4.18	3-1/4
Petro	3.66	1.43	5.23	3.74	3
Metals	2.46	1.26	3.10	1.83	1-11/32

(1) R = recirculation factor
(2) T = technological change factor

TABLE II-E-45

GROWTH RATES NECESSARY FOR 1973 STATE FACTORS TO REACH 1973 USA FACTOR IN 45 OR 25 YEARS

45 Years

	New York State Rate (%)	New Jersey State Rate (%)
Food	23/32	State rate greater
Textile	-	-
Paper	-	State rate greater
Chemical	1-7/16	29/32
Petro	5-3/4	1-9/16
Metals	1/4	State rate greater

25 Years

	New York State Rate (%)	New Jersey State Rate (%)
Food	1-5/16	State rate greater
Textile	-	-
Paper	-	State rate greater
Chemical	2-9/16	1-5/8
Petro	10-2/3	2-7/8
Metals	43/96	State rate greater

TABLE II-E-46

GROWTH RATES - USA (1953-1973)
AND PREDICTED VALUES
OF RECIRCULATION FACTORS

	Rate 1953-73 (%)	Recirculation Factor* 2000	2020	Rounded 2020
Food	31/96	2.61	2.79	2.8
Textile	1-19/32	2.98	4.09	4.1
Paper	1-23/32	5.37	7.56	7.6
Chemical	3-3/4	9.11	19.02	19.0
Petro	5-5/8	73.26	229.81	20.0
Metals	1-7/8	3.01	4.35	4.3

*assuming same growth rate

TABLE II-E-47

GROWTH RATE NECESSARY FOR 1973
NJ & NYS FACTORS TO REACH
ROUNDED USA 2020 FACTOR

	New York State Rate (%)	New Jersey State Rate (%)
Food	1-1/16	State higher already
Textile	2-3/4	-
Paper	-	State higher already
Chemical	5-1/4	4-3/4
Petro	6-1/8	1-7/8
Metals	2-1/16	7/12

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NEWS SUMMARY REPORT

APPENDIX - PART II

HUDSON RIVER PROJECT
TECHNICAL REPORT

SECTION F - PLAN FORMULATION AND PUBLIC INVOLVEMENT

NORTHEASTERN UNITED STATES
WATER SUPPLY STUDY

North Atlantic Division
U.S. Army Corps of Engineers

PART II - TECHNICAL REPORT

SECTION F - PLAN FORMULATION AND PUBLIC INVOLVEMENT

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A. INTRODUCTION

Public involvement and plan formulation were closely intertwined in the conduct of the NEWS Study. The information received from state and local government agencies and the interested public played a key role, in conjunction with in-house technical analysis, in screening out alternatives and focusing on more desirable courses of action.

In spite of this interrelationship, however, the public involvement and technical plan formulation aspects are displayed separately for convenience of exposition. This section is, therefore, in two additional parts. Part B, Public Involvement, summarizes the meetings and public workshops that were held, the issues raised, and the significant results, as well as indicating the impact of these events on the direction of the planning process. Part C, Impact Assessment, outlines the procedures and results of the technical analyses used to narrow down the originally wide range of projects considered to detailed investigation of a Hudson River Project.

Considerable overlap of these two broad topics remains, since public comments were stimulated by the results of the technical analysis, whose subsequent direction was heavily influenced by the comments received.

B. PUBLIC INVOLVEMENT

The public involvement program has broadened from initial contact with the Governors of New York, New Jersey and Connecticut during the early phases of the study to public workshops during the reformulation phases.

1. Distribution of Reports and Information Materials

Technical reports and public information fact sheets have been distributed to inform government agencies and the general public of the study's progress and to obtain their comments. Such comments assisted in clarifying planning objectives and identifying the water supply source decisions that must be made, as well as focusing attention on the specific project considerations requiring further analysis. These agencies have also been involved in developing Scopes of Work for the technical studies, ranging from investigations of potential water supply sources to examining the institutional arrangements needed to implement a regional water supply program. The NEWS Information Sheet, which summarized the technical studies completed or in progress, and NEWS Update, Volumes I, II, and III, were distributed to over 1000 government agencies, elected officials, interest groups, and individual citizens.

2. Coordination With State and Local Agencies

A number of major conferences were sponsored by the Corps of Engineers and other agencies, at which the NEWS Study staff apprised state, county, local and regional agency officials of the status and direction of the study, and solicited their comments and suggestions. Attendees also included, at various times, non-governmental interests such as environmental groups and water purveyors. These meetings served as a forum for the exchange of information, views, and policy, not only between the NEWS Study and the other attendees, but also among the interested non-Federal parties.

Agency concerns that were aired in the earlier meetings included projections of future population, water demand, and water supply deficits; the potential efficacy of conservation measures, particularly metering in New York City; the hydrologic yield and quality of water sources such as the Hudson and Housatonic Rivers and the Long Island and South Jersey aquifers; and potential institutional arrangements needed for implementation and cost-sharing of a regional program.

Through 1975, the NEWS Study progressively focused on more intensive analysis of the Hudson River as a broadly accepted early-action source for the New York portion of the NYMA, and the con-

cerns that were voiced became correspondingly more specific. These included the hydrologic and hydraulic interaction of a Hudson River project with the existing New York City system; the quality of Hudson water in the river reach under discussion, with particular reference to contaminants such as PCBs; the engineering design and possible locations of intake, pumping station, tunnel and treatment facilities; and coordination of first-stage Hudson development with alternative subsequent upstream developments for water supply, power generation, and other purposes. Questions with regard to the Long Island aquifer concerned its safe yield and quality, and environmental and institutional barriers to its development. Issues surrounding conservation measures (particularly metering in New York City) related to specification of programs to implement them, costs and probable water savings of such programs, and institutional arrangements. At the same time, the spectrum of participants shifted also, as the State of Connecticut, and later New Jersey, developed plans to meet their water supply needs with their own internal resources. The Intergovernmental Planning Coordinating Committee, comprising high-level representatives of New York City and Westchester and Nassau Counties, working to address common problems in a unified way, became a principal avenue of coordination with local-level agencies. Contacts in other local areas were pursued under the aegis of the New York State Department of Environmental Conservation (DEC), the chief coordinating entity at the state level, and by direct communication with interested parties.

In February and early March 1976, the New York DEC held three major meetings at the DEC regional offices in New York City, New Paltz, and Albany, to advise local government and environmental interests of the nature of the alternative water supply projects in the NEWS Interim Report (via presentations by the NEWS Study staff) and to invite them to comment, both at those meetings and at the NEWS Formulation Stage Public Meeting on the NYMA, on 19 March 1976. Issues raised at these pre-hearing briefings concerned the nature of operation of a Hudson River project, its costs, alternatives that might have been considered, and the importance of conservation measures in projecting demands to be met by a major new structural project. The suggestion was also made that completion of City Tunnel Number 3 of the New York City system might be made a part of a Federally-constructed Hudson River project.

3. Public Workshops

a. Chronology and Structure - In order to broaden the planning process to include individuals and groups outside the state government structure, each of the three states was asked to advise the NYMA Study about how to achieve a greater public exposure. In

New York, the Department of Environmental Conservation agreed to sponsor, through its regional offices in the study area, a series of public workshops with the Regional Advisory Committees in Region 1, on Long Island, and Region 3, in the Mid-Hudson area. These Committees consist of a representative group of conservationists, businessmen, sportsmen, local government officials, and water resource professionals. The purposes of these meetings were to present up-to-date study findings, to obtain feedback on the information presented, and to obtain advice as to the most effective ways to broaden the NEWS Study's open planning effort.

The participants at these meetings recommended that additional meetings should be held at the county level, coordinated through the County Planning Departments or the County Environmental Management Councils. Meetings were subsequently held in Nassau, Orange, Westchester, Ulster, Dutchess and Putnam Counties and in New York City. Below is a chronological listing of the meetings in New York State, which indicates the sponsoring organizations and the number of attendees, excluding Corps personnel.

DATE	PLACE	SPONSORING	NO. OF ATTENDEES
13 Feb. 75	New Paltz	DEC Region 3	16
26 Feb. 75	Stony Brook, L.I.	DEC Region 1	17
20 Mar. 75	Mineola, L.I.	Nassau County Environmental Management Council	15
29 May 75	Goshen	Orange County Planning Dept.	15
3 June 75	White Plains	Westchester County Planning Department	27
10 July 75	New York City	DEC Region 2	21
16 July 75	Millbrook	Dutchess County Cooperative Extension Service	37
30 July 75	Kingston	Ulster County Environmental Management Council	35

Each of the sponsoring organizations was asked to invite a representative group of citizens. The number of invitations sent for each meeting ranged from approximately 20 (for the Regional Advisory Committees of DEC Regions 1 and 3) to 200 (for the Dutchess County Cooperative Extension Service, which sent invitations to individuals and groups in Dutchess and Putnam Counties).

The format of these meetings usually consisted of a slide presentation of up-to-date study findings followed by a question and comment period. The slide presentation included descriptions and illustrations of: (1) the planning process used in conducting the study; (2) alternative regional programs; (3) specific projects

which may be located in or may impact on the county concerned; (4) the potential impacts of the projects; and (5) the existing institutional setting and institutional problems and options associated with regional water supply development. The major issues addressed during the question and comment period are summarized in the following section. During this period, participants were asked to fill out a worksheet which was structured to indicate the respondents' preferences among objectives, water resource management techniques, and impact assessment categories. An analysis of these work sheets is discussed later.

The possibility of holding public workshops in Connecticut was discussed with members of the State's Interagency Water Resources Planning Board and the Directors of the Regional Planning Agencies located within the New York Metropolitan Study Area. Meetings were not scheduled in New Jersey at the State's request because that State was contemplating conducting public meetings on its own water resources plan.

b. Major Issues - The major issues brought out during the question and comment period following each of the eight public workshops are summarized below. This summary is based on analyses of the memoranda of each workshop and of worksheet comments. These issues are:

i. Use of Hudson River for Water Supply - Concerns were expressed about the quality of Hudson water and the environmental effects of withdrawing large quantities of water from the river. The presence of heavy metals and phenols, and the effect of nuclear power plants on water quality, especially the presence of strontium 90, should be carefully considered when designing a water treatment plant. Some individuals expressed a preference for the gravity system, despite its high cost, because of its higher water quality, greater reliability, and lower energy requirements compared to a high-flow skimming and river diversion scheme on the Hudson. It was felt that more extensive environmental data is needed to assess the effects of withdrawing water from the Hudson on aquatic species. It is also important to examine the withdrawals for water supply in conjunction with other major users which withdraw from the river, such as nuclear power plants.

ii. Use of Long Island Groundwater for Water Supply - The definition of safe yield for Suffolk County groundwater should include criteria other than water supply. The potential reduction of surface flows by withdrawing 150 mgd (as called for by the Long Island Exchange Project) could have an adverse effect on recreation, esthetics, and the ecology of the estuaries. It was recommended that water from the Hudson River be extended from

Nassau to Suffolk during wet years to allow for the natural recharge of Suffolk's groundwater reservoir. However, it is possible that reduced pumping from the aquifer during wet years could result in many flooded basements.

iii. New Water Supply Technologies - It was asked if wastewater reuse and desalinization have been considered as alternatives to additional source development. Opinions were expressed that these techniques should be utilized by 2020 to avoid adverse ecological effects caused by extensive surface source and groundwater development. While wastewater management is a potential long range method of recharging groundwater, especially on Long Island, it was felt that technical uncertainties must be addressed more thoroughly.

iv. Conservation Measures and Devices - The implementation of conservation measures and devices, particularly the universal metering of New York City, was strongly urged at many of the meetings.

v. Cost of Regional Water Supply Program - Concern was expressed about the cost of regional water supply program to users and taxpayers and that such a program could duplicate, rather than supplement, locally developed sources. It was felt that the wholesale cost of water from a regional system would be much greater than present costs, particularly in the upstate counties which currently obtain water from the New York City system's aqueducts.

vi. Population and Water Deficit Projections - It was stated that the NYMA Study should consider using recently revised population projections for the metropolitan area as a basis for projecting water demands and deficits. Recent publications by the Tri-State Regional Planning Commission and the Regional Plan Association project a level of growth lower than OBERS Series E, the basis of the NYMA Study projections. On the other hand it was stated that the projected 1980 deficits for the New York portion of the study area may be too low, since the New York City system's 1974 deficit was greater than the projected 1980 deficit for the City system.

vii. Institutional Considerations - Concern was expressed about the capabilities of existing institutional arrangements to fund a regional water supply program. It was asked whether or not the Corps would recommend changes in existing funding arrangements. It was suggested that 90/10

Federal-local funding formula, similar to highway funding, be instituted for water supply. It was stated that NEWS should recommend Federal funding of water supply while the States should manage and develop supply sources. A closer liaison with local governments was advocated by one elected official.

There were several criticisms of existing institutional arrangements, because of their adverse impact on the upstate counties in which the New York City system's reservoirs and transmission lines are located. The Water Supply Act of 1905 permits municipalities through which the transmission lines pass, but not counties, to tie into the City system. These municipalities are limited to New York City's per capita consumption, which is a constraint for those towns in which large water consuming industries are located. It was asked if existing or future aqueducts could be fully taxable under the institutional arrangements recommended by the NEWS Study. Currently, only the land, not the improvements represented by the aqueducts, is taxable. The use of existing City system reservoirs, such as Ashokan Reservoir, for multiple purposes was desired.

viii. Growth Control - Growth control was advocated by a number of individuals in order to reduce the need to develop additional water supply sources. However, an opinion was expressed that the causes of growth are largely independent of the availability of large quantities of water, as would be provided by a regional water supply program.

ix. Conduct of the NYMA Study - Concern was expressed that the NYMA Study may be a duplication of the effort of the Temporary State Commission of Water Supply Needs of Southeastern New York. It was recommended that the NYMA Study should incorporate into its records the testimony presented at the Commission's public hearings. The records of these hearings have been published.

The Corps' public involvement program was criticized because it was not extensive enough and did not contact individuals and groups outside the State government during the early phases of the study. The environmental assessment of the Hudson was criticized because it was felt that the study is not comprehensive and insufficient time has been allotted for its completion.

c. Analysis of Worksheets - Worksheets were distributed to the participants at each public workshop to obtain their preference for objectives, water resource management techniques, and

impact categories. The purpose of the worksheets was to provide a consistent format for indicating preferences, so that the preferences could be analyzed for the entire study area, for each county, and by source and service areas.

The worksheets consisted of five sections in which respondents were asked to numerically rank their preferences. Two additional sections asked for narrative responses. The results of the latter were included in the "public workshop issues" described earlier.

The analysis of the worksheets for the study area as a whole indicates that the public workshop participants considered reliability and environmental impact to be the most important objectives, from both regional and local perspectives. Water conservation measures were viewed as the most preferable water resource management technique. The environmental category was considered the most important impact category and it was also felt that more detailed information was most essential for this category.

d. Discussion - The public involvement effort of the NYMA study, both coordination with government agencies and the public workshops, surfaced a number of significant issues. Foremost among these was a preference for water conservation measures, including the universal metering of New York City. The use of river diversions for water supply was one of the least preferred water resource management techniques. Use of Suffolk County groundwater as a part of a regional water supply system was strongly opposed by local residents. These issues had important implications for the reformulation of alternative regional programs. Programs which do not emphasize conservation measures and devices are not likely to be viewed favorably. The quality of Hudson River water and the probable environmental impacts of withdrawing large quantities for water supply are concerns which will continue to be expressed. The comments received on the use of Suffolk groundwater (as called for in some alternative programs) suggested that the feasibility of utilizing this source be reexamined.

The concerns expressed at the public workshops were a factor in determining the scope of subsequent studies that were undertaken. A detailed investigation of various water conservation measures was undertaken. Also, the Long Island Exchange Project, which would remove up to 150 mgd of Suffolk groundwater, was eliminated from consideration as a possible early action project. Concerns about the quality of Hudson River water and the environmental impact of withdrawals resulted in detailed feasibility investigations of these issues.

4. Formulation Stage Public Meeting on the NYMA

A public meeting was held on 19 March 1976 to obtain public comments about the results of the planning process through its third iteration (formulation and display of alternative action programs). Speakers included elected officials such as Representative Bella S. Abzug, New York City Council President Paul O'Dwyer, and Nassau County Executive Ralph G. Caso. Water resource officials from the States of Connecticut, New Jersey and New York, New York City, Westchester and Nassau Counties among others, also presented their views. Other speakers included representatives of water companies, environmental groups, and other citizen's organizations. Additional comments were submitted in writing, and although not presented orally, were included in the written record.

The various statements submitted to the official record of the public meeting pointed to the following conclusions:

a. Connecticut and New Jersey expect to be able to meet their water demands through the year 2020 by developing their intrastate sources. Therefore, an early action project, designed to meet deficits of the year 2000, need include only the New York State portion of the Study area.

b. The Hudson River is central to all future regional programs, and appears to be the most viable source for an early action project. It was recommended that the NEWS Study should include, in its report to Congress, to assure adequate regional distribution of water supply. This idea was also endorsed, in a letter, by the Governor of New York.

5. Subsequent Coordination

a. Dissemination of Reports - Analytical work by the NEWS Study staff after the 19 March 1976 hearing comprised an ongoing, detailed examination of the engineering, environmental, and socio-economic feasibility of alternative Hudson River project configurations. This effort culminated in a draft Environmental Impact Statement, which was distributed in January, 1977 to Federal, regional, state and local agencies for their comments.

b. Interagency Coordination - Meetings with state and local agencies continued through 1976, with the focus on the meetings, at approximately monthly intervals, of the Intergovernmental Planning Coordinating Committee, and on briefings with the New York State Department of Environmental Conservation. In addition to general exchange of information, a major issue surfaced in mid-1976 concerning differing projections of population and water demand.

This was the topic of a major conference of 20 July 1976, attended by representatives of the New York State DEC, Economic Development Board, Department of Health and Attorney General; the New York City Departments of Water Resources, Health, and Planning and the Board of Water Supply; Nassau County health, public works and planning agencies; the Westchester County Water Agency; Planning Commissions in Ulster and Putnam Counties, and the Tri-State Regional Planning Commission.

The crux of the controversy was the release of new sets of future population projections by the State Economic Development Board and the Tri-State Planning Commission, which forecast significant decreases in population in the state's most populous areas. Since the OBERS Series E projections, on which NEWS projections are based, forecast slow but substantial population growth in those areas, the resulting conflict, with its implications for water demands to be met by a new regional project, required full discussion and prompt resolution. The eventual basis of this resolution was that a drastic reduction in projected population implied changes in demographic characteristics (e.g., household size), economic structure, rigorousness of water conservation enforcement in homes and industries, and other factors influencing per capita demand. It was also asserted by New York State that the existing safe yields of the water supplies in New York City and Nassau County are lower than estimated in NEWS analyses. When the total impact on water demand from these differing population projections was analyzed, it was found that the ultimate water supply deficits to be met by a Hudson River project, after allowing for all reasonable conservation saving, fell in the range of 300 to 400 mgd, in good agreement with the NEWS estimate of 390 mgd.

Other topics at the 20 July 1976 meeting, as at other such meetings, concerned the progress of the Hudson River project analysis with regard to engineering studies, environmental analyses, and the appropriate depiction of the region's future condition in the absence of any major new water supply development - the baseline to which a project's impacts could be compared.

A new element in interagency coordination was the creation, by the Governor of New York, of a task force to assist in the development of state policies on the construction, operation and maintenance of a regional water system in southeastern New York. The task force, chaired by the State Commissioner of Environmental Conservation with representation of New York City and the other affected counties, had its first meeting on 2 December 1976, with subsequent meetings approximately at five-week intervals. These meetings have focused on the specific, detailed institutional and cost-sharing arrangements for construction and operation of a Hudson River project and for implementation of conservation measures.

NEWS staff members have also attended meetings of the Section 208 coordinating committee for the New York City area, one of whose concerns is water supply, and are participating in the State-sponsored Hudson River Basin Study.

c. Public Workshops - The NYMA staff entered another round of public briefings at the following times and locations.

Date	Place
1 February 1977	New Paltz, N. Y.
17 February 1977	Mineola, N. Y.
3 March 1977	Wave Hill Center for the Environment
10 March 1977	General Contractor's Association
15 March 1977	N.Y.C. 208 Advisory Group
18 March 1977	Westchester Water Works Conference
21 March 1977	N.Y.C. Environmental Protection Admin.
24 March 1977	Dutchess County Environmental Management Council
12 April 1977	Rockland County Environmental Management Council
25 April 1977	Long Island Water Conference

At these meetings, local interests were informed of the contents of the draft Hudson River Project Report and Environmental Impact Statement, and their comments solicited. These briefings, preparatory to Late Stage Public Meetings on the Hudson River Project, were similar in nature to those held prior to the NEWS Formulation Stage Public Meeting on 19 March 1976. Because the Hudson River Project analyses are considerably more specific and immediate than was the NEWS Interim Report, the concerns voiced in this round of briefings have been correspondingly more detailed, regarding the specific sites of project facilities and their local impacts (particularly environmental) of construction and operation; environmental, streamflow and water quality impacts on the river; the role of conservation and the specific measures that would be required; alternatives to the Hudson River Project; the cost of the project and the specific allocation of its repayment among local users; the eligibility of local systems to tie into the augmented City system or to develop their own sources, including their own diversions from the Hudson; the mutual constraints on the Hudson River Project and power plant cooling water withdrawals; and the possibility of amending the existing law governing withdrawals from the City system by users in its source areas.

6. Late Stage Public Meetings

On 29 March 1977, in New York City, and on 10 May 1977, in Poughkeepsie, New York, Late Stage Public Meetings were held on the Hudson River Project. The findings of the detailed feasibility study of alternative configurations for that project were presented, and oral and written statements were recorded from a broad spectrum of elected officials, governmental and private water resources professionals, labor and trade organizations, environmental and civic groups, and private citizens.

The views expressed at the meetings were mixed. In general, representatives of state and local governmental agencies, the water industry, labor and trade organizations, and a small proportion of environmental groups, indicated a desire to see the project proceed to the next phase of study. The great majority of environmental organizations expressed the view that the project was unnecessary and could, if constructed, seriously damage the environmetnal quality of the region; more information, it was asserted, was needed before proceeding any further.

Written comments on the draft project report and environmental impact statement followed a similar pattern. Many expressed the opinion that available information (the basis of a feasibility study) may not be adequate for complete analysis of the project's cultural, environmental and institutional impacts, while differing on whether additional information should be generated before, or in the course of, further study. One particular point of information received concerned the siting of project facilities: alternate locations were suggested that might be more beneficial and less disturbing to existing land uses.

C. IMPACT ASSESSMENT

This part summarizes the selection process whereby alternative projects were evaluated and the Hudson River project chosen for more intensive analysis. The following material comprises a brief description of the evaluation framework, and a summary of project impacts as determined by public input and technical analysis.

Information on the detailed evaluation techniques and project impacts may be found in the various publications and reports prepared in the course of the NEWS Study, that are listed in the Bibliography.

1. Project Evaluation Framework

In order to select rationally from among a large number of alternative projects, it is necessary to define planning goals, and criteria and impact measures to determine whether those goals would be met by a particular project, and to what extent.

a. Planning Goals

i. Overall NEWS Study Planning Goals - The U.S. Congress established the Northeastern United States Water Supply (NEWS) Study with one general goal: to produce a comprehensive, coordinated long range plan for timely water supply development and management, assuring and adequate supply of water to the major urban areas of the northeastern U.S. especially under severe drought conditions similar to those which occurred in the 1960's.

Planning for such a large and complex region (Virginia to Maine) required a careful and orderly analysis of the many significant factors involved. The NEWS planning process established four goals to be considered and addressed when selecting a course of action. They include:

Reliability -- The assurance of adequate water supplies during conditions of severe drought.

Flexibility -- The ease with which plans can be altered to take into account future changes in the location and size of water demands and to consider changes in economic, environmental, social and technological pressures.

Timeliness -- The ability of a plan to meet water supply and other needs in a timely fashion, so as to provide for an orderly development of projects to meet additional water demands in the future.

Equity -- The effectiveness of a plan in distributing, in a reasonable and logical manner, the economic, social and environmental costs of providing adequate water supplies to all who benefit; and its effectiveness in compensating those who relinquish water or land rights to meet the water demands of others.

ii. New York Metropolitan Area (NYMA) Planning Goals -- Early in the NEWS Study analysis of the NYMA, analysis of public responses indicated that additional regional planning goals were desirable. These additional goals comprise:

Regionality, the use of water from a single source over as wide an area of need as is efficient, regardless of political boundaries, through regional programs.

Cost, the ability to meet water demands at the least monetary cost.

Environmental Quality, the maintenance or enhancement of existing conditions as a result of the impact of a project both on the population it serves with water (cultural, economic and institutional effects), and on the physical environment it alters to provide that water.

Control of Growth Patterns, the tendency of water supply programs or projects to influence the rate and/or distribution of development in an area.

Energy Conservation, the minimal use of scarce energy resources, and the general improvement of the region's energy posture.

b. Criteria and Impact Measures

i. Related to Project Effects - Table II-F-1 displays criteria and impact measures corresponding to the above planning goals. In early stages of the NYMA Study, the level of analysis applied was concerned with the direction and relative magnitude of impacts in broad categories, rather than with absolute quantitative estimates of detailed impacts. Its purpose was to identify projects likely to be weeded out, because of grossly adverse consequences, or favored with closer scrutiny, by virtue of relatively beneficial effects. The analysis therefore concentrated on potentially sensitive impact areas: ecological, socio-economic, institutional, and equity impacts. The technique was essentially one of relating a project of a given type (reservoir, pipeline, river diversion, etc.) to known local impacts of projects of the same type in similar areas elsewere in the country. Impact categories used were summations of, or proxies for, groups of specific data items. Project impacts reflected maximum development of each project, which would not necessarily be the case.

TABLE II-F-1

PLANNING GOALS, CRITERIA AND IMPACT MEASURES

Planning Goal	Criterion	Impact Measure
Reliability	Reliability of yield	1 - (failure probability)
	Adequacy of transmission	Transmission capability
	Reliability of quality	Expected source quality
Flexibility	Responsiveness to altered level of demand	Potential yield range
	Responsiveness to altered distribution of demand	Pop. served/regional pop.
Timeliness	Size of residual deficit when project goes on line	Demand (t=0) - yield (t=0)
	Size of deficit in year 2000	Demand (t=2000)- yield (t=2000)
	Project size	Yield
Equity	Resource distribution	Service area pop./source area pop.
	Cost distribution	Avg. annual project cost/ population served
	Adequate source area compensation	Annual project tax payments/ source county population
Cost	Min. cost to developer	Project average annual cost
	Min. cost to user	Project annual O & M cost
	Investment cost	Project construction cost plus interest accruing during construction
Environmental Quality	Physical alteration	Land used for project facilities (acres)
		Streamflow changes (mgd)
	Water, air, noise pollution	Water quality changes
		Air quality changes
		Noise level changes at nearest habitation
	Aquatic and terrestrial ecosystems	Effects on resident flora and fauna
	Cultural	People displaced
		Historical sites affected
		Recreational opportunities changed
	Economic	Regional earnings impact
		Regional employment impact
		Tax rate changes
	Institutional	Legal or organizational changes required for implementation
Regionality	Area and population served	No. of counties served
		Population served
	Efficiency of use	Yield (t=0)/deficit (t=f)
	Extent of inter-basin transfer of water	Yield delivered out of watershed/total yield
Control of Growth Patterns	Population	Regional population impact
	Economic Activity	Regional earnings impact
	Growth distribution	Descriptive shift in growth patterns
Energy Conservation	Construction energy requirements	Relative scalar
	Operation energy requirements	Electrical power (Kw)
		Mechanical energy (Hp)

In the later phases of the work, the task was to focus on a preferred course of action from among the relatively small number remaining after prior rounds of analysis and public comment. A more intensive level of analysis was therefore appropriate. At this level of analysis, project impacts were estimated quantitatively where possible, and in all cases with respect to the effect of the project as specified on this particular area (rather than by relating similar projects to other areas of the country, as in earlier rounds of work). The impacts were based on functional relationships estimated or assumed between project characteristics and the environmental, ecological, social, economic, and institutional structures of the region, and covered the full range of project effects relevant to project evaluation.

ii. Related to Implementation of Programs - One aspect of a regional plan's institutional impacts concerns the characteristics of the legal and organizational authority that would implement it. Illustrative institutional arrangements for regional water supply development were considered, ranging from continuation of the status quo (essentially uncoordinated, *ad hoc* local development) to strongly centralized regional planning and development by a newly-created public authority or corporation. The nature of these alternative institutional structures would be largely independent of the particular projects that they would implement, and it should be noted that no project was eliminated from further consideration on the basis of this analysis. Its purpose was, rather, to stimulate discussion of the institutional implications of major water source development, regardless of by whom such development would be performed. The following criteria were utilized for this purpose:

1. Comprehensiveness of planning with respect to multiple-purpose project use,

2. Flexibility of planning in the face of changing needs and circumstances,

3. Responsiveness to various interest groups,

4. Adequate geographic scope to embrace and resolve source area - service area conflicts,

5. Adequate technical capacity for competent planning,

6. Adequate technical capacity to raise required capital sums and allocate costs and reimbursals in an equitable way,

7. Political and legal acceptability to all interested parties, and

8. Minimal required changes to existing legal and institutional structures.

These criteria were used to evaluate the various institutional options, both independently of projects, and with respect to ease of implementing particular illustrative regional programs.

2. Project Selection

a. Projects Considered - In earlier iterations of plan formulation, a large number of technically feasible water supply projects was reduced to seventeen because of cost considerations, environmental concerns, or institutional constraints revealed by technical analysis and public comment. Public responses received during those early stages also reflected broad interest in water conservation practices to supplement or substitute for development of new supply sources, and three additional "projects" were defined to incorporate these concerns. The projects remaining at that point were:

1. Raritan River, Spruce Run - Round Valley
2. Confluence Reservoir
3. Delaware Diversion (Frenchtown-Round Valley-Raritan River)
4. Delaware Diversion to Round Valley
5. Tocks Island Lake Project Exchange
6. Two Bridges Reservoir
7. Delaware Diversion (Frenchtown-Two Bridges)
8. South Jersey Groundwater
9. Hudson-Ramapo Diversion
10. Hudson River Basin Storage
11. Gravity Development of Hudson River
12. Housatonic River Power Reservoirs
13. Trap Falls Reservoir
14. Housatonic River with Konkapot and Robbins Pumped Storage Reservoirs
15. Connecticut River Middletown Diversion
16. Long Island Groundwater
17. Long Island Groundwater Exchange
18. Long Island Total Resource Management
19. Metering and System Leakage Control
20. Domestic Conservation Devices

Brief technical descriptions of these projects, with the exception of Gravity Development of Hudson River, may be found in

the Summary Report. It should also be noted that at the time of this initial screening, the Hudson River Project was part of several of the long run project developments listed above.

b. Screening of Projects - The number of projects to be evaluated in detail was reduced by preliminary technical analysis of the impacts of the 20 projects, and by consideration of the public input described in Part B of this section. Note that for the sake of analysis the Hudson River Basin Storage Project was considered in its two separate configurations, with diversions at Hyde Park and West Park, respectively, so that the tables and subsequent discussion will have 21 separate entries.

Table II-F-2 summarizes the potential local impacts of the projects, as estimated in in-house technical analysis by the NEWS Study Staff. This analysis indicated that projects based on the Tocks Island project (i.e., Projects 3, 5 and 7) could create serious local problems of human displacement, visual and cultural deterioration, and institutional arrangement; it has, moreover, been recommended for deauthorization. Housatonic upstream storage (Project 14) would be disruptive in nearly every category. Pronounced institutional problems would attend the Hudson and Connecticut River diversion projects, as well as the groundwater exchange and total resource management projects on Long Island, but the Hudson Projects (except for the Hudson-Ramapo diversion, Project 9) would have favorable effects on nearly every other impact category. The two conservation-oriented projects (Projects 19 and 20) on the other hand, would rank among the most favorable of all. The general guidance furnished by the analysis was to concentrate subsequent evaluation efforts on conservation and intrastate development projects, with further caveats noted on the Long Island and upper Housatonic projects.

The public input that was received reinforced the preliminary analytical findings, enabling the list of 21 potential projects to be reduced considerably prior to evaluation and selection of the most viable alternative. In deference to the expressed policies of the three states, primary emphasis was placed on projects to meet the needs of New York rather than New Jersey and Connecticut, assuming their needs to be met by their respective in-state plans, and on meeting the needs of the year 2000. The projects that remained were modified by deleting or scaling down certain features (storage, transmission, etc.) intended to meet water demands in that time frame outside the New York State portion of the NYMA, as well as demands within that area in the more distant future, without losing the flexibility to adapt to those distant demands. These projects are:

TABLE II-F-2

POTENTIAL LOCAL PROJECT IMPACTS

	EQUITY		ECOLOGICAL EFFECTS			SOCIO-ECONOMIC EFFECTS				INSTITUTIONAL EFFECTS	
				Human							
	To User	To Suplr.	Fish, Wildlife, Flora	Displacement	Visual, Cultural	Earnings, Emp.	Recreation	Tourism	Land Development	Property Values	Institutional Status Quo
1. Raritan R., Spruce Run-Round Valley	++	++	0	0	0	0	0	0	0	0	0
2. Confluence Reservoir	+	+	0	-	0	0	+	0	0	0	0
3. Del. Div. (Frenchtown -Rnd. Val.-Raritan R.)	++	-	-	--	-	+	++	++	+	+	--
4. Delaware Div. to Round Valley	+	-	0	0	0	0	0	0	0	0	-
5. Tocks Island Lake Project Exchange	++	-	-	--	-	+	++	++	+	+	--
6. Two Bridges Reservoir	+	-	-	-	0	+	+	0	0	0	-
7. Del. Div. (Frenchtown -Two Bridges)	++	-	-	--	-	+	++	++	+	+	--
8. South Jersey Groundwater	+	-	-	0	-	+	0	0	+	+	-
9. Hudson-Ramapo Diversion	+	-	0	-	0	+	0	0	0	0	--
10. Hudson River Project-East Bank Alternative	++	+	+	-	+	+	+	+	+	+	--
11. Hudson River Project-West Bank Alternative	++	+	+	-	+	+	+	+	+	+	--
12. Gravity Development of Hudson River	+	+	0	-	+	+	+	+	+	+	-
13. Trap Falls Reservoir	+	0	0	-	0	+	0	0	0	0	0
14. Housatonic River Power Reservoirs	++	-	-	0	-	0	0	0	0	-	-
15. Hous. R. with Konkapot and Robbins Reservoirs	+	--	--	-	-	-	-	-	-	-	--
16. Connecticut River *Middletown Diversion*	+	0	0	-	0	+	0	0	0	0	--
17. Long Island Groundwater	+	0	-	0	-	+	0	0	0	0	-
18. Long Island Groundwater Exchange	+	+	-	0	-	+	0	0	+	0	--
19. Long Island Total Resource Management	+	+	0	0	+	0	0	0	-	0	--
20. Metering and System Leakage Control	+	+	+	0	0	0	0	0	0	0	0
21. Domestic Conservation Devices	+	+	+	0	0	0	0	0	0	0	-

++ VERY FAVORABLE -- VERY ADVERSE 0 NO SIGNIFICANT NET IMPACT
+ FAVORABLE - ADVERSE

1. Hudson River Project - East Bank Alternative
2. Hudson River Project - West Bank Alternative
3. Hudson Gravity Development
4. Long Island Groundwater
5. Long Island Groundwater Exchange
6. Long Island Total Resource Management
7. Metering and System Leakage Control
8. Domestic Conservation Devices

(The Hudson-Ramapo diversion was deleted because, although it would have incidentally served Orange and Rockland Counties, its primary justification was to bring water to New Jersey.) Of the eight projects listed above, Long Island Total Resource Management was removed from consideration for early action because of uncertainties about the water supply yield, ecological and public health impacts, and engineering design, as well as a lack of unified local support for some of the measures involved.

The latter two conservation projects, on the other hand, enjoyed widespread approval, and were in fact considered a prerequisite for any structural project. Metering and leakage control have been endorsed in principle by the City of New York. Domestic conservation devices have received broad support, albeit with uresolved questions about the precise arrangements for implementing them. For these reasons, it has been assumed that these conservation projects will be implemented regardless of the other source developments that might be undertaken, and the water demands to be met by new source developments include these water conservation measures. The conservation projects, which are not considered appropriate for Federal implementation in any case, do not therefore require presentation of fully detailed analytical findings.

c. Evaluation of projects - Table II-F-3 displays the impacts of the five remaining projects. The project cost data have been corrected to reflect more recent price levels and interest rates than prevailed at the time of the original analysis, and the "regional" parameters (population, employment, earnings, water supply deficit) refer to the New York State portion of the NYMA only. Transmission capacity to Kensico Reservoir in all three Hudson projects exceeds nominal yield, to retain flexibility beyond the year 2000. The two Long Island groundwater projects are as described.

i. Hudson River Project - East Bank - Of the three Hudson projects this has the lowest reliability, chiefly because of its complexity (which is, however, shared by the other Hudson alternatives) and the lack of redundancy in transmission lines. Moreover, it would require a new tunnel on the east side of the river with

TABLE II-F-3 DETAILED PROJECT IMPACTS

Planning goal	Impact Measure	Hudson River Project-East Bank Alternative	Hudson River Project-West Bank Alternative	Gravity Development of Hudson River
RELIABILITY	1-(failure prob.)	0.65	0.96	0.96+
	Transmission cap. (mgd)	950	1,300	900
	Expected source qual.	good	good	very good
FLEXIBILITY	Potential yield range (mgd)	0-510	0-480	0-600
	Pop. served/reg. pop.*	0.85	0.88	0.85
TIMELINESS	Yield - deficit (t=0) (mgd)	235	205	325
	Yield - def. (t=2000) (mgd)	120	90	210
	Yield (mgd)	510	480	600
EQUITY	Service area pop. /source area pop. (t=2000)	28.7	70.8	15.9
	Avg. ann. cost/pop. served ($)	6.08	7.99	46.25
	Ann. project tax payment/ source area pop. ($)	10.41	34.82	6.14
COST	Avg. ann. cost (mill. '75 $)	77.2	104.2	587.1
	Ann. O&M cost (mill. '75 $)	19.2	17.9	13.3
	Construction cost (mill. '75 $)	920.6	1,242.7	7,004.2
ENVIRONMENTAL QUALITY	Land use (acres)	about 200	about 200	about 10,300 (incl. reservoir)
	Streamflow changes (mgd)	minor decrease	minor decrease	minor decrease
	Water quality	insig.	insig.	insig.
	Air quality	insig.	insig.	insig.
	Noise level at nearest human habitation	insig.	insig.	insig.
	Aquatic flora & fauna	minor adverse	minor adverse	minor adverse
	Terrestrial flora & fauna	insig.	insig.	insig.
	People displaced	insig.	insig.	moderate at reservoir site
	Historical sites affected	none	none	none
	Recreation affected	insig.	insig.	increased lake area
	Regional earnings*	minor increase	minor increase	minor increase
	Regional employment*	minor increase	minor increase	minor increase
	Local tax revenues	moderate increase	moderate increase	moderate increase
	Legal or organizational implications	some local opposition	some local opposition	land use conflict at reservoir site; local opposition
REGIONALITY	No. of counties served	12	13	12
	Population served (t=2000)	12,694,000	13,033,000	12,694,000
	Yield/deficit (t=2000)	1.3	1.2	1.5
	Yield delivered out of watershed/total yield	0.55	0.55	0.55
CONTROL OF GROWTH PATTERNS	Regional population*	minor increase	minor increase	minor increase
	Regional earnings*	minor increase	minor increase	minor increase
	Distribution of growth	more growth in Nassau and upstate counties	more growth in Nassau and upstate counties	more growth in Nassau and upstate counties
ENERGY CONSERVATION	Construction energy req.	high	high	very high
	Elec. power req. for O&M (kW)	164,100	249,400	112,800
	Mech. power req. for O&M (hP)	220,000	334,300	157,200

*"Region" = N.Y.S. Portion of NYMA.

TABLE II-F-3 (CONT.) DETAILED PROJECT IMPACTS

Planning goal	Impact Measure	Long Island Groundwater	Long Island Groundwater Exchange
RELIABILITY	1-(failure prob.)	0.85	0.85
	Transmission cap. (mgd)	150	150
	Expected source qual.	good	good
FLEXIBILITY	Potential yield range (mgd)	0-150	0-150
	Pop. served/reg. pop.*	0.77	0.77
TIMELINESS	Yield - deficit (t=0) (mgd)	-125	-240
	Yield - def. (t=2000) (mgd)	-240	-720
	Yield (mgd)	150 until 2010; 0 after	150 until 2010; 0 after
EQUITY	Service area pop. /source area pop. (t=2000)	6.3	6.3
	Avg. ann. cost/pop. served ($)	2.46	2.61
	Ann. project tax payment/ source area pop. ($)	0.26	0.14
COST	Avg. ann. cost (mill. '75 $)	28.0	29.7
	Ann. O&M cost (mill. '75 $)	6.7	7.1
	Construction cost (mill. '75 $)	334.2	354.4
ENVIRONMENTAL QUALITY	Land use (acres)	insig.	insig.
	Streamflow changes (mgd)	potential decrease	potential decrease
	Water quality	insig.	insig.
	Air quality	insig.	insig.
	Noise level at nearest human habitation	insig.	insig.
	Aquatic flora & fauna	potential adverse	potential adverse
	Terrestrial flora & fauna	insig.	insig.
	People displaced	none	none
	Historical sites affected	none	none
	Recreation affected	none	none
	Regional earnings*	minor increase	minor increase
	Regional employment*	minor increase	minor increase
	Local tax revenues	minor increase	minor increase
	Legal or organizational implications	local opposition; Suffolk Co. statute prohibits water exports	local opposition; Suffolk Co. statute prohibits water exports
REGIONALITY	No. of counties served	7	7
	Population served (t=2000)	11,383,000	11,383,000
	Yield/deficit (t=2000)	0.4	0.4
	Yield delivered out of watershed/total yield	1.00	1.00
CONTROL OF GROWTH PATTERNS	Regional population*	minor increase	minor increase
	Regional earnings*	minor increase	minor increase
	Distribution of growth	more growth in Nassau, N.Y.C.	more growth in Nassau, N.Y.C.
ENERGY CONSERVATION	Construction energy req.	moderate	moderate
	Elec. power req. for O&M (kW)	28,275	30,140
	Mech. power req. for O&M (hP)	37,900	40,400

*"Region" = N.Y.S. Portion of NYMA.

no potential for tying into the existing aqueducts if a problem should occur. It is flexible in yield and would serve over five-sixths of the New York subregion. Timeliness would be served by the staged nature of the project, its comparatively early implementation (1990), and its yield. Equity is satisfied by a widespread use of resources and by compensation to source area residents. This project is the least costly of the Hudson alternatives, and has slightly smaller impacts on the environment. Some minor impact on the ecology of the estuary might occur in low-flow years, but the project would create significant regional economic benefits. Local opposition has been voiced to both the Hyde Park diversion and any reservoir construction that might be required in the distant future. Regionality would be satisfied by the large service area and the proportion of the project's yield that would be utilized outside the Hudson basin. Significant regional growth impact would occur, both in overall level and in distribution, further stimulating the proportionally greater growth of the outer suburban counties. Construction energy requirements would be high, because of the tunneling needed, and operational energy needs (chiefly for pumping) would be the second highest of the five projects.

ii. Hudson River Project - West Bank - The reliability of this alternative is quite high, because of the availability of alternate transmission paths. It would be slightly less flexible in yield than the Hyde Park diversion and would serve the largest population of any of the five projects: seven-eighths of the N. Y. subregion. Its impact on timeliness would satisfy the equity goal more fully. It is, however, the second most expensive project of the five. Environmentally, more tunneling would be required than for the Hyde Park diversion, but this project's regional economic benefits would be greater. Other environmental impacts would be substantially the same, so the overall impact on the environmental quality goal would be about the same as for the first project. Regionality would be more fully satisfied by this project's larger service area, and the impact on regional growth would be greater, with a particular impact on Rockland County (which would be served by this project alone.) Energy requirements for construction would be greater than for the Hyde Park diversion, because of the longer tunnel, and operational energy requirements are the highest of the five projects.

iii. Hudson Gravity Development - This project is the most reliable of the five, because of transmission redundancies, principal reliance on gravity rather than mechanical pumping, superior source quality, and less risk of contamination enroute than with open-channel conveyance. Although the project has the greatest yield range of the five, and a service area equal to

the Hyde Park diversion, it has less physical variability of components after intitial construction, and its overall impact on flexibility may be considered about the same as that of the Hyde Park diversion. In terms of timeliness, the greater yield of gravity development is muted by its longer construction time (it would probably not be on line before 2000), and the overall impact would be less favorable than that of the other two Hudson projects. The impact on equity would also not be as beneficial as for the Hyde Park diversion. Gravity development is by far the costliest alternative, chiefly because of the 175-mile tunnel required. Environmentally, this project would be more adverse overall than the other two Hudson Projects: upstream storage would be required, and the additional tunneling would pose a serious spoil disposal problem during construction, while the beneficial economic impacts would not be larger than for the Hyde Park diversion. Moreover, reservoir development could encroach on the Adirondack State Park, and might conflict with designated wild and scenic rivers. Regionality and growth control impacts would be substantially the same as for the Hyde Park diversion. Energy requirements for construction would be the greatest of the five projects, but operating requirements would be moderate because of the lesser emphasis on pumping.

iv. Long Island Groundwater and Long Island Groundwater Exchange - These two projects are considered together because their regional impacts are nearly the same. The overall reliability of the groundwater projects must be considered inferior to the Hudson alternatives because of limited transmission capacity, and questions that have been raised about the safe yield of the aquifer. Flexibility, too, suffers because of the limited yield range and the smaller proportion of the N.Y. subregion population served. In terms of timeliness, these projects would not be adequate: they would not meet the deficit when implemented, and they could not operate beyond about 2000, when Suffolk County's own growing needs would prevent further exports of its water. Impacts on equity would be relatively less favorable than for the Hudson projects, because of less comprehensive use of resources and lower per capita compensation to source area residents. The groundwater projects have the most favorable impact on cost, each being less than one-third the total cost of the least expensive Hudson project. Their environmental impacts are the least of the five projects, because of their small scale and the absence of surface impoundments, but the beneficial economic impacts would also be smaller because of their smaller service area. Uncertainties also exist about potential adverse effects on Suffolk's surface waters and coastal wetlands. Institutionally, an existing Suffolk County statute prohibits water exports from the county, and local opposition has been expressed to both groundwater project concepts. From the standpoint of regionality, either project would serve between one and two million fewer people than the Hudson projects; however, all of

the water is utilized in an interbasin, regionally unified fashion. The groundwater projects' impact on growth control would be smaller in magnitude than that of the Hudson projects, with the distributional emphasis on Nassau County and New York City rather than the upstate counties. The energy requirements for both construction and operation would be considerably lower than for any of the Hudson alternatives.

v. Discussion - Analysis of the potential source developments pointed strongly to the elimination of the two Long Island groundwater projects, even as interim projects for immediate action (in which context their low yields would be less of a handicap). They would be relatively ineffective in fulfilling the goals of reliability, flexibility, equity, regionality, and control of growth patterns. Uncertainties exist about impacts on groundwater quality, the level of the water table, and the ecosystems of surface streams and wetlands; economic stimulus would be smaller, and legal and political barriers exist to their implementation. Their impact on environmental quality would therefore not be dramatically supperior to that of a Hudson project. Most importantly, they would not provide an adequate long run source of water for the region.

The focus for early action source development therefore narrowed to the Hudson River. The three Hudson projects, including the initial stage of Hudson Gravity Development, are all similar, comprising intake and treatment facilities in the reach of the river near Hyde Park with a tunnel to Kensico Reservoir, the project operating intermittently in conjunction with the existing New York City system to increase the safe yield of the whole. The major difference among the projects (as well as the most significant types of adverse environmental impacts) would arise from the potential upstream impoundments required in the Hudson Gravity Development to attain high yields. But if project selection is based on an early-action program, with the flexibility to adapt to whatever measures might be chosen to meet distant water needs, the relevant questions then include: (1) What would be the facility locations, tunnel routes, etc. that would coordinate most advantageously with developments that might occur in the long run? (2) What intake location and operating rules would maximize raw water quality and minimize adverse hydrological and ecological impacts on the estuary?

Further investigation was required of the hydrology, geology, environment, ecology, and socio-economic base of the region, and of the engineering design of the potential project facilities, in order to address these questions. One such investigation, Preliminary Analysis of Hudson River High-Flow Skimming Project and Framework for Environmental Analysis, considered the crucial engineering, geological, environmental and

ecological factors in refining the Hudson River Project concept, and developed the alternative physical configurations in greater detail. At the same time, improved information was developed on the hydrologic and hydraulic characteristics of a Hudson River Project integrated with the New York City system, which led to refinement of the yield and maximum capacity of project facilities associated with different operating regimes. Further analysis of water supply deficits to be met by the project also influenced the yield required.

These studies led to the specification of the alternative project configurations whose potential impacts are analyzed in the other sections of this Appendix. Both yield and capacity are reduced relative to the descriptions in Table II-F-3, in addition to the changes in physical layout.

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*Not a NEWS Study Report.
**Jointly sponsored by NEWS Study and New York State Energy Research and Development Authority (formerly the New York State Atomic and Space Development Authority).

ATTACHMENT II-F-1

SELECTED CORRESPONDENCE

The letters in this Attachment were among those received in reference to the work of the NEWS Study on the NYMA. It is not an all inclusive compilation, but rather a selection of communications that were of the greatest significance in terms of expressing policy and shaping the course of subsequent NEWS Study work.

The letters, in general, contain either expressions of overall policy positions on key issues, or specific comments on NEWS Study work. It should be noted that comments specifically addressing the Draft Environmental Impact Statement for the Hudson River Project are separately compiled and displayed with the Revised Draft EIS, along with itemized responses to the various issues raised.

Following is a synopsis of each item.

Governor of New York, 3 August 1977 - This letter provided formal endorsement of the Hudson River Project by the State of New York, including the required assurances of local cooperation.

State of New Jersey (statement for record of Late Stage Public Meeting, 29 March 1977) - This reaffirmed New Jersey's position that it would not need water from the Hudson River before approximately 2020, but urged that post-authorization studies on the Hudson River Project consider New Jersey's potential participation beyond that time.

Governor of New York, 28 March 1977 - This letter expressed support for the Hudson River Project and enumerated key environmental and institutional concerns of the state for resolution in post-authorization studies.

New York State Department of Environmental Conservation (DEC), 9 September 1976 - This letter transmitted New York's updated estimate of the size of the water supply deficit to be met in the year 2000 in the portion of the state within the NYMA, given the most current population projections of the State Economic Development Board.

New York State DEC, 5 May 1976 - This letter contained comments on, and general endorsement of, the findings of the NEWS Study analysis of water conservation measures for the NYMA.

Commissioner, New York State DEC, 19 March 1976 - This supported the ongoing work of the NEWS Study and strongly urged balanced development of water conservation and water supply measures.

Governor of New York, 15 March 1976 - This letter supported continued study of Hudson River development, with particular attention to environmental analysis, inclusion of transmission features specifically including completion of New York City Tunnel No. 3, and potential federal cost-sharing.

Administrator, City of New York Environmental Protection Administration, 17 February 1976 - This emphasized the need for major conveyance facilities in any new regional water supply project, and requested that Federal completion of New York City Tunnel No. 3 be considered to achieve this end.

Governor of Connecticut, 17 October 1975 - This letter affirmed that Connecticut's own state water supply plan would suffice to meet their needs without recourse to any of the NEWS Study - developed projects.

Commissioner, New York State DEC, 23 December 1974 - This affirmed that Hudson River development would most feasibly meet the future water needs of the area, and that detailed analysis of such development should be undertaken by the NEWS Study, along with concurrent and equal study of a water conservation program.

New York State DEC, 9 February 1973 - This letter suggested that the plan of study for the NEWS Study in the NYMA give primary consideration to Hudson River development, with or without additional upstream storage, to meet the needs of the state portion of the NYMA, with possible further study of water conservation measures.

LIST OF EXHIBITS

SOURCE	PAGE NO.
Governor of New York, 3 August 1977	II-F-35
State of New Jersey (statement for record of Late Stage Public Meeting, 29 March 1977)	II-F-37
Governor of New York, 28 March 1977	II-F-43
New York State Department of Environmental Conservation (DEC), 9 September 1976	II-F-47
New York State DEC, 5 May 1976	II-F-49
Commissioner, New York State DEC, 19 March 1976	II-F-51
Governor of New York, 15 March 1976	II-F-53
Administrator, City of New York Environmental Protection Administration, 17 February 1976	II-F-55
Governor of Connecticut, 17 October 1975	II-F-57
Commissioner, New York State DEC, 23 December 1974	II-F-59
New York State DEC, 9 February 1973	II-F-61

STATE OF NEW YORK
EXECUTIVE CHAMBER
ALBANY 12224

HUGH L. CAREY
GOVERNOR

August 3, 1977

Dear General Kelly:

Thank you for your letter of April 14, 1977, regarding the Hudson River Water Supply Project.

The State of New York remains strongly committed to the concept of regional water supply in southeastern New York as the most efficacious means of addressing the serious areawide water supply deficit.

Our cooperative endeavors with the Corps have developed a convincing body of evidence of the need for a reordering of the current individualized delivery systems in this region and for the development of a substantial new source of supply. The Hudson River appears to be the most cost-effective source of any major new supply and the Corps' Hudson River Project recommends itself as the most acceptable means of developing this source.

In light of the above, we support the Hudson River Project and we recommend that it be forwarded to the Chief of Engineers and subsequently to the Congress of the United States with the strongest of recommendations for immediate authorization and appropriation.

Provided the final design affirms that the project is economically feasible and environmentally sound, the State of New York will, working closely with the local jurisdictions involved, bring about compliance with the following nonfederal responsibilities:

1. Conservation Program -- Design and implementation in all jurisdictions served by the project the following:

-- A program with specific early actions leading to the goal of universal metering of all users of water supplies.

-- A program for effective leakage monitoring and control.

-- Enactment of ordinances requiring water saving fixtures and devices consistent with public health requirements, in all new construction and major reconstruction.

-- A drought contingency program to be instituted in a water emergency.

2. Operation and Maintenance -- Local interests will be responsible for all project operation and maintenance without cost to the United States.

3. Environmental Monitoring Program -- Local interests will also be responsible for the development and implementation of an environmental monitoring program to assure that project operations do not cause severe adverse effects and to determine modifications required in project operations to mitigate such effects if they are found to occur.

4. Repayment of Investment Costs -- Upon acceptance of the project for operation, local interests shall repay to the United States costs expended by the United States for advanced planning, design and construction of the project in accordance with the terms of the authorizing legislation. Preauthorization study costs will be excluded from repayment.

My March 28, 1977, letter on this subject requests adequate provision for federal cost-sharing in the entire project including transmission facilities to New York City and Nassau County. I would reiterate that request and urge that the Corps give strong consideration to starting construction on the transmission facilities as soon as possible, and that this activity include reimbursement for costs previously incurred by local government.

I believe I represent the preponderence of opinion among local elected officials in asking the Corps to move expeditiously in this matter, and I look forward to a close cooperative local, state and federal participation in bringing about solutions to the many complex questions to be addressed before this project, which is crucial to the health and well-being of 12,000,000 people in southeastern New York, can become a reality.

Sincerely,

Hugh L. Carey

General James L. Kelly
Engineer, North Atlantic Division
Corps of Engineers
Department of the Army
90 Church Street
New York, New York 10007

STATEMENT OF

DIRK C. HOFMAN, PROJECT DIRECTOR

DIVISION OF WATER RESOURCES

AT PUBLIC HEARING ON

THE HUDSON RIVER PROJECT

NEW YORK CITY

MARCH 29, 1977

On behalf of the State of New Jersey, I want to express our appreciation for this opportunity to comment on the proposed Hudson River Project and for the past opportunities to participate in and support the U.S. Army Corps of Engineers in its various Water Supply Studies affecting New Jersey and the Northeastern Region of the United States.

New Jersey has for some time taken a great interest in the water supply problems of the New York-New Jersey Metropolitan Region and has sought to cooperate with the federal government and our sister states of New York and Connecticut in a regionalized approach to water supply development.

Many years have elapsed since the Region experienced the severe drought of the 1960's, but for those of us concerned with water supply, the memory of that drought and the specter of its return remain constant reminders of the

need for sound planning and implementation to assure adequate water supplies.

The New York Metropolitan Region encompasses the densely populated northeastern area of New Jersey composed of nine counties within the Raritan, Passaic and Hackensack Basins. Containing over four and a half million residents and the lion's share of the States industry, this area is dependent on the mercy, or perhaps the indulgence of the weather for the satisfaction of its water needs. Abnormally high rainfall in recent years has permitted it to use 30 million gallons per day (MGD) more water than presently developed supplies can yield, based on the 1960's drought.

More recently, if the 30-day weather forecast had not changed three weeks ago from below normal precipitation to above normal, and if that prediction had not come true, Northern New Jersey would be on the brink of a serious drought.

The State has recognized the urgency and seriousness of the Water Supply problem both for the shortand long term. With respect to the relatively near term, construction of outlet facilities for the Round Valley Reservoir will soon be completed, which will enable the State to increase the yield of its Round Valley-Spruce Run system by 80 MGD. The next

stage of development for this system is the Confluence Reservoir, pumping station and force main which will increase the yield by an additional 50 MGD.

Land has been acquired for the Confluence Reservoir as well as others on the Manasquan River in the Coastal Plain and Six Mile Run in the Raritan River Basin. The rehabilitation and modernization of the Delaware and Raritan Canal will permit full use of the 100 MGD Delaware diversion granted by the Supreme Court in 1954. Finally, public hearings are currently underway on the Ramapo-Two Bridges Project in the Passaic Basin and a decision on this proposal by the State Water Policy and Supply Council will follow.

Beyond the near term, New Jersey looks to our recently-begun Statewide Water Supply Master Plan for an assessment of our long range water supply needs and the formulation of proposals for meeting those needs. The Master Plan is a three-year project to be conducted by a consortium of five consulting firms under the direction of a small State staff. The planning performed under the project will cover not only the engineering and other technical aspects of meeting water supply needs but the fiscal, governmental and institutional factors as well. The Plan will be completed late in 1979.

In addition to identifying various programs for developing surface and groundwaters, the Master Plan will also guide us in the more efficient use of existing supplies and in the protection of water resources to be tapped in the future. Contingency plans for drought conditions and system failures, such as the one which occurred in Trenton in 1975, will be prepared and long term conservation plans for the reduction of water demand will be developed. Lastly, recommendations will be made for strengthening the State's water resource regulation capability and for improving the financial and administrative aspects of its water utility operations.

With specific reference to the Hudson River, the Master Plan is required to consider the feasibility of using the Hudson River as a source of water supply. The major water supply development options to be presented to the State will include, among others, alternatives predicated on the availability of Hudson River water. The Plan must also delineate the steps and procedures necessary for New Jersey to participate in a Hudson River diversion, such as the one being considered here today. Until it is determined in the Master Plan, the time at which there would be a need by New Jersey for Hudson River water cannot be pinpointed. It appears to be sometime towards the end of the first quarter of the next century.

As presented, this project gives no consideration to New Jersey's future needs and as such would deny us a valuable option in planning for our future water supply requirements. Unfortunately , there is no disucssion in the prepared reports of the operation of the facilities beyond the target year of 2020.

It is our understanding that the 400 MGD supply is to be fully utilized by just New York City and Nassau County. Moreover, only one of the three alternative tunnel alignments would make it feasible for the State of New Jersey to eventually tie into the proposed facilities. This is the Spring Valley alignment which runs through Rockland County, New York.

We would be supportive of a Project which will not preclude New Jersey's eventual participation. We therefore, request that the advanced engineering and design studies take into account New Jersey's potential future role in the Project.

New Jersey will continue to work for regional approaches for solutions to the water problems of the Metropolitan Region and will continue to cooperate closely with our sister states and the federal government in these endeavors.

STATE OF NEW YORK
EXECUTIVE CHAMBER
ALBANY 12224

HUGH L. CAREY
GOVERNOR

March 28, 1977

Dear General Kelly:

We commend the Corps of Engineers upon completion of this phase of the Northeastern New York Water Supply (NEWS) Study, and more particularly, that portion of the study concerned with the water supply for the lower Hudson Valley and Long Island areas of New York State.

The State of New York has had a strong interest in the NEWS Study since its inception shortly after the drought of the mid-1960's. The importance of developing long-range solutions to the serious problems of water shortages encountered at that time was recognized by all levels of government involved, and there has been a consistent support for the planning activities of the Corps throughout the past ten years.

The State's interest was exemplified through creation of the Temporary State Commission on Water Supply Needs of Southeastern New York to study the technical, administrative, and environmental aspects of water supply and to propose legislation for bringing about solutions to the problems identified. In addition, during this past year, I established a State Task Force on Institutional Arrangements for Water Supply in Southeastern New York to provide a forum for representatives of the State and local jurisdictions to discuss and begin to arrive at agreement on the solutions to institutional and intergovernmental problems involved in the creation of a regional water supply system for that area.

We recommend that the Hudson River Project identified by the NEWS Study be forwarded to the Chief of Engineers and subsequently to the Congress of the United States. We ask the Congress to give priority consideration to the next step of this proposed project, which in our judgment must include satisfactory resolution of the following environmental and institutional questions:

-- Determine downstream flows required to control the estuarine location of the salt front and to maintain the ecological balance of the Hudson River and New York Harbor.

-- Determine demands from service areas before establishing a design criteria which would dedicate all flows greater than 3,500 cfs to the proposed water supply project.

-- Conduct studies and recommend plans for operation to insure that no pumping of water would occur during the critical ecologically stressed months of June, July and August.

-- Evaluate fully the impact on the important fish species of the Hudson River (including entrainment and impingement) from withdrawals of water.

-- Establish the most advanced methods to monitor and treat the intake water so as to remove any hazardous materials from the water.

-- Establish methods for disposal of sludge materials from the water treatment facilities.

-- Evaluate alternative rate structures for use of the water from the project.

In recognition of the importance of a safe, reliable water supply as a major component of a healthy, economically sound environment, the State of New York understands that, should a Hudson River Project ultimately be authorized, compliance with the nonfederal responsibilities listed below is necessary.

1. Conservation Program. Local interests will design and implement, in all jurisdictions served by the project, the following:

-- A program with specific early actions leading to the goal of universal metering of all users of water supplies,

-- a program for effective leakage monitoring and control,

-- enactment of ordinances requiring water-saving fixtures and devices consistent with public health requirements in all new construction and major reconstruction, and

-- a drought contingency program to be instituted in a water emergency.

2. Operation and Maintenance. Local interest will be responsible for all project operation and maintenance without cost to the United States.

3. Environmental Monitoring Program. Local interests will also be responsible for the development and implementation of an environmental monitoring program to assure that project operations do not cause severe adverse effects, and to determine modifications required in project operations and to mitigate such effects if they are found to occur.

4. Repayment of Investment Costs. Upon acceptance of the project for operation, local interests shall repay to the United States, in accordance with the terms of the authorizing legislation, all costs expended by the United States for advanced planning, design and construction of the project. Preauthorization study costs will be excluded from repayment.

We believe the Hudson River Project should include adequate provisions for federal cost-sharing in the entire project including transmission facilities to New York City and Nassau County and the implementation of universal metering to meet the nonfederal responsibilities as recommended by the Corps. As a minimum, the general repayment provisions of the Water Supply Act of 1958 should be used as a basis for federal cost-sharing.

The Corps has done an exemplary job of generating the background information for the NEWS Study and development recommendations for the most efficacious solutions to the serious water supply problems of this region.

We look forward to working closely with the Corps, other federal agencies, and the local governments in providing input to the post-authorization studies required to bring about solution in these important areas.

Sincerely,

Hugh L. Carey

General James L. Kelly
U. S. Army Division Engineer
North Atlantic Division
Corps of Engineers
90 Church Street
New York, New York 10007

New York State Department of Environmental Conservation
50 Wolf Road, Albany, New York 12233

Peter A.A. Berle
Commissioner

September 9, 1976

Dear Mr. Howard:

In response to your request at the NEWS study meeting on July 20, 1976 following are our views on the water supply deficit in the New York State portion of the New York Metropolitan area.

Based on a review and analysis of information provided by your office, work of the Temporary State Commission on Water Supply Needs of Southeastern New York and other available information we have concluded that the estimated water supply deficit for the southeastern New York region at 2000 is on the order of 300-350 mgd using current population projections of the State Economic Development Board. Our estimate is derived from the NEWS study projected per capita demands for 2000 with an adjustment for a decrease in household size and reductions in the savings anticipated from leakage control in New York City and in the estimated available local supplies for New York City and Nassau County. The results of our analysis are shown in the attached table.

No change has been made in the NEWS study estimate of savings for domestic conservation devices or industrial water conservation. The NEWS study industrial water conservation estimates are believed to be overly optimistic but we have not been able to develop a rationale for adjustment based on available information. We believe that a complete re-analysis of industrial water demands and savings is necessary and should be one of the first steps in the detailed planning stage after project authorization. We estimate that industrial water demands in 2000 would be at least on the order of an additional 50 mgd with a corresponding increase in the total deficit shown in the table.

I hope this information is sufficient at this time to provide guidance for your continuing survey scope study.

Sincerely,

Theodore L. Hullar

Theodore L. Hullar, Ph.D.
Deputy Commissioner for
Programs and Research

Attachment

Mr. Herbert Howard, Chief
Planning Division
North Atlantic Division
Corps of Engineers
90 Church Street
New York, New York 10007

New York State Department of Environmental Conservation
50 Wolf Road, Albany, New York 12233

Peter A. A. Berle
Acting Commissioner

May 5, 1976

Mr. Herbert Howard
Corps of Engineers
North Atlantic Division
90 Church Street
New York, N.Y. 10007

Dear Herb:

We have reviewed your working paper, "Water Conservation Measures for the NYMA, January 1976." We believe the information presented generally meets our request for additional investigation of water conservation measures. We have the following comments on the specific measures:

Metering - We support universal metering in New York City and the remainder of the southeastern New York region as a water conservation measure and management tool. We generally concur in your analytical procedure but have some reservations about your conclusions, particularly that universal metering would not affect water use in multi-unit dwellings and that water use in one and two unit structures would be reduced as much as 35.4 gpcd from 65.4 gpcd (low consumption). We would reasonably expect some reductions in water use in multi-unit dwellings and a lesser reduction than indicated in your report in one and two-unit structures. Based on your analysis and the results of other studies we believe the water savings from metering are speculative. However it is a measure that must be undertaken but not equated to reducing a specific amount of projected water supply demands. More detailed comments on the metering analysis are attached.

Leakage Control - We support the leakage control program outlined in your report based on its cost effectiveness in comparison with other alternatives, even if water savings are less than projected in your study. We note that your projection of annual new water main construction may be high based on City comments, and we recommend that you reevaluate this aspect.

Domestic Conservation Devices - We support the program for installation of domestic conservation devices outlined in your report. However, we believe that uniform and effective implementation of this measure throughout the NYMA will be difficult and that the savings estimated for the total metropolitan area are optimistic.

Pricing - We have no major comments on your analysis and conclusions on pricing discussed in the report.

Industrial Recirculation - The projected savings appear to be overly optimistic in view of industrial and economic conditions in the State, and we need to meet with you and discuss this further. Attached are more detailed comments indicating some of our concerns.

Drought Contingency Plan - We support the program outlined in your report for drought contingency measures in New York City. We believe, however, that the water savings attributed to such measures should be viewed as contingency savings and should not be used to reduce projected design deficits. We question the practicability of importing 32 mgd of bottled water under Phase 3 of the drought contingency plan.

Educational Program - We strongly support an educational program for water conservation in New York City. However, we question the phased program outlined in the report, particularly the evaluation of results. We believe that a low cost continuing program of education to increase public awareness of the need for water conservation should be implemented on the assumption that wasteful practices do exist and that there is an inherent benefit to such a program.

Based on the foregoing comments we believe the projected deficits being used at present in the NEWS study are of a reasonable order of magnitude with the only possible change being an allowance for leakage control measures.

The foregoing conclusion does not take into consideration the impact of new preliminary State population projections which indicate significantly less population growth in the New York State portion of the NYMA. We are evaluating this aspect further.

Sincerely,

Thomas P. Eichler

Thomas P. Eichler, Director
Office of Program Development,
Planning and Research

OGDEN REID
COMMISSIONER

STATE OF NEW YORK
DEPARTMENT OF
ENVIRONMENTAL CONSERVATION
ALBANY, NEW YORK 12233

March 19, 1976

Dear General Kelly:

I welcome the opportunity to express the views of the New York State Department of Environmental Conservation on the NEWS Study of the New York Metropolitan Area. Governor Carey has presented the New York State position on the Study to you.

We strongly support completion by the Corps of Engineers of the Study. We urge the Corps to complete the Study in sufficient detail to the end that a decision can be made next fall on project feasibilities and project authorization.

A balanced program of water conservation and water supply should be contained in the NEWS Study and both must be pursued vigorously so as to provide water to Southeastern New York in the decades ahead. At our request the Corps has investigated water conservation measures. We urge the incorporation of all feasible water conservation measures in the survey scope study including possible metering for New York City which could save 100-200 million gallons per day. We are pleased to work closely with the Corps and other state and local interests to further this Study, and we are appreciative of the technical assistance the North Atlantic Division of the Corps has provided to us in the NEWS Study.

We believe the NEWS Study can provide the means for augmenting the water supply and for instituting the conservation measures needed in the New York Metropolitan Region. We urge completion of the Study and look forward to our continuing support of it and of projects which may derive from it.

With best regards.

Sincerely yours,

Ogden Reid

General James L. Kelly
U.S. Army Division Engineer
Department of the Army
North Atlantic Division
Corps of Engineers
90 Church Street
New York, New York 10007

STATE OF NEW YORK
EXECUTIVE CHAMBER
ALBANY 12224

HUGH L. CAREY
GOVERNOR

March 15, 1976

Dear General Kelly:

We are pleased that a public meeting is being held on the Northeastern United States Water Supply (NEWS) Study at this time to discuss the study results and to give State, local and other interests an opportunity to express their views. We are especially pleased to join with your New York District Office and New Jersey and Connecticut in cosponsoring the March 19th public meeting which will concentrate on the New York Metropolitan Area. The timing is opportune in relation to the current status of your studies on the Hudson River high flow skimming proposal and water conservation measures.

New York State has had a strong interest in the NEWS study since it was started shortly after the mid-1960's drought. We have viewed the study as a means of identifying and implementing projects and programs that are necessary to meet our critical water supply needs in Southeastern New York.

Based on your earlier studies and the work of the State's Southeast Water Supply Commission, the Department of Environmental Conservation, acting on behalf of the State, agreed in December 1974 that the Corps should initiate a more detailed study at the survey scope level for a high flow skimming project on the Hudson River. The Department also urged strongly that water conservation measures be investigated further and included as an essential part of the regional water supply program. Reports on the results of these two phases of study have been prepared and, although they are still being reviewed, we would like to emphasize the following points at this time.

We urge that you continue with your survey scope study of the Hudson River high flow skimming project and complete the study in sufficient detail so that we can make a sound judgment on the feasibility and acceptability of the project. The Department of Environmental Conservation will coordinate with you on details of the work we believe is necessary to complete the survey scope study. High priority should be given to environmental impact analysis in your remaining work.

We urge that you include in your study the need for major conveyance facilities to deliver Hudson River water to all parts of New York City and to Nassau County. This includes provisions for completion of the third City tunnel. Consideration should also be given to supplying water to the counties adjoining the river. We view these facilities as an integral part of the high flow skimming project and well within the scope of your study authorization.

We believe the survey scope study should include adequate provisions for Federal cost-sharing on any major projects that may be recommended, such as the Hudson River high flow skimming project, transmission facilities to the City and Nassau County and universal metering in New York City. As a minimum, the general repayment provisions of the Water Supply Act of 1958 should be used as a basis for Federal cost-sharing. However, we believe that further consideration should be given to a more direct Federal contribution.

We appreciate the work the Corps has done on the NEWS study. During the remainder of the study we will be working closely with you, New Jersey and Connecticut, and other State and local interests to obtain the most satisfactory results. Hopefully, we will be able to make significant progress toward solving the region's water supply problems.

Sincerely,

Hugh L. Carey

Brigadier General James L. Kelly
District Engineer
North Atlantic District
Corps of Engineers
Department of the Army
90 Church Street
New York, New York 10007

The City of New York

ENVIRONMENTAL PROTECTION ADMINISTRATION
2358 MUNICIPAL BUILDING, NEW YORK, N. Y. 10007
Telephone: 566-4124

ROBERT A. LOW, *Administrator*

February 17, 1976

Major General James L. Kelly
Division Engineer
North Atlantic Division
U.S. Army Corps of Engineers
90 Church Street
New York, N. Y. 10007

Dear General Kelly:

This is to apprise you of a situation that exists in the New York Area and to enlist your help in solving the problem.

The water demand is increasing and, as a result therefrom, we are not able to maintain adequate pressures in the present large transmission lines to meet the growing demand. The problem is not in the distribution system but rather in not having adequate capacity to transmit water to our large demand centers from which it is then distributed.

In the N.E.W.S. Study, I don't think you have considered the need for transmission extending into the City demand centers or into Westchester and Nassau Counties. If such transmission is not provided, water from any project cannot reach the consumer, whether it be from the Hudson River or from any other source.

It is true that the City had intended to undertake the provision of such transmission facilities and did, in fact, begin such an undertaking. However, fiscal conditions make it financially impossible for us to continue the project.

Since the authorizing legislation for the N.E.W.S. Study allows you to include major transmission as a legitimate element for inclusion in your long range plans, we respectfully request that you consider provision of such transmission to and through the City to the large demand centers not only contained in the City, but also in Westchester and Nassau Counties.

- cont'd

If such transmission is provided through your efforts, then large quantities of water can be delivered not only to the regional demand centers in the City, but the City can also assist Westchester and Nassau Counties through the use of such transmission backed up by new sources of supply you might recommend and backed up by the existing systems.

We, therefore, ask you to review the report of the New York City Board of Water Supply on the Third City Tunnel sent to your office, under separate cover, to determine the validity of including the Tunnel in any planning you may undertake for additional transmission capacity for this New York Metropolitan Area.

Very truly yours,

Robert A. Low

ROBERT A. LOW
Administrator

ELLA GRASSO
GOVERNOR

STATE OF CONNECTICUT
EXECUTIVE CHAMBERS
HARTFORD

October 17, 1975

Major General James L. Kelly, USA
Division Engineer
Department of the Army
North Atlantic Division, Corps of Engineers
90 Church Street
New York, N. Y. 10007

Dear General Kelly:

Thank you for your letter indicating that the Corps has accepted the water supply plan submitted by Connecticut as part of the NEWS Study interim report.

I am particularly pleased that the NEWS Study will not contain any of the alternatives which have been proposed in the past. Connecticut, as you may know, has devoted a great deal of time and resources in developing a sound water supply program. This water supply program, as reflected in Connecticut's Plan of Conservation and Development, assures that adequate clean upland and ground water resources will be available to meet the future needs of Connecticut citizens for high quality domestic water.

The alternate plans quite correctly rejected by you involved the use of effluent bearing water, which would be contrary to existing Connecticut law, regulation and policy.

At your earliest convenience, I hope you will forward a copy of your draft interim report. I want my staff to begin review of this report immediately, and specifically that portion of the report dealing with Connecticut's relation to the water supply plan for the New York Metropolitan area. A timely staff level review of the plan will enable us to identify any problem areas and resolve any questions of interpretation.

I would be pleased to co-sponsor the meeting for the New York Metropolitan area which you suggest. As you know, I am a strong advocate of an open planning process, and I have continuously encouraged maximum public participation in these decisions. I would hope that the limited number of meetings which will be held in the New England area will be given the widest possible exposure.

Thank you for forwarding the letter of Governor Dukakis, where he discusses the position of Massachusetts relative to the diversion of Connecticut River waters to serve eastern Massachusetts. It is encouraging that Massachusetts intends to give serious consideration to exploring alternatives to further diversions from the Connecticut River.

Needless to say, I would encourage a commitment from the State of Massachusetts indicating its desire to enter into a formal interstate compact which would establish an equitable and realistic allocation of Connecticut River waters. Connecticut's position on this issue is already a matter of record, and the proposed diversion continues to be of severe concern to us.

Thank you once again for this opportunity to communicate our views on these issues, which are of such critical and lasting concern to all of us who must share the natural resources of New England.

With best wishes,

Cordially,

Ella Grasso

ELLA GRASSO
Governor

STATE OF NEW YORK
DEPARTMENT OF
ENVIRONMENTAL CONSERVATION
ALBANY

COMMISSIONER
James L. Biggane

December 23, 1974

Dear Mr. Howard:

Thank you for your letter of November 22, 1974 advising of the status of the Northeastern United States Water Supply (NEWS) study pertaining to New York State.

We note that your feasibility level studies were used as an information base by the Temporary State Commission on Water Supply Needs of Southeastern New York and that there is no marked difference in the technical conclusions you have developed to date and those of the Commission. Although no official action has been taken on the Commission recommendations, it is apparent there is a consensus among those knowledgeable on the water supply problems in southeastern New York that the Hudson River is the most feasible source of additional water supply and that a high-flow skimming project has significant potential for development.

In view of the results of your investigations and those of the Commission and other previous studies we agree that more detailed study by NEWS at survey scope level should be initiated for a high-flow skimming project on the Hudson River. Before the study is initiated, however, we request an opportunity to review the scope of work to be sure it covers our concerns adequately. In particular we would like to see that sufficient analysis is made of the environmental impact on the estuary of withdrawals from the Hudson River and that there is adequate opportunity for our participation and public involvement in the detailed study.

We also believe that your moving ahead on further study of this potential new source development project should be accompanied

by development of an effective water conservation program including universal metering for the study area. We believe that a significant reduction in water demands can be made by conservation measures and that these should be an essential part of the regional water supply program. Therefore, we request that you undertake a detailed study of a water conservation program at a scope and depth at least equivalent to the high-flow skimming project study.

Sincerely,

J. L. Biggins

Commissioner

Mr. Herbert Howard
Chief of Planning
North Atlantic Division
Corps of Engineers
90 Church Street
New York, New York 10007

New York State Department of Environmental Conservation
Albany, N. Y. 12201

Henry L. Diamond,
Commissioner

February 9, 1973

Mr. Harry E. Schwarz
NEWS Study Group
North Atlantic Division
Corps of Engineers
90 Church Street
New York, New York 10007

Dear Mr. Schwarz:

We understand that you are preparing a plan of study for an authorization report on water supply alternatives for the Northern New Jersey - New York City - Western Connecticut metropolitan area, as part of the NEWS Study.

We believe that first consideration in your study should be given to development and management of the available water resources in the Hudson River Basin and adjacent basins in New York State to provide the additional public water supply needed through 2020 for the State portion of the study area. It appears that the required storage to provide supplemental flows on the Hudson River can be developed within the Hudson basin or immediately contiguous to it without the need for diverting water into the basin from other distant sources such as Lake Ontario, Lake Champlain, or the Housatonic or Connecticut River Basin.

In considering the development of additional in-basin storagewe suggest that Hinckley Reservoir should be given priority consideration, that Schaghticoke and Fort Hunter sites should be considered as alternatives and that the Gooley #1 site should not be considered as a viable alternative at this time. We also feel there is a potential for greater utilization of Great Sacandaga Lake for public water supply, primarily through river regulation.

We suggest that the following alternative water supply projects be investigated further in your authorization study.

1. Hudson Project HU-1 including storage for flow regulation with water supply diversion at Hyde Park. You should investigate an additional tunnel from Hyde Park to Ashokan Reservoir and give particular attention to possible eutrophication in Ashokan and Kensico Reservoirs resulting from introduction of Hudson River water.

2. Hudson Project HU-6 including Hudson high-flow skimming with water supply diversion at West Park and later development of in-basin storage for Hudson releases. Major concerns which should be investigated further are the feasibility of additional loadings of the Catskill and Delaware aqueducts, the results of changed disposition of the Delaware system yield, the method of integrating the pumped supplies with the present New York City gravity system, and institutional and cost sharing

arrangements for the New York-New Jersey supplies. Our comments and those of the New York City Board of Water Supply and Department of Water Resources, transmitted by letter of June 9, 1970, provide additional information on these questions.

3. Hudson River high level supply with upper basin storage and a gravity tunnel to New York City. A similar proposal using Sacandaga storage and provided equivalent storage in the Adirondack Region was considered in the New York City - Westchester County public water supply study in 1966 and found to be costly. Basin storage sites that should be investigated again for this potential include existing Great Sacandaga Lake, Hinckley re-development, and a new reservoir at Forestport or Hawkinsville with the McKeever Diversion and a tunnel to Hinckley. Particular attention should be given to tunnel construction costs. Some work on this concept has been done by a consultant for the New York City Board of Water Supply, and the scope of your work should be based on the additional information developed by the City.

In considering withdrawals from the Hudson River, you should verify the range of withdrawals that can be made with and without additional in-basin storage and determine the environmental impact on the estuary of withdrawals of varying magnitudes. In considering storage you should investigate the advantages and disadvantages of single-purpose and multi-purpose reservoirs and the benefical and detrimental effects of flow regulation in downstream areas. Insofar as possible, a true comparison should be made of all benefits and costs of the alternative projects.

Our suggestion that these three alternatives be investigated further does not imply any particular preference for one over the other at this time. In our judgment each alternative is of current interest and has some degree of potential for implementation.

In addition to the project proposals, we believe it may be desirable for you to do follow-up work on conservation measures, including metering, pricing, leakage control, etc. It is our understanding that these measures will be reported on by the Temporary State Commission on Water Supply Needs of Southeastern New York within the next few months.

As you may know, the Temporary State Commission will be making its findings and holding public meetings during the next six months and will make recommendations on a water program for southeastern New York next December. Your plan of study should be coordinated with the Commission's schedule and be flexible enough to allow for extension of the Commission's work and possible implementation of their recommendations.

We will be glad to discuss these comments with you further.

Sincerely,

Edward A. Karath

Edward A. Karath
New York State Representative
NEWS Study

cc: Dr. Lawrence
R. Pedersen
J. A. Finck
R. Hennigan
E. Maguire

NEWS SUMMARY REPORT

APPENDIX - PART II

HUDSON RIVER PROJECT
TECHNICAL REPORT

SECTION G - TECHNICAL ASSISTANCE REPORT
U.S. FISH AND WILDLIFE SERVICE REPORT

NORTHEASTERN UNITED STATES
WATER SUPPLY STUDY

North Atlantic Division
U.S. Army Corps of Engineers

PART II - TECHNICAL REPORT

SECTION G - TECHNICAL ASSISTANCE REPORT
U.S. FISH AND WILDLIFE SERVICE REPORT

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SECTION G - TECHNICAL ASSISTANCE REPORT
U.S. FISH AND WILDLIFE SERVICE REPORT

SYNOPSIS

The U.S. Fish and Wildlife Service in accordance with the Fish and Wildlife Coordination Act has provided a report on the biology of the entire Hudson River basin so as to insure a comprehensive ecological perspective in analyzing impacts of the Hudson River Project. Essentially the report is a detailed summary of published information dealing with the physical and biological characteristics of the area. Included in the report are faunal and floral biota, information on wetlands, rare and endangered species and evaluations of Hudson River fishery resources. Much of the information comes from studies by the Boyce Thompson Institute, the State of New York, Texas Instruments Inc., Prof. J.T. McFadden, Lawler, Matsuky and Skelly Engineers, and the U.S. Public Health Service. Much of the source material upon which this report is based has been used by the Corps in the Environmental Impact Statement. The Fish and Wildlife Servive report includes a series of "Resource Study Requirements" for post-authorization analyses. These environmental study recommendations indicate more data are needed on the aquatic biota and to a lesser extent more data are required on terrestrial ecosystems in the project area "if the project proceeds in the Corps Post-Authorization (AED) studies." The following items must be assessed in greater detail prior to operation of the intake structure and treatment plant:

1. Zone of withdrawal of the intake facility.

2. Zone of influence of the intake facility.

3. Concentrations of organisms in the intake water as determined by actual field research. This infers a sound statistical design and sampling scheme.

4. Effect of nutrient withdrawal on the estuarine dynamics.

5. "Sludge" monitoring for toxic chemicals as well as the identification of sludge disposal sites.

6. A monitoring program at the intake screens for entrainment and impingement of aquatic organisms.

7. Specific descriptions of the reservoir manipulations that will be required to operate the pumping station under "normal flow conditions" and "drought flow conditions" such as existed in the mid 1960's.

8. Future demands upon the pumping station (that would be required to meet New York City needs) for water from the Hudson River as this relates to increased reservoir makeup water for the Hudson River, e.g., construction of additional reservoirs, increasing capacity of existing reservoirs, or diverting water from other basins.

9. Potential effects of the intake on the Shortnose sturgeon.

ATTACHMENT II-G-1

TECHNICAL ASSISTANCE REPORT

ATTACHMENT II-G-1

TECHNICAL ASSISTANCE REPORT

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UNITED STATES
DEPARTMENT OF THE INTERIOR
FISH AND WILDLIFE SERVICE
100 Grange Place, Room 202
Cortland, New York 13045

May 17, 1977

Mr. Herbert Howard
Chief, Planning Division
Corps of Engineers
90 Church Street
New York, New York 10007

Dear Mr. Howard:

Enclosed is the Technical Assistance Report for the Hudson River Project. This constitutes the report of the U.S. Fish and Wildlife Service and is submitted in accordance with provisions of the Fish and Wildlife Coordination Act (48 Stat. 401, as amended; 16 U.S.C. 661 et seq.).

We also wish to thank you for your indulgence with respect to the delay of this report.

Sincerely yours,

Gary C. Evans

Acting Field Supervisor

AMERICAN REVOLUTION BICENTENNIAL 1776-1976

Introduction

This report is not limited in scope to only the proposed Hudson River Project's direct environmental impact areas; it encompasses the entire Hudson River Basin. Water withdrawal from the Hudson, by previous obligations, will necessitate manipulation of significant water amounts within the Hudson Basin, i.e., reservoir regulation. The U.S. Fish and Wildlife Service (USFWS) is concerned that the proposed construction will cause long term adverse impacts on the biotic community of the Hudson River Basin.

One of the major inadequacies of present biological and hydrological research (study) is the lack of comprehensive ecological orientation. Most research is directed toward assessing the impact of large-scale projects such as the proposed project, but we have as yet no concept for the total environment. Therefore, in consideration of the U.S. Fish and Wildlife Service's objectives--to maintain and protect natural resources for future generations--it's the USFWS obligation to aid in developing projects in such a way that they continue to make important contributions to economic development with minimum adverse ecological impacts.

This report, then, is intended to provide a resource overview for the entire Hudson Basin. Further, it's hoped that the information will be used judiciously with respect to the future of the resources. We are all aware that past inadequate foresight and guidance has precipitated the present natural resource problems.

THE HUDSON RIVER BASIN

1.0 General Description Of Basin

1.1 The Hudson River Basin is located in the eastern part of New York State and drains about 13,400 square miles. The Hudson River Basin is composed of three sub-basins: the Mohawk, the Upper Hudson, and the Lower Hudson (Fig. 1).

The Mohawk sub-basin is drained by the Mohawk River. The Mohawk's source is in the hills of Lewis and Oneida Counties. The river's head is in the southern part of the Tug Hill area and flows generally in an easterly direction for about a 120 miles to its junction with the Hudson River just above Troy, NY. It drains an area of about 3,460 square miles. It's main tributaries are Schoharie Creek, West Canada Creek, East Canada Creek, and Oriskany Creek having drainage areas of 926, 526, 291, and 146 square miles respectively. The Mohawk sub-basin has a mean annual temperature of 45° F and a mean annual precipitation of 46 inches.

The rivers and streams in the sub-basin generally are good quality. Pollution, however, is a problem in several segments of the river. Several reservoirs regulate the flow of the Mohawk,

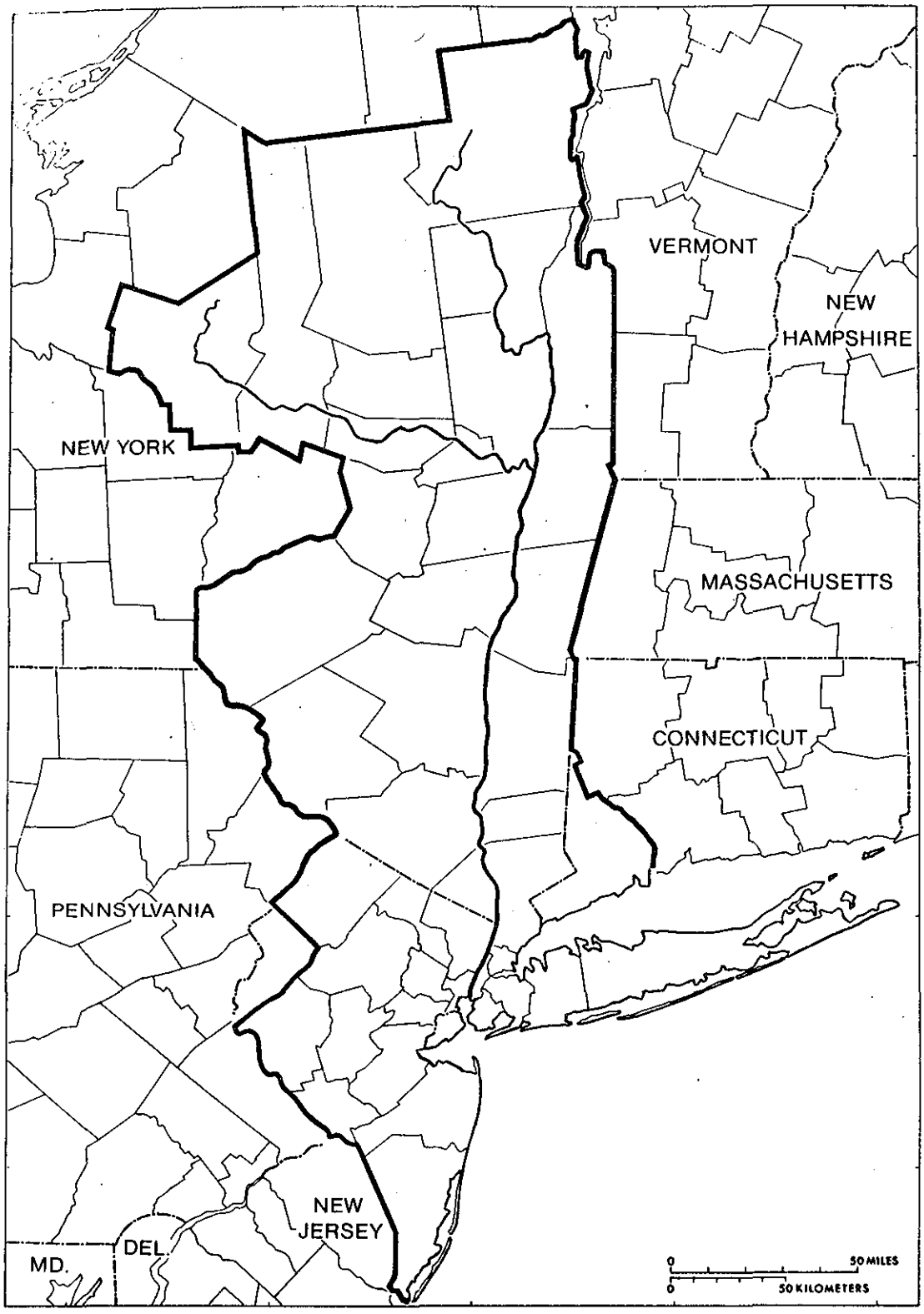

Figure 1. Hudson Basin Project Study Area

mostly for the operation of the Barge Canal. The three major reservoirs of the sub-basin are: Delta on the Mohawk River, Hinckley on West Canada Creek, and Schoharie on Schoharie Creek. Delta and Hinckley reservoirs provide water for the Barge Canal; Schoharie supplys water to New York City.

The Mohawk River Valley comprises the lowlands area that separate the Catskill Mountains in the south and the Adirondacks in the north. The flood plain is two miles wide in places and is bounded by steep slopes of up to 700 feet in height.

1.2 The Upper Hudson sub-basin begins at the Hudson River's headwaters (Lake Tear-of-the-clouds on the southwest slope of Mount Marcy, Essex Co.). The length of this segment of the river is about 160 miles. The southern boundary is the Troy Dam; the northeast, the Adirondacks; and the eastern part lies in the Berkshire Mountains of Vermont and Massachusetts. The area has a mean annual temperature of about 40^{0} F and a mean annual precipitation of 40 inches. The Upper Hudson sub-basin drains about 4,600 square miles..

The major tributaries of the Hudson River in this sub-basin are: Sacandaga River, 1,058 square miles; Hoosic River, 713 square miles; Schroon River, 568 square miles; Batten Kill, 441 square miles;

Fish Creek, 252 square miles; and the Indian River, 201 square miles. The water of the Upper Hudson River and its tributaries are generally good quality: Pollution is not a problem except the Hudson River section between Ft. Edwards and Troy, NY. Several reservoirs have been built in the sub-basin to control flooding and to keep low flows in the Hudson River as high as possible.

The major reservoirs of the Upper Hudson sub-basin are Sacandaga and Indian. The largest lakes of the area are Schroon, Saratoga, Piseco, Pleasant, and Sacandaga, but their combined surface area is only one-half of the man-made Sacandaga Reservoir.

1.3 The Lower Hudson sub-basin begins at the Troy Dam. The Hudson River in this section of the river is tidal and is considered to be estuarine: it flows almost due south to New York City for a length of about 150 miles. The area has a mean annual temperature of 48° F and a mean annual precipitation of 42 inches.

The main tributaries in this sub-basin are: Roundout Creek, draining 1200 square miles; Kenderhook Creek, 512 square miles; Catskill creek, 417 square miles; and Esopus Creek, 425 square miles. The total drainage area of the Lower Hudson sub-basin is 5,300 square miles. Eight major reservoirs are located in this sub-basin. They are: Prepacton, Cannosville, Neversink, Roundout, Croton, West Branch, Kensico, and the largest, Ashokan.

1.4 The major physiographic features of the Hudson River watershed are mountainous terrain covering about 48 percent of the basin; cultivated lands about 42 percent; lakes and water bodies about 2 percent; and urban development about 8 percent.
(Note: Section 1.0 information was obtained in part from a report on the Symposium on Hudson River Ecology by the Hudson River Valley Commission, Eisenbud and Stevens, Co-chairmen.).

2.0 The Hudson River

2.1 From its source in the Adirondack Mountains, the Hudson River flows approximately 150 miles in a generally southerly direction to its junction with its principal tributary, the Mohawk River. The Hudson then continues in a southerly direction for 155 miles to its mouth at the Battery where it empties into New York's Upper Bay.

The tidal effects in the Hudson River extend from the Battery to the Federal Lock and Dam at Troy, NY. The mean tidal range decreases from 4.4 feet at the Battery to a minimum of 3.0 feet at Beacon, 62 miles upstream of the battery, and then increases to 4.8 feet at Troy.

The Hudson River has been improved for navigation to provide depths varying from 30 to 48 feet from its mouth to Albany. North of Albany, the river to Ft. Edwards has been canalized to a depth of about 12 feet to provide barge access to Lake Champlain. The Mohawk has been canalized in areas where it serves as part of the Barge Canal system to a depth of 14 feet.

2.2 Hudson River flows exhibit a bimodal pattern with respect to time: summer discharges are low, followed by a peak discharge in November and December; a mid-winter depression is followed by a second, generally higher, peak discharge during March, April, and May, apparently responding to combined spring thaws and precipitation peaks. (Texas Instruments 1975) Approximately 60% of the total drainage basin of the Hudson River is upstream from the Federal Dam at Troy, NY. This represents 8,100 square miles with a regulated portion of about 30% or 2,450 square miles. Stream gauging records at Green Island upstream of the Troy Locks show the average annual flow to be 13,290 cubic feet per second (cfs). Additionally, 5,300 square miles are tributary to the river from Green Island to the Battery. Prorating flow on a square mile basis, the average annual discharge of fresh water at the Battery would be 21,800 cfs from the total drainage area of 13,400 square miles.

Reservoir and upstream flow regulation results in increased summer flows. The lowest 7 day average flow for a recurrence interval of 10 years is 2,900 cfs. A flow of 4,000 cfs represents the discharge

occurring for 90% of the days of the period of record. Critical conditions of extreme low flow occurred during the summer of 1965; minimum daily mean flows in the order of 1,600 cfs were recorded at the Green Island gauging station (USDHEW 1965).

The stream gradient in the Hudson River below the Troy Dam is very slight dropping only five feet. Virtually all fresh water entering the New York Harbor complex, with the exception of sewage and industrial wastes, is supplied by the Hudson.

2.3 The oscillating tidal flow of the Lower Hudson is much greater than the net freshwater flow: the usual tidal flow is from 10 to 100 times the freshwater flow. As a consequence, the net flow of the Hudson drainage is completely masked by the tidal flows superimposed on it. Heavier seawater intrudes upstream through the ocean entrance and flows beneath the lighter freshwater. Since the freshwater flows in a downstream direction, it increases the tidal ebb currents and decreases the flood currents. Also, since the freshwater is lighter and flows above the saltwater, its influence on ebb duration is greater than on flood duration and at the bottom the flood duration exceeds the ebb duration (Texas Instruments 1977). Because of the difference in density between salt and fresh water flows, the currents in the various sections vary from highly stratified (in distinct layers of fresh and salt water), to well mixed depending on the relation of the tidal flow to the fresh water flow

at a particular time. The point of the furthest intrusion of the leading edge of the saline waters is known as the salt front. The salt front is generally defined as the area where salinity is 0.10 parts per thousand (0/00). The salt front typically extends upriver as far as Newburgh, but the influence of salt water has reached as far as Poughkeepsie. Movement of the salt front is closely related to the rate of freshwater inflow into the estuary. Unusual wind and tide conditions may also produce extreme salt front movement (Dammer 1969).

The flow, then, of the Hudson River estuary can then be described as the super-position of tidal flow on the fresh water flow of the river; thus, water moves downriver in a two steps forward one step backwards manner.

2.4 The unique movement of the water within the Lower Hudson also affects the ability of the river system to transport and deposit sediments and/or nutrients. Generally, sediments are devided into three classes. First, colloidal materials in suspension; small particles that in the absence of electrolytic action such as that caused by the intrusion of salt water, would remain in suspension. Second, non-colloidal particulate matter that drops out when current velocity is not sufficient to keep it in suspension. The third class

of material is the bed load: larger particles already deposited on the bed of a stream, but moved irregularly by changes in velocity and turbulence.

Sediments and/or nutrients not carried in the above manner by the river, but that are in suspension or the bed load, are not deposited in a given location or reach, instead they are transported in a series of movements. In the upper reaches the materials settle when the transporting power of the current weakens. When the loss of transporting power is gradual, the materials are sorted by size and distributed over a considerable area. As a result of the tidal affect, the heavier particles are deposited in the upper reaches of the river. The lighter particles that are deposited during periods of slack current, are again placed in suspension and transported further downstream during successive current cycles until they are finally deposited in areas where current either as a result of the freshwater flow or tidal movement is too weak to generate further movement (HR Valley Comm.)

2.5 The estuarine environment is characterized by exceptionally high biological productivity, one that exceeds that of most modern agriculture on a per unit area basis. This high productivity results from the optimum availability of energy from the sun, water and nutrients brought together in a more or less enclosed area. The physical forces produced through tidal action and the meeting of fresh

and salt water impede net water flow from both directions and create a "nutrient trap" region where there is tremendous potential for photosynthetic production of organic matter. A substantial percentage of the nutrient energy of the system is fixed in plants and passes up the food chain through predation and prey animals.

There is increasing evidence that up to 9/10 of the biological productivity of the oceans is concentrated in shallow coastal waters, and that much of it appears dependent upon estuaries. For instance, nearly two-thirds of the commercial catch on Atlantic coastal fishing grounds is composed of extuarine-dependent species. The estuary of the Hudson, along with other estuaries, maintains the major offshore biological systems that support in large part our food resources (Boyce Thompson Institute 1974).

3.0 Species and Ecosystems

3.1 Terrestrial and aquatic information presented in this section is derived from a literature review and from correspondence with Federal, State, Private, and Local agencies.

The following describes the environment relative to species composition and their community associations.

3.2 Flora diversity reflects the local variations in soils, topography, geology, climate, and land use. The Hudson River Basin is covered by an oak-hickory-maple overstory system grading to a mixed conifer forest in the Adirondacks and portions of the Catskills. The overstory is predominantly second growth replacement of virgin forests. The original forest was composed of an oak-chestnut-hickory climax community; however, logging activities and the chestnut blight changed the basin's forests.

Plant species are listed in Table 1. Most species are native and occur in forested or aquatic communities. Vegetative communities are extremely important to the ecosystem: they are the base upon which rests the whole of the living or biotic community. Plants through photosynthesis provide the energy that is necessary to maintain life and provide for reporduction of species.
Rooted aquatic plants occuring in the Hudson River Basin are listed in Table 2. Rooted aquatic plants serve a valuable function; they provide shelter for fry and fingerling fish and habitat for aquatic invertebrates and epiphytic species of algae. The dying and eventual decay of these plants and nutrient material to the system for the microscopic feeders.

3.3 Taxa of phytoplankton collected in the Hudson River Basin are presented (Table 3). These small organisms provide the major food

Table 1. Prominent trees and shrubs located in the study area.

Common Names	Scientific Name
Alder	*Alnus* spp.
Ash, Black	*Fraxinus nigra*
, Mountain	*Pyrus americana*
, White	*Fraxinus americana*
Arborvetae	*Thuja occidentalis*
Aspen	*Populus* spp.
Basswood	*Tilia americana*
Beech	*Fagus grandifolia*
Birches	*Betula* spp.
Blueberries	*Vaccinium* spp.
Buck Thorn	*Rhamnis* spp.
Buttonbush	*Cephalanthus occidentalis*
Cherry	*Prunus* spp.
Crabapple	*Pyrus* spp.
Dogwood	*Cornus* spp.
Elm	*Ulmus* spp.
Grape	*Vitis* spp.
Hawthorns	*Crataegus* spp.
Heath	Ericaceae
Hemlock	*Tsuga canadensis*
Hickory	*Carya* spp.
Hornbeam	*Carpinus caroliniana*
Maple	*Acer* spp.
Oak	*Quercus* spp.
Pine	*Pinus* spp.
Sycamore	*Plantus occidentalis*
Sweetgum	*Liquidambar styraciflua*
Sassafras	*Sassafras abbidum*
Tamarack	*Thuja occidentalis*
White cedar	*Chamaecyparis Thyoidis*
Willow	*Salix* spp.

Table 2. Aquatic vegetation of the Hudson River Basin

Bullrush	*Scirpus* spp.
Burreed	*Sparganium* spp.
Cattail	*Typha* spp.
Chufa	*Cyperus* spp.
Cocklebur	*Xanthium* spp.
Cottongrass	*Eriophorum* spp.
Cordgrass	*Spartina* spp.
Mannagrass	*Glyceria* spp.
Millet	*Echinocholoa* spp.
Panicgrass	*Panicum* spp.
Pickerelweed	*Pontederia cordata*
Pondweed	*Potamogeton* spp.
Reedgrass	*Cinna* spp.
Rice cutgrass	*Leerisa oryzoides*
Rush	*Juncus* spp.
Smartweed	*Polygonum* spp.
Spatterdoek	*Nuphar* spp.
Spike-rush	*Eleocharis* spp..
Water-lily	*Nymphaceacae*
Water milfoil	*Brasenia schreberi*
Water chestnut	*Trapa natans*
Wild celery	*Vallisneria americana*
Wild rice	*Zizania aquatica*

Table 3. Prominent Phytoplankton in the Hudson River (1971-1974)*

TAXON

Diatoms
- *Asterionella* sp.
- *Coscinodiscus* sp.
- *Cyclotella* sp.
- *Melosira* spp.
- *Navicula* sp.
- *Skeletonema costatum*

Green Algea
- *Actinastrum* sp.
- *Ankistrodesmus*
- *Chlamydomonas* sp.
- *Coelastrum* sp.
- *Dictyosphaerium* sp.
- *Ecballocystis* sp.
- *Eudorina* sp.
- *Micractinium* sp.
- *Mougeotia* sp.
- *Pandorina* spp.
- *Pediastrum* sp.
- *Scenedesmus* sp.
- *Stichicoccus* sp.
- *Tetradesmus* sp.
- *Tetrastrum* sp.
- *Ulothrix* sp.
- *U. subtillissima*

Blue Green Algae
- *Anabeana* sp.
- *Anacystis* sp.
- *Aphanocapsa* sp.
- *Aphanizomenon flos-aquae*
- *Coelosphaerium* sp.
- *Gomphosphaeria* sp.
- *Lyngbya* sp.
- *Merisimopedia* sp.
- *Microcystis aeruginosa*
- *Oscillatoria* sp.

Other
- *Euglena* sp.

*Data from LMS Hudson River studies

source for plankton consumers such as zooplankton, benthos, and fish. Phytoplankton growth in the Hudson is light limited; potential eutrophication problems such as obnoxious algae blooms are minimal.

3.4 Taxa of zooplankton of the Hudson River are listed (Table 4). Unlike lakes where crustaceans are important, rotifers are the main zooplankton in flowing waters. Zooplankton feed on both algae and detrital particulates and, in turn, are eaten by other zooplankton as well as ichthyoplankton and planktivorous fish. Zooplankton serve as a middle link in the transfer of energy through the Hudson River food web.

3.5 Benthic invertebrates are primarily detritus feeders. Taxa of benthos are presented in Table 5. These invertebrates are important food sources of the lentic fishes and are, the most important foods of lotic fishes. The benthic organisms feed to a large extent on dead vegetative matter such as leaves and water-soaked wood.

3.6 Dominent amphibians, reptiles and mammals of the Hudson River Basin are presented (Table 6). These animals are indicative of the higher trophic levels found in the Hudson River community. Their presence or absence is relative to the existence of suitable habitat

Table 4. Prominent Zooplankton in Hudson River

Taxon

Rotifera
- *Asplanchna* sp.
- *Brachionus* sp.
- *Kellicottia* sp.
- *Keratella* sp.
- *Nothulca* sp.
- *Ploesoma* sp.
- *Polyarthra* sp.
- *Testuidinella* sp.

Cladocera
- *Baxmina* sp.
- *Daphnia* sp.
- *Leptodora* sp.
- *Noina* sp.

Copepoda
- *Acartia tonsa*
- *Capepod nauplii*
- Ectocyclops
- *Eurytemora affinis*
- Hallicyclops
- Paracyclops
- Temoridae

Others Cirripedia nauplii
- Epistylus (Protozoan)
- Gastropoda
- Polychaeta larvae

Amphipoda
- Gammarus
- Monoculoides

Diptera
- Chaoborus larvae
- Dipteran pupae

Isopoda

Caldocera
- *Daphnia* sp.
- *Leptodora kindtii*

Others
- Mysidacea
- Decapoda

*Data from Texas Instruments, Inc.

Table 5. Benthic Invertebrate Fauna of Hudson River

COELENTERATA
- Cordylophora lucustris
- Hydra sp.

PLATYHELMINTHES
- Turbellaria

NEMERTEA

ASCHELMINTHES
- Nematoda

BRYOZOAN

ANNELIDA
- Hirudinea (Leeches)
  - Erpobdella punctata
  - Helobdella elongata
  - H. stagnalis
  - Pisicola punctata
- Oligochaeta
  - Naidae
    - Nais pseudobtusa
    - Paranais frici
    - Srylaria fossularis
    - Vejdovskyella intermedia
    - V. comata
  - Tubificidae
    - Aulodrilus plusriseta
    - A. pigueti
    - A. americanus
    - Homochaeta naiclina
    - Ilodrilus templetoni
    - Limnodrilus profundicola
    - L. udekemianus
    - L. hoffmeisteri
    - Peloscolex benedeni
    - P. ferox
    - P. freyi
    - P. multisetosus
    - Potamothrix hammoniensis
    - P. vejdovskyi
  - Tubificidae (continued)
    - Rhyacodrilus coccineus
    - Tubifex tubifex
    - T. newaenis
    - T. (kessleri) americanus
- Polychaeta
  - Baccardiu bumatu
  - Hypaniolo grayi
  - Manayunkia sp.
  - Nereis succinea
  - Polydora sp.
  - Scolecolepides viridis

MOLLUSCA
- Pelecypoda
  - Congeria leucophaeta
  - Elliptio sp.
  - Macoma balthica
  - Mullinia lateralis
  - Mya areanaria
  - Pisidium sp.
  - Sphaerium sp.
- Gastropoda
  - Amnicola limosa
  - Bithinia tentaculata
  - Nassarius vibex
  - Viviparus sp.

ARTHROPODA
- Insecta
  - Diptera
    - Ceratopogonidae
      - Bezzia sp.
      - Palypomyia sp.
    - Culicidae
      - Chaoborus sp.
    - Chironomidae
      - Brillia sp.
      - Chironomus (=Tendipes) sp.
      - Coelotanypus sp.
      - cricotopus sp.
      - Cryptochironomus sp.
      - Dicrotendipus sp.
      - Eukieferiella sp.

Table 5. (continued).

Chironomidae (Continued)
- Harnischia sp.
- Orthocladius sp.
- Polypedilum sp.
- Procladius sp.
- Rheotanytarsus sp.
- Paracladopelma sp.
- Phaenosectra sp.
- Paralanterborniella sp.
- Stenochironomus sp.
- Psectrocladius sp.
- Tanytarsus (=Calospectra) sp.

Odonata

Collembola
- Istomurus palustris

Coleoptera
- Hydrophilidae

Tricoptera
- Agraylea costello
- Anthrispsodes dilutus
- Oecetis inconspicua
- O. cinerascens
- Oxyethira sp.

Arachnida
- Acarina sp.
- Unicola sp.

Crustacea

Amphipoda
- Corophium lacustre
- C. simile
- C. volutador
- Gammarus fasciatus
- G. daiberi
- G. daiberi-tigrinus (complex)
- G. tigrinus
- Hyalella sp.
- Leptochierus plumulosus
- L. pinguis
- Monoculoides edwardsi

Isopoda
- Asellus sp.
- Chiridotea almyra
- Cyathura polita
- Edotea Montosa
- Idotea sp.

Mysidacea
- Neomysis americana

Cumacea
- Alyracuma proximoculi

Decapoda
- Callinectes sapidus
- Crangon septemspinosa
- Cancer irroratus
- Neopanope (Texana) sayi
- Palaemonetes pugio
- Penaeus (Melicertus) aztecus azecus
- Penaeus (Litopenaeus) setiferus
- Orconectes limnosus
- Rhithropanopeus harrisii
- Uca minax

Copepoda
- Harpactocoida

*Data from Texas Instruments, Inc.

Table 6. Key to abundance, status, and preferred habitat of amphibians, reptiles, and mammals.

Status (A)

1) Common
2) Uncommon
3) Rare
4) Accidental
5) Undetermined

Preferred Habitat (H)

a Aquatic
o Open Land
f Forested

Table 6. (continued).

List of Amphibians

	A	H
Class - Amphibia		
Order - Caudala		
Family - Proteidae - mud puppies		
Mud puppy - *Necturus maculosus*	3	a
Family - Salamandridae - newts		
Newt - *Notophthalmus viridescens*	1	fa
Family - Ambystomidae - salamanders		
Jefferson salamander - *Ambystoma jeffersonianum*	1	fa
Blue spotted salamander - *Ambystoma laterale*	5	fa
Spotted salamander - *Ambystoma maculatum*	1	fa
Family - Plethodontidae - Lungless salamanders		
Four-toed salamander - *Hemidactylium scutatuna*	3	f
Red-backed salamander - *Plethodon cinereus*	1	f
Slimy salamander - *Plethodon glutinosus*	2	f
Spring salamander - *Gyrinophilus porphyriticus*	2	fa
Red salamander - *Pseudotriton ruber*	3	a
Two-lined salamander - *Eurycea bislineata*	1	fa
Long-tailed salamander - *Euycea longicauda*	3	fa
Dusky salamander - *Desmognathus fuscus*	1	a
Mountain salamander - *Desmognathus ochrophaeus*	1	f
Order - Salientia		
Family - Scaphiopodiadae - Spade foots		
Eastern Spadefoot toad - *Scophiopus halbrooki*	3	f
Family - Bufonidae - toads		
Fowler's toad - *Bufo woodhousii*	2	fo
American toad - *Bufo americanus*	1	fo

Table 6. (continued).

	A	H
Family - Hylidae - Tree Frog		
Cricket frog - *Acris gryllus*	3	f
Spring pepper - *Hyla crucifer*	1	f
Free frog - *Hyla versicolor*	1	f
Family - Ranidae - True Frogs		
Bull frog - *Rana catesbeiana*	1	a
Green frog - *Rana clamitans*	1	a
Wood frog - *Rana sylvatica*	1	fa
Leopard frog - *Rana pipens*	1	a
Pickeral frog - *Rana palustris*	1	a

Table 6. (continued).

List of Reptiles

	A	H
Class - Reptilia		
Order - Chelonia		
Family - Chelydridae - Snapping turtles		
Common snapping turtle - *Chelydra serpentina*	1	a
Family - Kinosternidae - Musk and Mud turtles		
Stink pot - *Sternotherus odoratus*	1	a
Family - Emydidae - Fresh water and Marsh turtles		
Spotted turtle - *Clemmys guttata*	2	o
Wood turtle - *Clemmys insculpta*	1	ao
Bog Turtle - *Clemmys muhlenbergi*	3	a
Painted turtle - *Chrysemys picta*	1	a
Box turtle - *Terrapene carolina*	2	fo
Order - Squamata		
Family - Scincidae - Skinks		
Five lined skink - *Eumesces fasccatus*	2	f
Family - Colubridae - Common harmless snakes		
Common water snake - *Natrix sipedon*	1	a
Brown snake - *Storeria deKayi*	1	fo
Red-bellied snake - *Storeria occipitomaculata*	1	fa
Ribbon snake - *Thamnophis sauritus*	2	fa
Common garter snake - *Thamnophis sirtalis*	1	fo
Eastern hog-nosed snake - *Heterodon platyrhinos*	1	f
Eastern ring-necked snake - *Diadophis panctatus*	1	fo
Eastern worm snake - *Carphophis amoenus*	2	f
Racer - *Coluber constrictor*	1	fo
Smooth green snake - *Opheodrys vernalis*	2	fo
Rat snake - *Elaphe obsoleta*	2	fo
Milk snake - *Lampropeltis doliata*	1	fo

Table 6. (continued).

	A	H
Family - Crotalidae - Pit vipers		
Copperhead - *Ancistrodon contortrix*	1	f
Timber rattlesnake - *Crotalus horridus*	2	f

Table 6. (continued).

List of Mammals	A	H
Class - Mammalia		
Order - Marsupiala		
Family - Didelphidae - Oppossums		
American opposum - *Didelphis marsupialis*	1	fo
Order - Insectivora		
Family - Soricidae - Shrews		
Masked shrew - *Sorex cinereus*	1	fo
Long-tailed shrew - *Sorex dispar*	3	f
Water shrew - *Sorex palustris*	3	fa
Smokey shrew - *Sorex fumeus*	1	f
Pigmy shrew - *Micro sorex hogi*	3	fa
Big short-tailed shrew - *Blarina brevicauda*	1	fo
Family - Talpidae - Moles		
Hairy-tailed mole - *Parascalops breweri*	1	fo
Eastern American mole - *Scalopus aquaticus*	2	o
Star-nosed mole - *Condylura cristata*	1	ao
Order - Chiroptera		
Family - Vespertilionidae - Vespertilionid bats		
Little brown bat - *Myotis lucifugus*	1	fo
Least myotis - *Myotis subulatus*	5	
Indiana myotis - *Myotis sodalis*	3	o
Keen's myotis - *Myotis keenii*	5	f
Eastern Pipistrelle - *Pipistrellus subflarus*	2	f
Big brown bat - *Eptesicus fuscus*	1	fo
Hoary bat - *Lasiurus cinereus*	3	f
Red bat - *Lasiurus borealis*	2	f
Silver-haired bat - *Lasionycteris noctivagans*	5	f

Table 6. (continued).

	A	H
Order - Carnivora		
Family - Ursidae - Bears		
Black bear - *Ursus americanus*	2	f
Family - Procyonidae - Raccoons		
Raccoon - *Procyon lotor*	1	f
Family - Mustelidae - Weasels, Ferrets, Mink		
Short-tailed weasel - *Mustela erminea*	1	fo
Long-tailed weasel - *Mustela frenata*	1	fo
Mink - *Mustela vison*	2	fa
Otter - *Lutra canadensis*	2	a
Striped skunk - *Mephitis mephitis*	1	fo
Family - Canidae - Foxes and Coyotes		
Red fox - *Vulpes fulva*	1	fo
Gray fox - *Urocyon cinereoargenteus*	1	fo
Coyote - *Canis latraus*	2	fo
Family - Felidae - Cats		
Bobcat - *Lynx rufus*	2	f
Order - Rodentia		
Family - Sciuridae - Squirrels and Chipmunks		
Wood chuck - *Marmota monax*	1	0
Eastern chipmunk - *Tamias striatus*	1	fo
Red squirrel - *Tamisciurus hudsonicus*	1	f
Eastern gray squirrel - *Sciurus carolinensis*	1	f
Southern flying squirrel - *Glaucomys volans*	1	f
Northern flying squirrel - *Glaucomys sbrinus*	1	f
Family - Castoridae - Beavers		
Beaver - *Castor canadensis*	1	a

Table 6. (continued)

	A	H
Family - Cricetidae - New world Rats, Mice, Voles, Lemmings		
Deer mouse - *Peromyscus maniculatus*	1	f
White-footed mouse - *Peromyscus leucopus*	1	f
Wood rat - *Neotoma floridana*	3	f
Wouthern bog lemming - *Synaptomys cooperi*	5	ao
Red-backed mouse - *Clethrionomys gapperi*	1	f
Meadow vole - *Microtus pennsylvanicus*	1	o
Rock vole - *Microtus chrotorrhinus*	3	o
Pine vole - *Microtus pinetorm*	2	fo
Muskrat - *Ondatra zibethicus*	1	a
Norway rat - *Rattus norvegicus*	1	o
House mouse - *Mus musculus*	1	o
Family - Zapodidae - Birch mice and Jumping mice		
Meadow jumping mouse - *Zapus hudsonius*	1	o
Woodland jumping mouse - *Napaeozapus insignis*	1	f
Family - Erethizontidae - Porcupines		
Common porcupine - *Erethizon dorsatum*	1	f
Order - Lagomorpha		
Family - Leporidae - Hares and Rabbits		
Varying hare - *Lepus americanus*	1	f
Eastern cottontail - *Sylvilagus floridanus*	1	o
New England cottontail - *Sylvilagus transitionalis*	2	f
Order - Artiodactyla		
Family - Cervidae - Deer		
White-tailed deer - *Odocoileus virginianus*	1	fo

and the abundance of their prey species. Behavior as well as food and habitat limit the number of any one species within a given area, i.e., reduction of food and/or habitat results in immediate displacement of the individual(s) and eventual reduction of that species population.

3.7 Birds known to occur in the habitats of the Hudson River Basin are listed (Table 7). Bird species much the same as plants and other animals inhabit areas where there is food and habitat suitable to their life needs. And like all other plants and animals will be found in greater than normal concentrations in preferred areas.

Some birds use the area during migration to summer nesting grounds and return movements to wintering areas in the south. Others winter in the project area after nesting in more northern areas. Many species use the area for nesting only while others are yearlong residents.

Table 7. Bird species found in the Hudson River Basin at some time in their life history

KEY STATUS (S)

TV - Transiet visitor
WV - Winter visitor
SR - Summer resident
RES - Resident
* - Breeds

ABUNDANCE (A)

AB - Abundant
C - Common
FC - Fairly Common
UNC - Uncommon
OC - Occasional occurence

PREFERRED HABITAT (H)

A - Aquatic
O - Open Land
F - Forested

Table 7. (continued)

SPECIES	S	A	H
Horned grebe	TV	OC	A
Pied-billed grebe	TV	AB	A
Common loon	TV	AB	A
Herring gull	TV	UNC	A
Bonapart's gull	TV	UNC	A
American Merganser	WV	AB	A
Red-breasted Merganser	TV	FC	A
Hooded Merganser	TV	FC	A
Mallard	*	AB	A
Black duck	*	AB	A
Baldpate	TV	FC	A
Green-winged teal	TV	AB	A
Blue-winged teal	TV, SR*	AB	A
Pintail	TV	UNC	A
Redhead	TV	UNC	A
Wood duck	SR*	AB	A
Greater scaup	TV	FC	A
Lesser scaup	TV	C	A
Smerican Goldeneye	TV	UNC	A
Bufflehead	TV	UNC	A
Oldsquaw	TV	UNC	A
American Scoter	TV	UNC	A
Ruddy duck	TV	OC	A
Canada Goose	TV, SR*	AB	A

Table 7. (continued)

SPECIES	S	A	H
American Bittern	SR *	FC	A
Great Blue Heron	SR *	C	A
Green Heron	SR *	AB	A
Virginia Fail	SR *	FC	A
Sora rail	SR *	FC	A
Florida Gallinule	SR *	UNC	A
American coot	TV	FC	A
American woodcock	SR *	C	O
Wilson's snipe	TV, SR	FC	AO
Greater yellowlegs	TV	UNC	A
Lesser yellowlegs	TV	FC	A
Solitary sandpiper	TV	C	A
Spotted sandpiper	SR *	C	A
Killdeer	SR *	C	O
Ruffed grouse	RES	AB	O
Mourning dove	SR *	FC	O
Turkey vulture	TV	UNC	FO
Marsh hawk	SR *	FC	A
Sharp-shinned hawk	SR *	C	F
Coopers hawk	SR *	C	F
American goshawk	RES *	UNC	F
Red-tailed hawk	RES *	C	FO
Red-shouldered hawk	RES *	C	F
Brood-winged hawk	SR *	C	FO

Table 7. (continued)

	S	A	H
American rough-legged hawk	TV	UNC	O
Golden eagle	TV	UNC	FO
Bald eagle	WV	UNC	A
Peregrine	TV	OC	FA
Pigeon hawk	TV	OC	FA
Sparrow hawk	RES *	AB	FO
American osprey	TV	UNC	A
Barred owl	RES *	C	F
Screech owl	RES *	C	F
Great horned owl	RES *	C	F
Snowy owl	WV	OC	O
Yellow-billed cuckoo	SR *	FC	FO
Black-billed cuckoo	SR *	FC	FO
Belted kingfisher	SR *	C	A
Hairy woodpecker	RES *	C	F
Bowny woodpecker	RES *	C	F
Arctic three-toed woodpecker	WV	OC	F
Yellow-bellied sapsucker	SR *	FC	F
Pileated woodpecker	RES *	FC	F
Red-headed woodpecker	SR *	FC	F
Northern flicker	SR *	C	FO
Whip-poor-will	SR *	OC	FO
Night hawk	SR *	FC	FO
Chimney swift	SR *	C	FO
Ruby-throated hummingbird	SR *	C	FO

Table 7. (continued)

SPECIES	S	A	H
Kingbird	SR *	C	O
Crested flycatcher	SR *	C	F
Phoebe	SR *	C	F
Olive sided flycatcher	SR *	FC	F
Wood pewee	SR *	C	F
Yellow-bellied flycatcher	SR *	C	F
Arcadian flycatcher	SR	FC	F
Alder flycatcher	SR *	C	F
Least flycatcher	SR *	C	F
Blue jay	RES *	C	FO
American crow	RES *	AB	FO
Starling	RES *	AB	O
Bobolink	SR *	C	O
Cowbird	SR *	C	FO
Redwing	SR *	AB	A
Meadowlark	SR *	AB	O
Orchard oriole	SR *	UNC	O
Baltimore Oriole	SR *	C	O
Rusty Blackbird	TV	UNC	A
Bronzed grackle	SR *	AB	O
Pine Grosbeak	WV	C	FO
House sparrow	RES *	AB	O
Purple finch	SR *	FC	FO

Table 7. (continued)

SPECIES	S	A	H
American crossbill	WV	FC	F
White-winged crossbill	WV	FC	F
American goldfinch	RES *	C	O
Pine siskin	WV	C	O
Snow bunting	WV	C	O
Vesper sparrow	SR *	C	O
Savannah sparrow	SR *	C	O
Grasshopper sparrow	SR *	C	O
White-crowned sparrow	TV	C	O
White-throated sparrow	TV	C	F
Tree sparrow	WV	C	O
Chipping sparrow	SR *	AB	O
Field sparrow	SR *	AB	O
Slate colored junco	WV	AB	O
Song sparrow	SR *	AB	O
Swamp sparrow	SR *	C	O
Fox sparrow	TV	AB	O
Towhee	SR *	AB	FO
Rose breasted grosbeak	SR *	AB	FO
Indigo bunting	SR *	AB	FO
Scarlet tanager	SR *	FC	F
Purple martin	SR *	FC	O
Cliff swallow	SR *	FC	AO

Table 7. (continued)

SPECIES	S	A	H
Barn swallow	SR *	C	O
Tree swallow	SR *	C	O
Bank swallow	SR *	C	O
Cedar waswing	WV	C	O
Northern shrike	TV	OC	O
Loggerhead shrike	SR *	OC	O
Red-eyed vireo	SR *	C	FO
Warbling vireo	SR *	FC	F
Yellow-throated vireo	SR *	AB	FO
Solitary vireo	SR *	AB	F
Blue-winged warbler	SR *	C	O
Golden-winged warbler	SR *	UNC	O
Nashville warbler	SR *	AB	FO
Perula warbler	TV	FC	FO
Yellow warbler	SR *	C	O
Black-throated blue warbler	SR *	C	FO
Myrtle warbler	TV	C	F
Magnolia warbler	SR *	C	F
Chestnut-sided warbler	SR *	AB	O
Bay-breated warbler	TV	AB	F
Black-poll warbler	SR *	AB	F
Black-burnion warbler	SR *	AB	F

Table 7. (continued)

SPECIES	S	A	H
Black-throated green warbler	SR *	AB	FO
Pine warbler	TV	UNC	F
Yellow palm warbler	TV	C	O
Ovenbird	SR *	AB	F
Northern waterthrush	SR *	AB	FA
Louisiana waterthrush	SR *	AB	FA
Mourning warbler	SR *	C	F
Northern yellow throat	SR *	AB	O
Yellow-breasted chat	SR *	UNC	O
Wilson's warbler	TV	C	O
Canada warbler	SR *	AB	F
American redstart	SR *	AB	F
American pipit	WV	UNC	O
Mockingbird	RES *	UNC	O
Catbird	SR *	A	O
Brown thrasher	SR *	A	O
House wren	SR *	FC	O
Long-billed marsh wren	SR *	C	AO
Brown creeper	RES *	AB	F
White-breasted nuthatch	RES *	AB	FO
Red-breasted nuthatch	RES *	AB	FO
Black-capped chickodee	RES *	AB	FO
Tufted titmouse	RES *	UNC	F

Table 7. (continued)

SPECIES	S	A	H
Winter wren	TV	AB	FO
Hudsonian chickodee	WV	UNC	FO
Golden-crowned kinglet	TV	C	F
Ruby-crowned kinglet	TV	C	F
Woodthrush	SR *	AB	F
Gray-cheeked thrush	TV	C	F
Bicknell's thrush	SR *	C	F
Olive-backed thrush	SR *	C	F
Hermit thrush	SR *	C	F
American robin	SR *	AB	O
Bluebird	SR *	UNC	O

3.8 Fishes of the Hudson Basin are listed (Table 8). Fish populations within the Hudson River Basin have been studied more intensively than any other group of organisms. Different cold and warm water species live in sections of the Basin's waters that will sustain their particular life's requirements. The presence of a particular species is determined by both man-made and natural factors. Many of the man-caused factors have been deleterious to almost all species present in the system. Pollution, domestic sewage and industrial wastes as well as migration blocks have been detrimental, because among others they affect the temperature, turbidity, pH, dissolved oxygen and bottom conditions. An example of the interactions of these factors with species composition is as the temperature and turbidity of an area increase the dissolved oxygen decreases and the species composition may change from cold water species to warm water species.

Commercial species are present in the lower Hudson and recreational species are present in both the upper and lower Hudson. The greatest concern has been expressed for populations of anadromous species such as striped bass and American shad because of their valuable commercial and recreational importance.

4.0 Wetlands

4.1 Wetlands are now recognized by Federal and state governments as critical habitat(s) for the maintenance of species and species diversity. In the project area-the Hudson River Basin-and

Table 8. Fishes of the Hudson River Basin

FAMILY	SCIENTIFIC NAME	COMMON NAME
Petromyzontidee	Petromyzon marinus	Sea lamprey
	Lampetra lamottei	American brook lamprey
Rajidae	Raja laevis	Barndoor skate
Acipenseridae	Acipenser brevirostrum	Shortnose sturgeon
	Acipenser oxyrhynchus	Atlantic sturgeon
Anguillidae	Anguilla restrata	American eel
Clupeidae	Alosa aestivalis	Blueback herring
	Alosa pseudoharengus	Alewife
	Alosa mediocris	Hickory shad
	Alosa sapidissima	American shad
	Brevooitia tyrannus	Atlantic menhaden
	Clupea harengus	Atlantic herring
	Dorosoma cepedianum	Gizzard shad
	Etrumeus teres	Round herring
Engraulidae	Anchoa mitchilli	Bay anchovy
	Anehoa hepsetus	Striped anchovy
Salmonidae	Salmo trutta	Brown trout
	Salvelinus fontinalis	Brook trout
	Salmo gandneri	Rainbow trout
Osmeridae	Osmerus mordax	Rainbow smelt
Esocidae	Esox americanus	Redfin pickerel
	Esox lucius	Northern pike
	Esox vermiculatus	Gross pickerel
	Esox niger	Chain pickerel
Synodontidae	Synodus foetens	Inshore lizardfish
Cyprinidae	Carassius auratus	Goldfish
	Cyprinus carpio	Carp
	Exoglossum maxilhngua	Cutlips minnow
	Hybognathus nuchalis	Silvery minnow
	Notemigonus crysoleucas	Golden shinner
	Notropis amoenus	Comely shinner
	Notropis analostanus	Satinfin shinner
	Notropis atherinoides	Emerald shinner
	Notropis bifrenatus	Bridle shinner
	Notropis cornutus	Common shinner

Table 8. (continued)

FAMILY	SCIENTIFIC NAME	COMMON NAME
	Notropis hudsonius	Spottail shinner
	Notropis rubellus	Rosyface shinner
	Notropis spilapterous	Spotfin shinner
	Notropis volucellus	Mimic shinner
	Pinephales promelas	Fathead minnow
	Pimphales notatus	Bluntnose minnow
	Rhinichthys atratulus	Blacknose dace
	Rhinichthys cataractae	Longnose dace
	Semotilus atromaculatus	Creek chub
	Semotilus corporalis	Fallfish
Catostomidal	Catostomus commersoni	White sucker
	Erimyzon oblongus	Creek chubsucker
	Hypentelium nigricans	Northern hogsucker
Ictaluridae	Ictalurus catus	White catfish
	Ictalurus natalis	Yellow bullhead
	Ictalurus nebulosus	Brown bullhead
	Ictalurus melas	Black bullhead
Percopsidae	Percopsis omescomaycus	Trout-perch
Godidae	Enchelyopus cimbrius	Fourbeard rockling
	Merluccius bilinearis	Silver hake
	Micogadus tomcod	Atlantic tomcod
	Pollachius virens	Pollock
	Urophycis chuss	Rad hake
	Urophycis regius	Spotted hake
Belonidae	Stongybura marina	Atlantic needlefish
Cyrinodontidae	Fandulus diaphanus	Banded killifish
	Fundulus heteroditus	Mummichog
	Fundulus luciae	Spotfin killifish
	Fundulus majalis	Striped killifish
Atherinidae	Membras martinica	Rough silverside
	Merridia beryllina	Tidewater silverside
	Menidia menidia	Atlantic silverside
Goster osteidae	Apeltis guadracus	Fourspine stickleback
	Culaea inconstaus	Brook sticklebrook
	Gasterosteus aculeatus	Threespine stickleback

Table 8. (continued)

FAMILY	SCIENTIFIC NAME	COMMON NAME
Syngnathidae	Hippocampus erectus	Lined seahorse
	Syngnathus fuscus	Northern pipefish
Percichthidae	Morone americana	White perch
	Morone chrysops	White bass
	Morone saxatilis	Striped bass
Centrachidae	Ambloplites rupestris	Rock bass
	Enneacanthus gloriosus	Blue spotted sunfish
	Lepomis auritus	Redbreast sunfish
	Lepomis cyanellus	Green sunfish
	Lepomis gibbosus	Pumpkinseed
	Lepmis macrochirus	Bluegill
	Micropterus dolomieui	Smallmouth bass
	Micropterus salmoides	Largemouth bass
	Pomoxis annularis	White crappie
	Pomoxis nigromaculatus	Black crappie
Percidae	Etheostoma nigrum	Johny darter
	Etheostoma olmstedi	Tessellated darter
	Perca flavescens	Yellow perch
	Percina caprodes	Logperch
	Percina peltata	Shield darter
	Stizostedion ritrum	Walleye
Pomatomidae	Pomatomus saltatrix	Bluefish
Carangidae	Caranx hippos	Crevalle jack
	Selene vomer	Lookdown
	Vomer setapinnis	Atlantic moonfish
Sparidae	Lagodon rhomboides	Pinfish
	Stenotomus chrysops	Scup
Sciaenidae	Bairdiella chrysura	Silver perch
	Cynoscion regalis	Weakfish
	Leiostomus xanthurus	Spot
	Menticirrhus saxatilis	Northern kingfish
	Micropogon undulatus	Atlantic croaker
Labridae	Taxtoga onitis	Tautog
Mugilidae	Mugil cephalus	Striped mullet
	Mugil curema	White mullet

Table 8. (continued)

FAMILY	SCIENTIFIC NAME	COMMON NAME
Uranoscopidae	*Astroscopus guttatus*	Northern stargazer
Ammodytidae	*Ammodytis americanus*	American sandlance
Eleotridae	*Dormitator maculatus*	Fat sleeper
Gobiidae	*Gobiosoma ginsburgi*	Seaboard Goby
Stromateidae	*Peprilus tricanthus*	Butterfish
Triglidae	*Prionotus carolinus*	Northern searobin
	Prionotus evolans	Striped searobin
Cottidae	*Myoxocephalus oeneus*	Grubby
Bothidae	*Paralichthys dentatus*	Summer flounder
	Paralichthys oblongus	Fourspot flounder
	Scopthalmus aguosus	Windowpane
Pleuronectidae	*Pseudopleuronectes americanus*	Winter flounder
Soleidae	*Trinectes maculatus*	Hogchoker
Tetraodontidae	*Sphaeroides maculatus*	Norther puffer

specifically along the Hudson River, especially the estuarine portion, there are numerous areas classified as wetlands. Some of these areas are being proposed as critical and/or unique habitats. Briefly, all wetlands are considered sensitive because of the dependence upon these areas by flora and fauna species, some of which are totally dependent on wetlands for their existence. Any extensive changes in the wetland areas may result in eventual changes in the biotic community and possible loss of some species. Note: New York's wetlands are presently being identified and classified by the State of New York.

5.0 Endangered, Threatened, And Status-Undetermined Species

5.1 The project area has within its boundaries floral and faunal species that are listed by Federal and/or state agencies as endangered, threatened, and status-undetermined. Species that are classified into any of the above categories are listed (Table 9). Additionally, New York State has a list of "Vulnerable" plants of New York that will be expanded and separated into five categories of endangered plants (Append. A).

6.0 Valuation Of The Hudson River Fishery Resources

6.1 Commercial fisheries were established in the Hudson River in the early 1800's: the principal finfish species taken were American shad, American eel, Atlantic tomcod, Atlantic sturgeon,

Table 9. Endangered, threatened, and status-undetermined species in the state of New York

FLORAL SPECIES	STATUS*
Scirpus ancestrochaetus	E
Schizaea pusilla	T
Panicum aculeatum	T
Cypripendium arietinum	T
Platanthera leucophaea	T
Platanthera peramoena	T
Isotria medeoloides	E

FAUNAL SPECIES	
Clemmys muhlenbergi	T
Emyoidae blandingi	T
Acipenser brevirostrum	E
Notropis ameonus	T
Haliaeetus leucocephalis	E
Falco peregrinus anatum	E
Falco c. columbarius	T
Pandion haliaeetus corolinensis	T
Pinicola enucleator eschatosus	T
Myotis sodalis	E
Felix concolor cougari	E
Martes pennanti	S-U

*E = Endangered
T = Threatened
S-U = Status-Undetermined

Shortnose sturgeon, Stirped bass, Alewife, Blueback herring, White perch, and Rainbow smelt. Shellfish were also important commercially. Three species of shellfish, the oyster, hardshell clam, and softshell clam were taken in large quanticies. The following summary of the Commercial Hudson River Fishery from 1913 to 1964 by Sheppard (1976) is indicative of the importance of the resources.

> The Hudson River commercial finfish fishery has produced rather limited catches except for American shad. For the period from 1913 to 1964, the total New York catch averaged 847,176 pounds (range: 146, /98-2, 880 lbs.) with an associated landed value of approximately $94,600 (range: $16,441-$261,283). When the New Jersey American shad catches are included, the total catches averaged 1,490,228 pounds with an approximate value of $142,000. Of these catches, the American shad fishery composed 86% of the catch and 88% of the economic value. The remaining 7 species comprise 14% of the catch and 12% of the value. With respect to shellfish, the statewide oyster harvest had averaged approximately 14,760,000 pounds (value: $2,239,285) between 1880 and 1921; however, the average statewide harvest between 1926 and 1963 (weight: 5,447,061 lbs.; value: $2,239,453) was approximately 9.3 million pounds lower than the 1880-1921 average harvest. This decline is due in part to the closure of the Hudson River section of the oyster fishery since 1925. No catch statistics were compiled for the two species of clams.

Sheppard (1976) also summarized the 1965-74 commercial fisheries. Six additional species contributed to the value of the fisheries: White catfish, Carp, Suckers, Bullheads, Yellow perch, and Sunfish. The summary is presented below.

> The total average catch for the New York sector of the Hudson River was approximately 170,300 pounds and the average value was $32,700 during the period

> 1965-74. When the New Jersey sector of the American shad fishery was included, the total average catch was 282,827 pounds and the average tota value was $53,118. This indicates a substantial reduction has occurred in the catches for this period as when compared to the previous period (1913-1964) which had a total average catch of 1,490,228 pounds (value: $142,000).

A bait fishery is also reported to exist but its economic value and importance have not been studied. Information on the shellfish fishery is lacking for this period (1965-74). However, because of the continuing pollution problems no commercial fishery presently exists.

Explanations for the decline of the fisheries include overfishing, destruction of estuarine wetlands, and degradation of water quality because of pollution.

6.2 The recovery of the Hudson River from its present pollution problem and the ability to manage the river based on a comprehensive plan is necessary to avoid increased losses of the resources. The present and potential value of the Hudson's fishery resource is described by Sheppard (1976) in the following paragraphs.

> The Hudson River is estimated to currently be making a multi-million dollar contribution to a variety of commercial and recreational fisheries, both marine and freshwater. Within the river, it is estimated that the river is currently generating at least $150,000-$200,000 from the commercial sector and approximately $1.65 million from the recreational sector annually. The contribution to the marine fisheries, commercial

and recreational, is estimated to exceed $20 million at the present time.

The potential fisheries which could be realized within the Hudson are considerably larger than the present fisheries. From a commercial fisheries standpoint, the reestablishment of oyster and clam fisheries to the Lower Hudson River could provide multi-million dollar revenues. A reestablishment of the fishery resources in the Upper Hudson River (Glens Falls to Federal Dam, Troy) and an improvement of fishery resources below Troy Dam could provide hundreds of thousands of additional angler-days to the recreational fishery. In addition, the development of new recreational fisheries, such as the one for blue-claw crab, also offers additional recreational fishing opportunities. The full potential for the marine fisheries still remains to be assessed.

7.0 Resource Study Requirements

7.1 Additional data on the Hudson River Basin's resources will be requiste for further input on the proposed project. These data will be especially necessary if the project proceeds in the Corps Post-Authorization (AED) studies. Principally, these environmental study requirements center on the aquatic community, but, also, there exists a need to obtain more data on the terrestrial community. The following topics will have to be assessed prior to operation of the intake structure and treatment plant:

1. Zone of withdrawal of the intake facility
2. Zone of influence of the intake facility

3. Concentrations of organisms in the intake water as determined by actual field research. This infers a sound statistical design and sampling scheme.
4. Effect of nutrient withdrawl on the estuarine dynamics
5. "Sludge" monitoring for toxic chamicals as well as the identification of ludge disposal sites.
6. A monitoring program at the intake screens for entrainment and impingement of aquatic organisms.
7. Specific descriptions of the reservoir manipulations that will be required to ooperate the pumping station under "normal flow conditions" and "drought flow conditions" such as existed in the mid 1960's.
8. Future demands upon the pumping station (that would be required to meet New York City needs) for water from the Hudson River as this relates to increased reservoir makeup water for the Hudson River, e.g., construction of additional reservoirs, increasing capacity of existing reservoirs, or diverting water from other Basins.
9. Potential effects of the intake on the Shortnose sturgeon.

Study cost for a project of this magnitude are generally estimated as 10% of the total project budget.

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APPENDIX A. Vulnerable plants of New York

The following list of "Vulnerable" plants of New York will ultimately be expanded and broken into five categories of endangered plants. The habitat of each plant and its range will be described.

Species listed here are those that are "Vulnerable" by being susceptible to devastation for their commercial, medicinal, horticultural, or decorative purposes, and, therefore, should be protected. The list includes plants that are "Endangered", "Threatened" and "Scarce" as well as "Vulnerable".

These plants are protected under Environmental Conservation Law, and anyone who "knowingly picks, plucks, severs, removes or carries away without the consent of the owner thereof, any protected plant" will be subject to a fine.

Some of these species are very common in certain locations, but rare in other areas. This list may be modified or amended by the Commissioner of Environmental Conservation.

Appendix A. (continued)

VULNERABLE PLANTS OF NEW YORK

Section 193.3 Protected native plants. (Statutory authority: Environmental Conservation Law § 9-1503) The following are native plants which shall be protected pursuant to Section 9-1503 of the Environmental Conservation Law; such list shall apply statewide:

[Note: In the list below, common names are not included if they repeat the generic common name with a modifier (e.g., "Trillium" is understood to include "Painted Trillium", "White Trillium", "Nodding Trillium" and all others.) Names appearing within parentheses are less familiar synonyms for the principal common names of each species listed]

Scientific Name	Common Name
Arisaema dracontium	Green-dragon (Dragonroot)
Asclepias tuberosa	Butterfly-weed (Chigger-flower; Orange Milkweed; Pleurisy-root)
Campanula rotundifolia	Bluebell-of-Scotland (Harebell)
Celastrus scandens	American Bittersweet (Waxwork)
Chimaphila spp.	Pipsissewa (Prince's-pine; Wax-flower) Spotted Evergreen (Spotted Wintergreen)
Cornus florida	Flowering Dogwood
Drosera spp.	Sundew (Daily-dew; Dewthread)
Epigaea repens	Trailing Arbutus (Ground Laurel; Mayflower)
Euonymus spp. (Native)	Burning-bush (Wahoo) Strawberry-bush (Bursting-heart)
Filices (Filicinae; Ophioglossales and Filicales) (Native)	All ferns, including: Adder's-tongue Azolla Buckhorn Cliff Brake Curly-grass Fiddleheads Hart's-tongue Maidenhair Moonwort Polypody Rock Brake
Filices (Filicinae, Ophioglossales and Filicales) (Native) continued...	Salvinia Spleenwort Walking-leaf Wall-rue Water-spangle Woodsia But excluding Bracken (Pteridium aquilinum); Hay-scented Fern (Dennstaedtia punctilobula); Sensitive Fern (Onoclea sensibilis)

Appendix A. (continued)

VULNERABLE PLANTS OF NEW YORK CONT'D.

Opuntia humifusa (O. compressa, p.p.)	Prickly Pear (Wild Cactus; Indian Fig)
Orchidaceae	All Native Orchids, including Adder's-mouth (Malaxis) Arethusa (Dragon's-mouth) Bog-candle Calopogon (Grass-pink; Swamp-pink) Calypso (Fairy-slipper) Coral root Cypripedium (Lady's-slipper) Goodyera (Lattice-leaf, Rattlesnake-plantain) Kirtle-pink Ladies'-tresses (Pearl-twist, Screw-auger) Moccasin-flower (Nerve-root) Orange-plume Orchis Pogonia (Beard-flower; Snake-mouth) Putty-root (Adam-and-Eve) Scent-bottle Soldier's-plume Three-birds Twayblade Whipporwill-shoe
Orontium aquaticum	Golden-club
Panax quinquefolius	Ginseng (Sang)
Pyrus coronaria	Wild Crab Apple
Rhododendron spp. (Native)	Azalea Great Laurel (White Laurel) Honeysuckle Pinxter (Election-pink; Pinxter-bloom) Rhododendron (Rosebay) Rhodora
Sabatia spp.	Bitterbloom (Marsh-pink; Rose-pink; Sabatia; Sea-pink)
Sanguinaria	Bloodroot (Puccoon-root; Red Puccoon)
Sarracenia purpurea	Pitcher-plant (Huntsman's-cup; Sidesaddle-flower)
Silene caroliniana	Wild Pink
Trillium spp.	Bethroot (Birthroot; Squawroot; Stinking Benjamin; Wake-robin) Toadshade Trillium
Trollius laxus	Globe-flower (Trollius)
Viola pedata	Bird's-foot Violet

Appendix A. (continued)

VULNERABLE PLANTS OF NEW YORK CONT'D.

Gentiana spp.	Ague-weed Blue-bottles Gentian (Gall-of-the-earth)
Hydrastis canadensis	Golden-Seal (Orange-root; Yellow Puccoon)
Ilex spp. (Native)	Holly (Hulver) Inkberry (Bitter Gallberry) Winterberry (Black Alder)
Kalmia spp.	Laurel Spoonwood (Calico-bush) Wicky (Lambkill)
Lilium spp. (Native)	Lily Turk's-cap
Lobelia cardinalis	Cardinal-flower (Red Lobelia)
Lycopodium spp.	All Clubmosses, including: Bear's-bed (Christmas-green, Running Evergreen; Trailing Evergreen; Ground Pine) Bunch Evergreen Festoon Pine (Coral Evergreen; Buckhorn; Staghorn Evergreen; Wolf's-claws) Ground Cedar (Creeping Jenny) Ground Fir Heath Cypress
Mertensia virginica	Bluebell (Roanoke-bells; Tree Lungwort; Virginia Bluebell; Virginia Lungwort; Virginia Cow-slip)
Monarda didyma	American Bee-balm Oswego Tea (Indian-heads; Scarlet Bee-balm)
Myrica pensilvanica	Bayberry (Candleberry)
Nelumbo lutea	Lotus (Lotus Lily; Nelumbo; Pond-nuts; Water Chinquapin; Wonkapin; Yellow Lotus)