WATER RESOURCE DEVELOPMENT PLAN

NORTH NASHUA RIVER BASIN

REPORT

MERRIMACK RIVER, MASSACHUSETTS

U.S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS WALTHAM, MASS.

25 JANUARY 1965

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SYLLABUS

The Division Engineer finds that there is an immediate and urgent need for development of the water resources of the North Nashua River Basin to provide flood protection, municipal and industrial water supply, and recreation opportunities. The North Nashua River watershed area represents approximately 132 square miles of the Merrimack River Basin. He finds that a serious flood problem exists, particularly in the upper portion of the watershed which includes the highly industrialized complex which extends from Snows Mill Pond in Fitchburg downstream to its confluence with Monoosnoc Brook. The acuteness of the flood problem is indicated by the fact that four floods of moderate to major proportions have occurred in the past 28 years on the North Nashua River. A recurrence of the 18 March 1936 flood of record would result in flood damages of over $24,000,000 at 1964 price levels. Average annual damages from flooding amount to over $1,300,000 in the basin.

The Division Engineer also finds need in the basin to provide storage for future municipal and industrial water supply as well as facilities for the preservation and development of recreation and fish and wildlife resources.

The Division Engineer recommends for the protection of Fitchburg, Leominster and other downstream communities the adoption of a plan for the development and beneficial uses of the water resources of the North Nashua River. The plan is composed of six multiple-purpose reservoirs for flood control, municipal and industrial water supply, recreation and other allied purposes, one single-purpose flood control reservoir, and three channel improvement projects along the North Nashua River, Baker Brook, and Monoosnoc Brook.

The Division Engineer further recommends:

a. That four of the reservoirs, namely, Whitmanville, Nookagee, Phillips, and Monoosnoc and the three local protection projects be authorized for construction generally in accordance with plans contained herein at a total estimated first cost at June 1964 price levels of $16,090,000, of which $15,816,000 would be the Federal construction cost, and $3,830,000 would be reimbursable by non-Federal interests for water supply features, with non-Federal costs of $274,000 for the local protection projects. The net Federal cost is $11,986,000.

b. That three reservoir projects in the plan, namely, Shattuck, Pearl Hill and Saima Dam sites estimated to cost $4,160,000 of which $2,764,000 would be Federal cost and $1,396,000 non-Federal cost, be reserved for

future construction, to be undertaken at such time as the Chief of Engineers determines sufficient need, and at that time to be based on redetermination of benefits and costs.

c. That immediately following authorization of the reservoir sites listed above, sufficient site investigations and designs be made for the purpose of defining the project lands required, and subsequently, advance acquisition be made of such title to such lands as may be required to preserve the sites against incompatible development,

d. That prior to construction of the Whitmanville, Nookagee, Phillips, and Monoosnoc projects, responsible non-Federal interests give assurances satisfactory to the Secretary of the Army that they will:

(1) Repay the costs allocated to water supply, as determined by the Chief of Engineers, in accordance with the provisions of the Water Supply Act of 1958, as amended in 1961. Cost of water supply storage is presently estimated at $3,830,000 for construction and $6,000 annually for operation, maintenance and major replacements.

(2) Repay that portion of the construction costs allocated to recreation, including the recreational aspects of fish and wildlife in accordance with the cost sharing policy outlined in H. R. 9032, 88th Congress. No such costs are presently anticipated.

(3) Establish encroachment lines downstream from the dams to permit efficient reservoir operation.

e. That, prior to construction of each of the local protection channel improvement projects, responsible non-Federal interests give assurances satisfactory to the Secretary of the Army that they will:

(1) Provide without cost to the United States all lands, easements, and rights-of-way necessary for the construction of the projects; provide necessary relocations and alterations to highways, roads and highway bridges; relocate all utilities; and construct necessary interior drainage ditches.

(2) Hold and save the United States free from damages due to the construction works.

(3) Maintain and operate all works after completion in accordance with regulations prescribed by the Secretary of the Army.

(4) Prevent encroachment on improved channels.

WATER RESOURCE DEVELOPMENT PLAN
NORTH NASHUA RIVER BASIN
FITCHBURG - LEOMINSTER AREA, MASSACHUSETTS

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ATTACHMENT

I Information Called for by Senate Resolution 148

U. S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS
424 TRAPELO ROAD
WALTHAM, MASS. 02154

ADDRESS REPLY TO:
DIVISION ENGINEER

REFER TO FILE NO.

NEDED-R

25 January 1965

SUBJECT: Report on Review of Survey for Flood Control and Allied Purposes, North Nashua River and Tributaries, Merrimack River Basin, Massachusetts

TO: Chief of Engineers
ATTN: ENGCW-PD
Department of the Army
Washington, D. C. 20315

SECTION I

GENERAL

1. PURPOSE

This report presents a water resource development plan of the North Nashua River Basin for the development and beneficial uses of the water resources. It is submitted at this time for early consideration of the needs in the North Nashua River, Baker and Monoosnoc Brooks tributaries of the Merrimack River. This portion of the Nashua River Basin is geographically a separable entity in relation to the Merrimack River Basin. The project plan considered herein is compatible with the long-range plan for water resource development for the entire Merrimack River Basin.

2. AUTHORITY

This report is submitted as an Interim Report in partial compliance with authority provided in the Resolution by the Committee on Public Works of the United States Senate adopted 9 February 1961.

"That the Board of Engineers for Rivers and Harbors, created under Section 3 of the River and Harbor Act approved 13 June 1902, be, and is hereby requested to review the reports of the Chief of Engineers on the Merrimack River, New Hampshire and Massachusetts, published as House Document Numbered 689, Seventy-fifth Congress, third session, and other reports, with a view to determining the need for modification of the recommendations contained in such reports, and the advisability of adopting further improvements for flood control and allied purposes in view of the heavy damages and loss of life caused by recent severe storms in the Merrimack River Basin."

3. SCOPE OF REPORT

This report of survey scope comprises a review of water resource problem areas in the watershed of the North Nashua River Basin, a tributary of the Merrimack River Basin, for purposes of determining the economic advisability of further improvements for flood control and other water resource purposes. The area covered by this report is shown on Plate No. 1.

4. SCOPE OF STUDIES

a. Surveys and Studies. - The U. S. Army Map Service, U. S. Geological Survey, local maps supplemented with centerline profiles of the potential dam sites, and the utilization of other existing maps, were used in this study. Subsurface explorations by means of drive sample bore holes and geologic reconnaissance have been made at the four larger dam sites. Surveys of flood damages were made following the floods of 1938 and 1955. Detailed damage surveys were accomplished in 1962. The surveys consisted of personal interviews with municipal and state officials, officers of industrial concerns, and private individuals experiencing losses. Office studies consisted of hydrologic and hydraulic analyses, economic studies and evaluations, and estimates of quantities and costs of the major items of construction. Field reconnaissance and determination of recent sales in the potential reservoir and local protection areas were used as the basis for estimating real estate costs.

b. Consultations with Interested Parties. - A public hearing sponsored jointly with the Water Resources Commission, Commonwealth of Massachusetts, was held in Fitchburg on 13 November 1962. Several other meetings have been held since that date with State and city officials relative to the comprehensive water resource plan under consideration.

c. Field Reconnaissance. - Field reconnaissance of problem areas and sites of potential improvements was made by the Division Engineer and representatives of his office.

SECTION II

PRIOR REPORTS

5. PUBLISHED REPORTS

a. "308" Report. - The Merrimack River in New Hampshire and Massachusetts was studied by the Corps of Engineers under provisions of House Document No. 308, 69th Congress, 1st Session, which was enacted into law with modifications in Section 1 of the River and Harbor Act of 21 January 1927. The reports prepared became known as the "308" Reports. The Merrimack River report was published as House Document No. 649, 71st Congress, 3rd Session.

b. Survey Reports for Flood Control. - Following the disastrous flood of March 1936, a report for the Merrimack River Basin was submitted and published as House Document 689, 75th Congress. The report recommended modification of the existing project adopted in the Flood Control Act of 1936 to provide for the construction of a system of flood control reservoirs and related flood control works which may be found necessary by the Chief of Engineers. The present reservoir system constructed under this authority includes four reservoirs and local protection projects at five locations as indicated in paragraph 25.

c. NENYIAC Report. - The report of the New England-New York Inter-Agency Committee (NENYIAC) considered all aspects of the land and water resources of the area. The report was published as Senate Document No. 14, 85th Congress, 1st Session. Chapter XV of Part Two of the report covers the Merrimack River Basin in New Hampshire and Massachusetts. The NENYIAC Report considered the problem of flood control and determined that there was need for additional flood control measures in the basin.

SECTION III

DESCRIPTION

6. LOCATION AND EXTENT

The North Nashua River Basin is situated in north-central Massachusetts in the northern portion of Worcester County and northwest Middlesex County. The study area comprises the entire basin encompassing three cities and seven towns lying wholly or partially within the basin. The largest urban area, Fitchburg-Leominster, is one of ten Standard Metropolitan Statistical Areas (SMSA) in Massachusetts and constitutes the major population center within the basin. The study area is about 40 miles from Boston, 210 miles from New York City and 25 miles from Worcester. The North Nashua River, above the confluence of Baker Brook, conducts some 64 square miles of watershed drainage. Baker Brook, which has its confluence with the North Nashua River northwest of the Fitchburg-Leominster Airport, has a watershed of 20 square miles. About four miles downstream of the airport, a U.S.G.S. gage records the runoff from a drainage area of 107 square miles, of which 11.5 square miles is contributed by Monoosnoc Brook. The total basin area is about 132 square miles.

The North Nashua River and its watershed are shown on standard quadrangle sheets of the U.S. Geological Survey (1:31,680 and 1:62,500) and on standard quadrangle sheets of the Army Map Service (1:24,000, 1:25,000 and 1:50,000).

7. TOPOGRAPHY AND GEOLOGY

The North Nashua River and its tributary system is located along the eastern margin of the New England upland in central Massachusetts. This is a region of moderate relief characterized by wide valleys and broad, steep-sided hills, affording a watershed which is highly conducive to rapid runoff. The basin lies within the western highland of Massachusetts, a rough, naturally disected upland controlled largely by the underlying crystalline bedrocks which outcrop on the upper slopes and top of many of the hills. Remnants of once vast deposits of glacial outwash occupy the bottoms of many of the major valleys. Above the outwash, the slopes are mantled with a variably thick deposit of glacial till. The bedrock of the region consists principally of granite with localized areas of schist and phyllite, and has an apparent north-south structural trend. Deposits of the various types of sand, gravel and other materials used in construction occur scattered throughout the basin and are available in adequate quantities within reasonable proximity of any locality in the area.

8. STREAM CHARACTERISTICS

a. Main Stream. - The North Nashua River is formed at the confluence of the Whitman River with Flagg Brook in the City of Fitchburg, Worcester County, Massachusetts, at an elevation of 590 feet above mean sea level (m. s. l.). The river pursues a generally northeasterly course for about three miles into the center of Fitchburg and then turns to a generally southeasterly course for about eight miles to the U. S. G. S. gage in Leominster, and thence seven miles to its confluence with the Nashua River in the Town of Lancaster. The 132 sq. mi. watershed of the North Nashua River, all contributing to the Nashua River drainage area of 530 square miles, has a fall of 360 feet. The Merrimack River, at its outlet, has a drainage area of about 5,000 square miles.

b. Tributaries. - The principal tributaries of the North Nashua River are Whitman River, Flagg, Phillips, Baker and Monoosnoc Brooks. There are also a number of smaller streams in the North Nashua River system. Flagg Brook and the Whitman River form the headwaters of the North Nashua River.

(1) Flagg Brook - Flagg Brook has its source in Crocker Pond (elev. 823 msl) at the Princeton-Westminster town line and flows northward for a distance of about three miles to the headwaters of the North Nashua River. It has a drainage area of about 12 square miles and a total fall of about 230 feet.

(2) Whitman River - The Whitman River has its source in Lake Wampanoag (elev. 1079 msl) in the Town of Ashburnham and flows in a southeasterly direction for about nine miles to the headwaters of the North Nashua River. It has a drainage area of 27.5 square miles and a total fall of about 490 feet.

(3) Phillips Brook - Phillips Brook has its source in Winnekeag Lake (elev. 1,126 msl) in the Town of Ashburnham and flows generally southward for a distance of eight miles to its confluence with the North Nashua River. It has a drainage area of 15.9 square miles and a total fall of about 600 feet.

(4) Baker Brook - Baker Brook is formed by Falulah Brook and Pearl Hill Brook about 2.5 miles above the North Nashua River confluence near the Fitchburg-Leominster Airport. Baker Brook has a total drainage area of 20 square miles of which 11 square miles are drained by Falulah Brook and four square miles by Pearl Hill Brook.

(5) Monoosnoc Brook - Monoosnoc Brook rises in Rocky Pond in the hills west of the city of Leominster and flows in a general easterly direction for 8.7 miles through the business center of Leominster to its confluence with the North Nashua River about nine miles upstream of the junction of the North Nashua and Nashua Rivers. The drainage area at the mouth of the brook is 11.5 square miles. The brook has a total fall of about 550 feet.

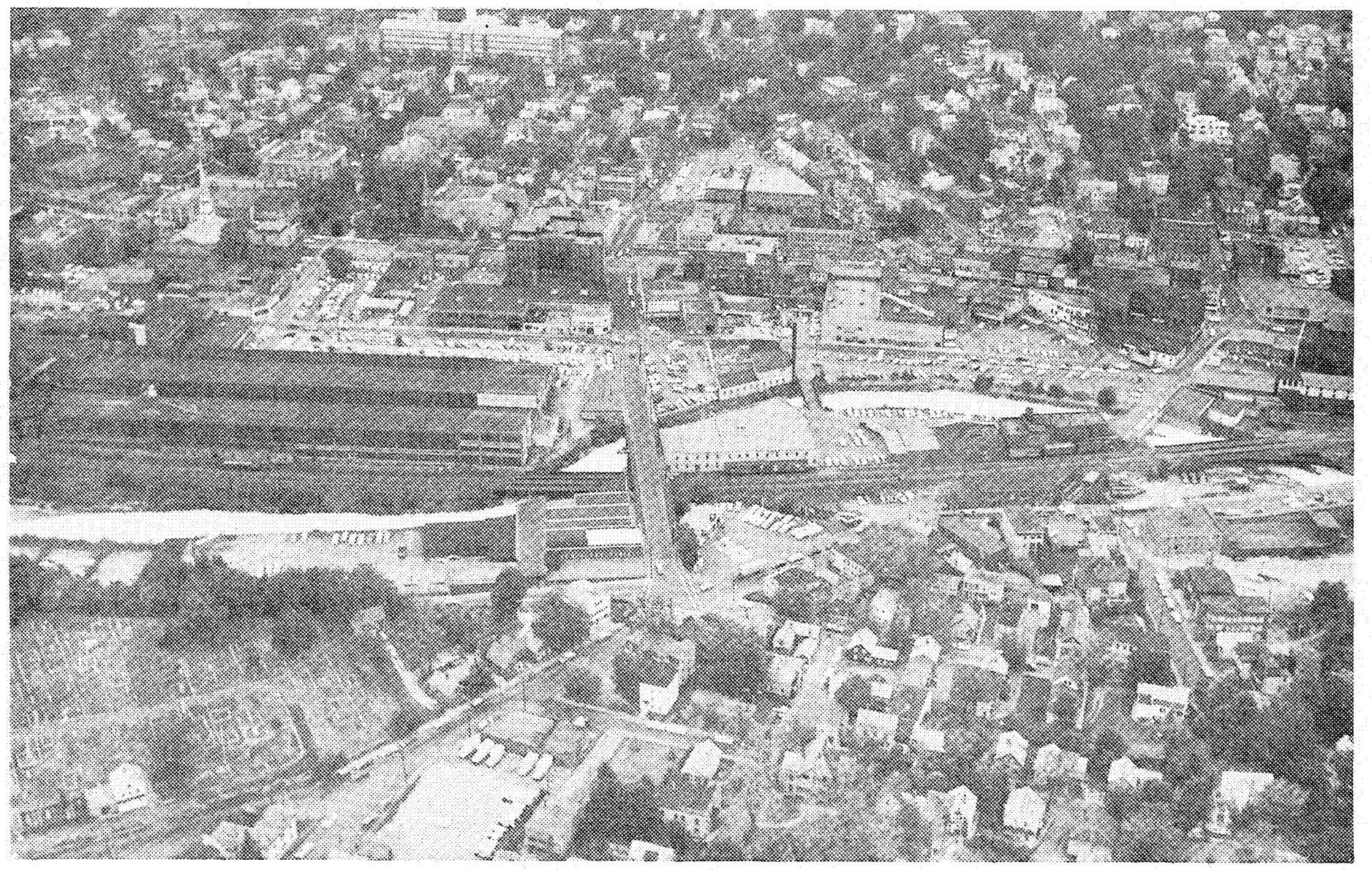
SECTION IV

ECONOMIC DEVELOPMENT

9. EXISTING ECONOMIC CONDITIONS

a. General. - The economy of the North Nashua River Basin is based on the large industrial complex which lines both banks of the river for a distance of eight miles in the City of Fitchburg and a smaller cluster of manufacturing plants in Leominster. The products of the large units in these complexes enter into the national economy; such plants as Foster-Grant and Standard Pyroxoloid in plastics, Simond Saw in cutting tools, and Independent Lock in hardware are examples. On the regional scale the market is much broader with the basin's industry supplying paper, textiles, shoes and plastics to the economy. Lying just to the north of the highly industrialized Worcester area whose northernmost outpost, Clinton, is on the South Branch Nashua River, the basin is a key segment of an industrial belt which stretches across Worcester County from Rhode Island in the south almost to New Hampshire in the north.

b. Population. - The population of the cities and towns located wholly or partly in the basin at the time of the 1960 census was 116,000. The bulk of this population, 70,950 people, resided in the Fitchburg-Leominster urbanized area. The core cities along with some tributary areas in Lunenburg and Shirley have been designated as a Standard Metropolitan Statistical Area (SMSA) called Fitchburg-Leominster. The SMSA population in 1960 was 82,500. The rate of increase in the population of the basin has been less than that of the state and the nation for the past two decades; 12.4 percent compared with 19.3 percent and 36.7 percent, respectively. The basic reason for the lower rate is that Fitchburg and to a lesser extent Leominster, the largest units in the basin, had already used its then available land by 1940. This fact is revealed by a review of the population increases in the contiguous towns surrounding Fitchburg and Leominster which reveal a sizeable increase during the last 10 years.



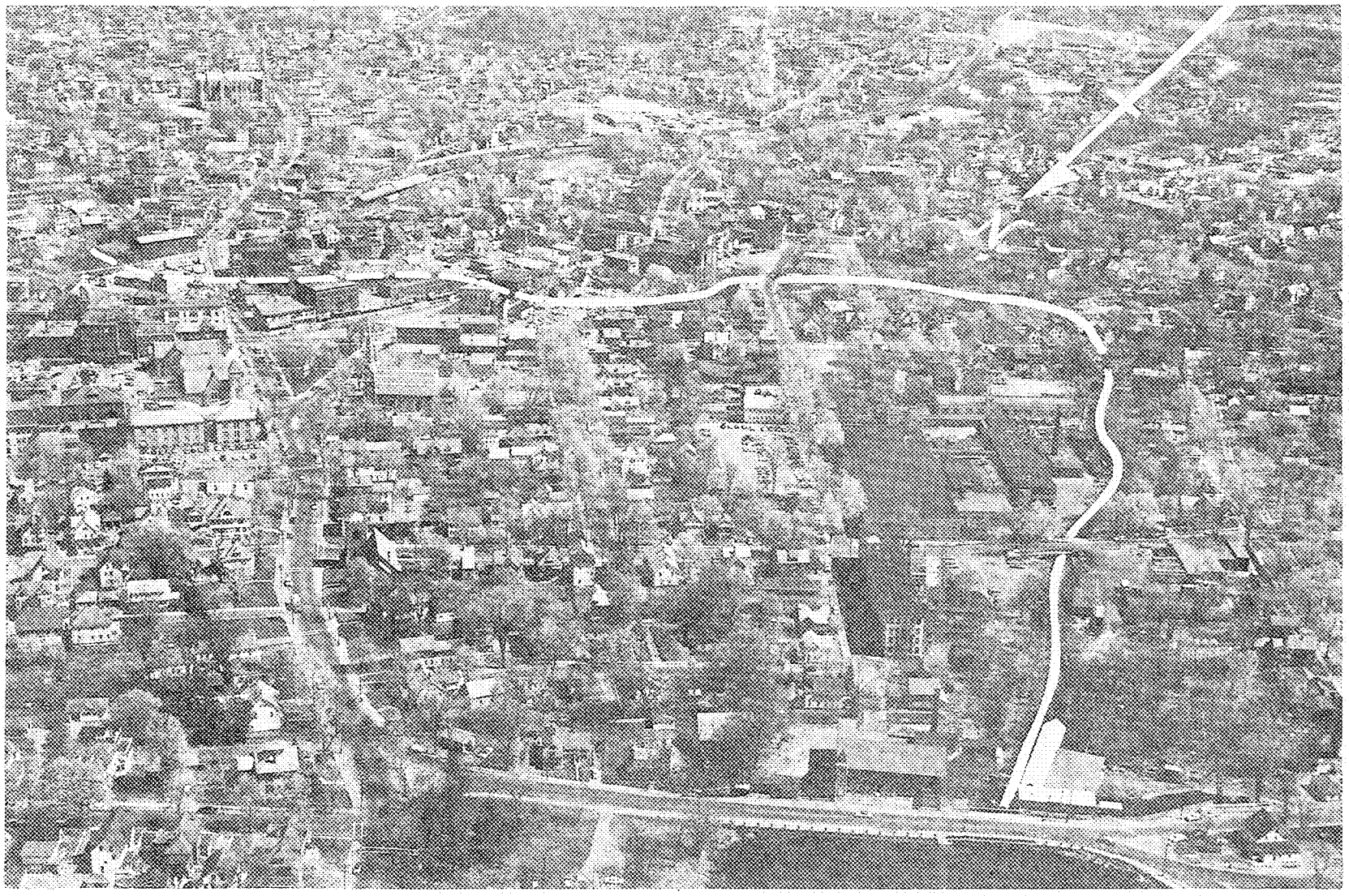
Fitchburg's downtown business section. Putnam Street in center. Area to be protected by upstream reservoirs. Note large industrial plant complex along left bank.

c. Industry - Manufacturing accounts for over 68 percent of the total employment of the basin. Products of the basic industries of the area enter directly into commerce, various plastic products from Leominster; coated papers, building hardware, saws of all types, shoes, textiles and firearms to mention a few products of Fitchburg. More specialized in their markets are such plants as the Small Stream Turbine Department of General Electric, and the Dixie Cawdrey Corportion, a division of the American Can Company which makes the special machines used in producing paper containers, both located in Fitchburg. In both Leominster and Fitchburg, the plants which produce the basic items of commerce are backed up by a sizeable group of service industries, foundries, makers of wood pallets and crates; and tool machine shops which make the dyes and molds for plastic plants. Physically, most of the industrial plants in Fitchburg are located in the flood plain of the river. In Leominster at present, five plants are situated in the flood plain of the main river. One of these plants is a paper mill. Along Monoosnoc Brook, 16 additional manufacturing enterprises are susceptible to flooding.

Employment by industries in the flood plain represents over 50 percent of total employment in Fitchburg and 10 percent of total employment in Leominster. In terms of Leominster's industrial payroll, the flood plain industry represents 13 percent of the total.

d. Other Land Use - The intensity of land use in the North Nashua River basin varies inversely with the distance from the headwaters at Snows Mill Pond. In Fitchburg, population density was 1,566 persons per square mile in 1960, for Leominster the figure was 969 in 1960, and for Lancaster the figure was 143 in the same year.

In the flood plain of the river, the disparity in use is even greater. In Fitchburg, the upper four miles of the river are heavily built over. In addition to the area occupied by industries, 216 commercial establishments, over 100 dwellings of various types, the railroad, a public utilities plant, and city streets and parks take up most available space. Only in the vicinity of the airport and on Baker Brook is there any vacant land available for development. In Leominster, with the exception of six properties in north Leominster and the sewage treatment plant below Monoosnoc Brook, the main river flood plain is unoccupied at present. On Monoosnoc Brook, the flood plain is built over with industrial, commercial and residential properties from the edge of the main river flood plain to the westerly edge of the central city. In



Leominster's downtown business section

Monoosnoc Brook flowing south
from Rockwell Pond in foreground

Lancaster, the flood plain is currently idle land but some housing development is beginning to take place just above the plain. In Lunenburg, there are four commercial establishments and some residential properties in the flood plain.

e. Transportation. - An improving network of highways and the New Haven and Boston and Maine Railroads serve the basin. The Boston and Maine Railroad provides passenger service between Fitchburg and Boston and freight service from Fitchburg and North Leominster to the east and north and to western Massachusetts and beyond, interchanging with railroads from the south and west at Mechanicsville, New York. As part of its freight service, the railroad provides a yard in Fitchburg for "piggy-back" truck service with loading and unloading facilities for the trailers. The New Haven Railroad provides freight service to Fitchburg and Leominster, connecting to the southeast with eastern Massachusetts and by a connecting line with the Boston and Maine Railroad to Worcester and to points in Rhode Island and Connecticut.

At present, one limited access highway services the basin. Massachusetts Route 2, a four-lane dual-highway connecting Fitchburg and Leominster with Concord, Massachusetts at a point about eight miles west of Route 128, a limited access expressway known as the "Circumferential Highway" which encompasses Boston from the North Shore of Massachusetts Bay to the South Shore at an average distance of 12 miles from the heart of the City of Boston. From the present eastern terminus of the limited access section of Route 2 to Boston, the route is a four-lane undivided highway through a heavily built over area. To the west of the basin, Route 2 has been designed as a dual-highway with limited access from Fitchburg to Interstate Route I-91 in the vicinity of Greenfield, Massachusetts, about 40 miles to the west. Approximately 40 percent of the dual-highway portion is completed; for the rest of the route one side of a future dual-highway has been built and is being used for two-way traffic. In a north-south direction, the basin is served by Massachusetts Route 12, an undivided highway, generally two lanes wide. To the south, the road connects the basin to Worcester and thence south into eastern Connecticut; to the north, the road runs to Keene, New Hampshire and then to northern New Hampshire. The Highway Master Plan for Massachusetts calls for reconstruction of Route 12 as a limited access, dual-highway from the Connecticut line in the south to the New Hampshire line in the north.

Of great importance to the basin is the present highway construction going on about 12 miles to the east of Route 12 and roughly parallel to it. Interstate Route I-495, a belt highway running in an arc from an intersection with Route I-95 at Foxboro, Massachusetts, to the south of Boston to a planned intersection with I-95 at the New Hampshire line north of Boston is being constructed as a limited access expressway, at an average distance of 27 miles from the city of Boston. Approximately 15 miles of the highway are completed at the present time with an additional 25 miles under construction. Completion of the entire highway is scheduled for 1970. The total length of the highway will be 87 miles.

f. Mineral Resources. - There are two active quarries and three sand and gravel operations within the study area. Limited potential development of sand and gravel is represented in the glacial outwash deposits which are present in and along the bottoms of some valleys. There are no mineral prospects within the limits of the study area.

g. Water Supply. - According to studies made for the New England-New York Inter-Agency Committee Report and more recent studies by the U.S. Public Health Service, the Merrimack River and its major tributaries have ample water supply for present and future needs except in the Fitchburg area of Massachusetts, and Lincoln, New Hampshire areas. A major portion of the surface water resources of the North Nashua River is presently utilized to satisfy the needs of the paper and plastic industries. City officials and officials of paper companies have indicated a need for additional water supply. In considering development of the water resources of the basin, industrial and domestic water demands have been evaluated.

h. Power Development. - There are three small existing hydroelectric plants in the North Nashua River with an installed capacity of 750 kilowatts and a gross head of 95 feet. These plants, used for industrial purposes, are located in West Fitchburg and are owned and operated by the Corker-Burbank Paper Company, a Division of the Weyerhaeuser Corporation. The total drainage area behind the three plants is approximately 40 square miles. Nearly all industrial and domestic power supply needs are provided by the Fitchburg Gas and Electric Company with a thermal plant located on the North Nashua River in the heart of the City of Fitchburg and through interchange arrangements with other utilities. Owing to small natural drainage areas, the hydroelectric power potential is limited.

i. Agriculture. - In general, infertile soil and rugged terrain combine to reduce the agricultural importance of the North Nashua River Basin. Except in relatively small areas of rich, intensely cultivated land, there has been a general decline in the importance of agriculture in relation to other economic activity in the basin.

j. Recreation. - There are three developed State Forests in the North Nashua River Basin, Willard Brook, Otter River and Leominster State Forests. Two of these, Willard Brook and Otter River, have limited facilities for swimming and all three offer hunting, fishing and hiking. Existing recreation areas are heavily used and facilities are inadequate to meet the demands of the heavy population in the area. The proposed plan of improvement provides for the associated development of recreation areas within the study watershed.

k. Urban Renewal. - A proposed Urban Renewal Project is currently under consideration for downtown Leominster. The renewal area which is currently bisected by Monoosnoc Brook, bounded to the north by Pleasant Street and to the south by the New York, New Haven and Hartford Railroad, would replace the present business section of the city. Included in the project is approximately 2,400 feet of channel relocation of Monoosnoc Brook.

10. MEASURES OF ECONOMIC ACTIVITY

Perhaps the best indication of the economic health of the basin is the data on "Value Added by Manufacture" for the last 20 years for which complete data is available. In terms of 1963 constant dollars, this value climbed from $57,300,000 in 1939 to $130,000,000 in 1958, the last year for which complete data is currently available. Percentage-wise the increase of 127 percent exceeded that of Worcester County as a whole for the period (56.7%) and even exceeded that of the state as a whole (90.7%). Annual payrolls in the manufacturing plants in the basin exceed $80,000,000 according to data published by the Massachusetts Department of Commerce. In "Retail Trade" the basin has shown a growth from $63,400,000 in 1939 to $97,600,000 in 1958 in terms of constant 1963 dollars. The rate of increase, percentage-wise was approximately equal to the state as a whole for the period (53.9% for the basin, 55.9% for the State) and some 14 percent higher than for Worcester County. Available data on "Selected Services" in the period 1948 to 1958 indicate a growth from $5,400,000 to $8,000,000 in terms of constant 1963 dollars. This growth of 32.5 percent compares favorably with the growth rate for the State in this category, of 22.3 percent. Based on data from the 1960 Census, the 1959 per capita income

for the Fitchburg-Leominster area, which represents 94 percent of the population of the basin, was $2,152. Although this is some 11 percent lower than the Massachusetts average for the year, it approximated the National per capita of $2,163 for the year 1959.

11. TRENDS AND FACTORS UNDERLYING ECONOMIC GROWTH IN STUDY AREA

a. General. - The recent past of the North Nashua River Basin has been one of a stable, relatively prosperous economy. A study of past and present trends in the economy of the area indicates that the basin will continue to prosper. Specific indicators are discussed below.

b. Highways. - Of prime importance to the future economy of the basin is the growing network of modern highways. The area lies just to the north and west and only 20 miles from the broad belt of coastal New England which the demographers have noted as the northern extension of "Megalopolis", the future super city which is projected to stretch from Washington, D. C. to north of Boston, Massachusetts, and which already contains over eight million people in the New England portion alone. Access to the markets of this super city for the basin's manufactured products is dependent on the expansion and improvement of the present network of roads. The continuing construction of Interstate I-495 will mean convenient access to all of southeastern Massachusetts and eastern Rhode Island within the next half dozen years; access to the population centers of the Merrimack Basin to the northeast is already possible over the completed section of the highway.

An even greater effect of Interstate I-495 on the basin will be the demand for land for industrial development. Even prior to the completion of Massachusetts Route 128, a similar belt highway some 16 miles to the east of I-495 and roughly parallel to it, the industrial development along the route used up all nearby developable land and earned for the route the name of "the Golden Crescent". Land at some distance from the route is now commanding prices in excess of $20,000 an acre. The ease of highway access to all other routes which a belt highway makes possible is the overriding consideration in the selection of sites with access thereto. The location of industrial sites and their development in turn generates a demand for smaller tracts for housing. All this may be expected to occur along Interstate I-495.

The growth which Route I-495 is expected to generate in the eastern portion of Worcester County will increase the need for the reconstruction of Massachusetts Route 12 to modern standards within the next 15 years. The State of Connecticut is already constructing its portion of the road to such standards from the Massachusetts line south to the Connecticut Turnpike, one of the State's important east-west trunk highways.

c. Retail Trade. The North Nashua Basin in retail trade serves a tributary area which had a population in 1960 of 116,000. The tributary area has a present growth rate based on the past 20 years of 17.7 percent or almost equal to that of the state for the same period (19.3%). The rate of growth in the tributary area is expected to increase slightly over the next few years and equal the national projection rate for the next 20 years at which time a leveling off will take place. The Fitchburg-Leominster area can be expected to continue to be the trade center for the entire area so that retail trade can be expected to expand at least at its present rate for the forseeable future.

d. Value Added by Manufacture. - As previously noted in "Value Added by Manufacture" the historic trend in the basin over the period since 1939 has been at a much higher rate of growth than the State as a whole (127% in a 20-year period). During the 20-year period for which the comparison was made, the increase in GNP in constant dollars was 110 percent. As the largest component in GNP is generally the personal consumption demand for goods which are the products of manufacturing, the basin's economy can be seen to be a strong one. It is projected to remain so. Most manufacturing is carried on in modern, well-equipped plants. Many of the processes, especially in paper-making, are automated. The diversity of product mix in the basin tends to cushion the effects of changes in demand which has brought blight to other areas centered around one product.

e. Per Capita Income. - With the strength shown in the other economic indices and the current trends in these indices, it is reasonable to project that per capita income currently at the National average, will continue to grow at least at the same rate as the National rate.

f. Growth and Land Use

(1) Population. - The population of the tributary area is expected to grow at a rate of 1 percent for the next 20 years reaching a total population of 139,000 for the year 1984. The rate of growth will then level off

and a total population of 150,000 is projected by the year 2000 in the basin and tributary area. The projected growth will mean an addition of approximately 14,000 people to the working force by the year 2000. Currently, each industrial employee in the basin represents an annual contribution of $6,500 to the "Value Added by Manufacture". Assuming the growth rate in "Value Added" for the basin to be 60 percent of the project GNP over the next 36 years, a very conservative assumption, "Value Added" in the year 2000 will have increased by $260,000,000. The present work force will account for $137 million of the increase. Using the projected rate of $15,800 (National Projection for year 2000) for gross product per worker would mean that 7,800 additional employees would be needed by industry alone to realize the remaining increase. Currently in the study area there are as many employees in trade and services as there are in manufacturing. Assuming that ratio to hold true in the future will require all of the remaining increase in the work force.

(2) Land Use. - The pressures from both industry and population growth for suitable land for future expansion will rapidly use up all available land in the North Nashua River flood plain above Mechanic Street bridge in Leominster and along Baker Brook by 1970 regardless of whether flood control is provided or not. In Lancaster, approximately 40 percent of the flood plain will gradually come into use if flood control is provided.

SECTION V

WEATHER AND FLOODS

12. TEMPERATURE, PRECIPITATION AND SNOW

The North Nashua River Basin has a variable climate. The mean annual temperature is about 48°F. Temperature extremes within the basin range from a summertime high of about 100°F to subzero for short periods in the winter. Freezing temperatures may be expected from the latter part of September until late in April. The basin frequently experiences periods of heavy precipitation produced by local thunderstorms and larger weather systems of tropical and extra-tropical origin. It lies in the path of the prevailing "westerlies" which traverse the country in an easterly or northeasterly direction and produce frequent weather changes. The average annual precipitation over the North Nashua River basin is approximately 45 inches, uniformly distributed throughout the year. The annual snowfall over the basin averages about 60 inches and the average water content of the snow cover in early spring often totals four to six inches.

13. STREAMFLOW DATA

The U. S. Geological Survey has published records of river stage and streamflow for the gaging station near Leominster, Massachusetts which has a drainage area of 107 square miles. The period of record is from 1935 to date.

14. HISTORIC FLOODS

Records of historic floods in the North Nashua River and tributaries are meager. Local newspaper files indicate that a damaging flood occurred at Fitchburg in 1850 but details on this flood are lacking.

15. RECENT FLOODS

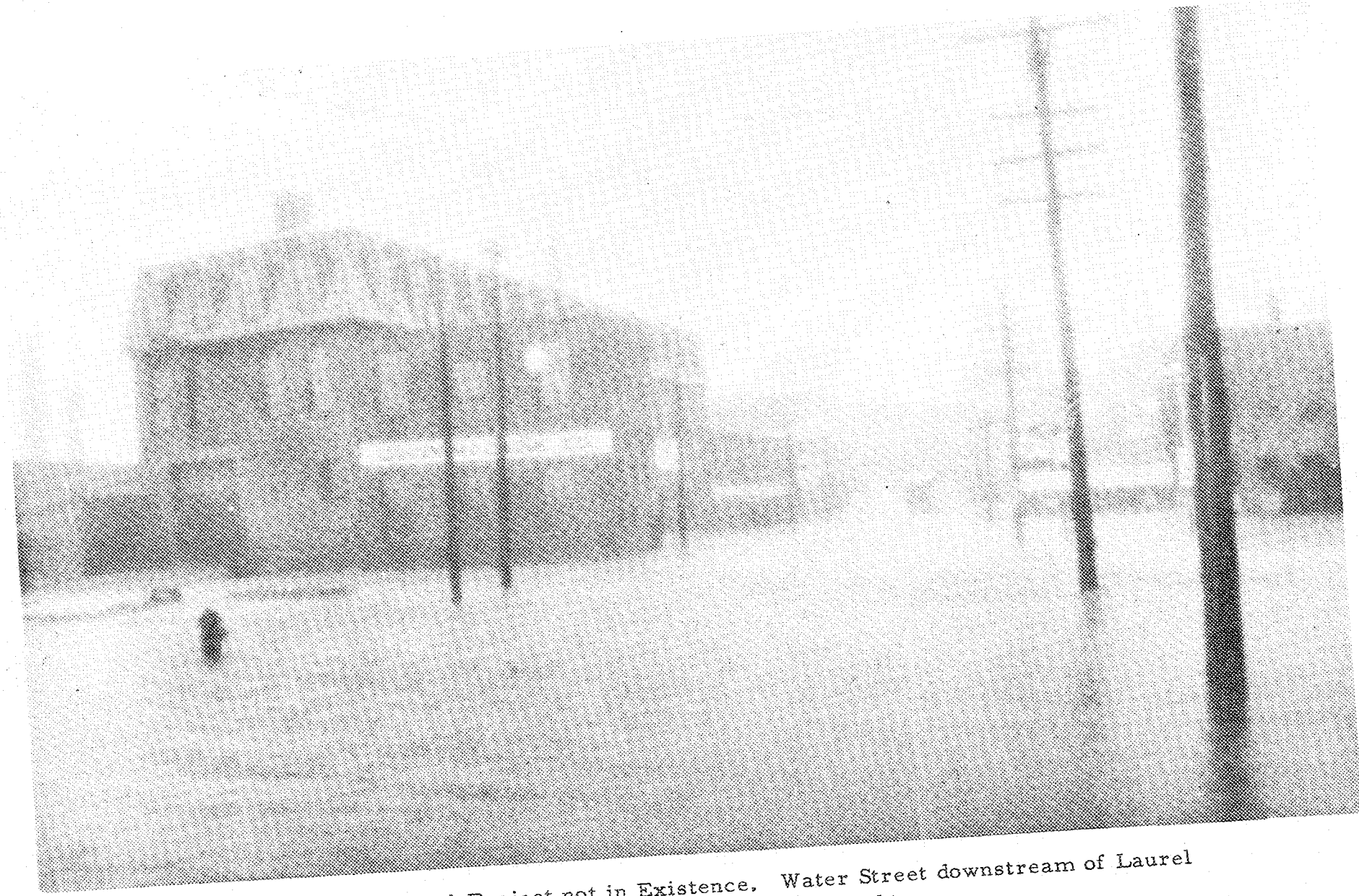
The North Nashua River basin has experienced four floods during the past 28 years. A brief description of these floods is included in the following paragraphs and a summary of the comparative magnitude of the three largest floods is shown in Table I.

(1) March 18, 1936. - The greatest flood of record, 16-19 March, resulted from intense rainfall which averaged about five inches over the North Nashua River watershed. The high peak discharge was augmented by snowmelt and an antecedent storm and a smaller flood occuring on 12 March.

(2) September 21, 1938. - The flood resulted from torrential rains which preceded a hurricane that passed up the Connecticut River Valley on the 21st. Rainfall on 20-21 September averaged about 7.5 inches over the North Nashua River basin.

(3) October 15, 1955. - The flood was produced by heavy precipitation from 14-17 October. At Ashburnham, Massachusetts in the upper basin a total of 11.96 inches of rainfall was recorded between 6:00 AM 14 October and 6:00 AM 17 October.

(4) June 24, 1944. - The fourth largest flood in the basin resulted from torrential rain on the 24th which fell on ground previously saturated by intermittent showers that began on the 17th.



1936 Flood. Channel Project not in Existence. Water Street downstream of Laurel Street Bridge. North Nashua River is 300 feet to the right.

1936 Flood. Channel Project not in Existence. Corner of Cushing and Broad Streets in downtown business section.

16. FLOOD CHARACTERISTICS

Available records indicate that floods can occur in the North Nashua River during any season of the year. The more critical floods result from intense rainfall alone which determines the magnitude of flood peaks. The short and relatively steep tributaries discharge into the main stream almost concurrently which results in rapid flood development. Major floods in the area reach crest within a few hours after the end of rainfall and the duration of high stages is usually about 48 hours.

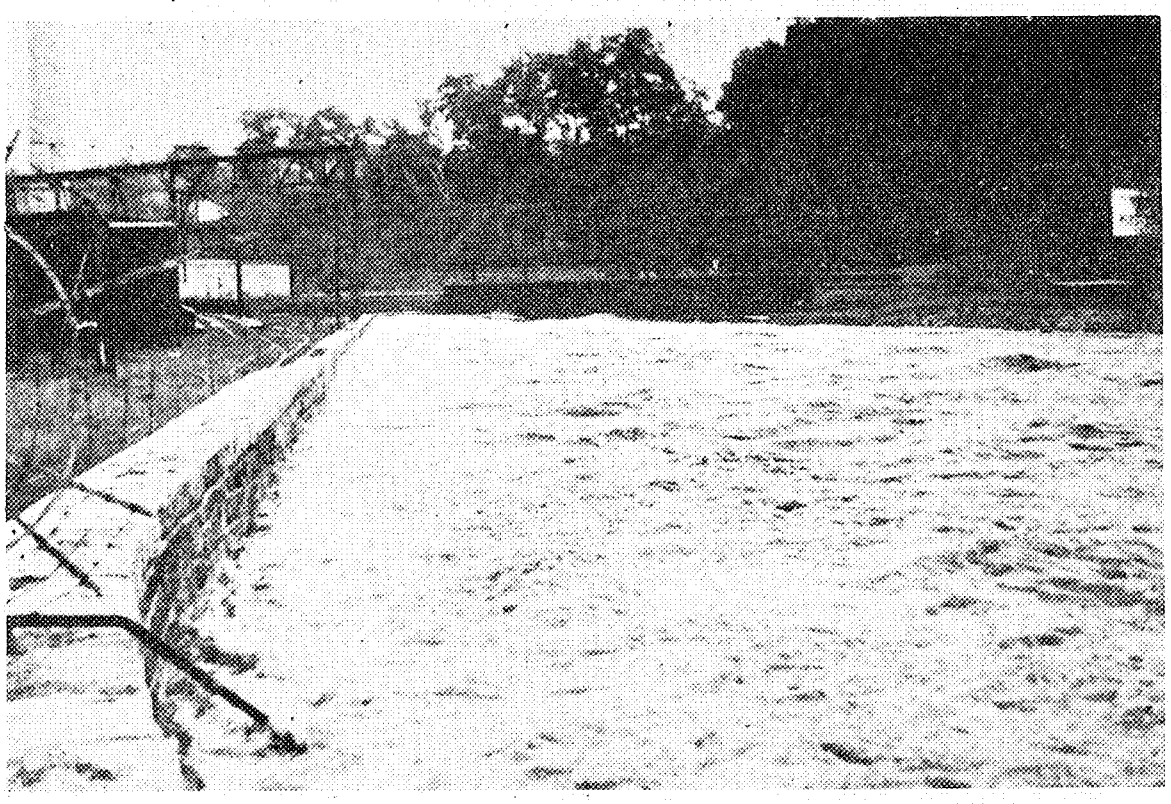
17. STANDARD PROJECT FLOOD

The standard project flood is a synthetic flood used to measure the flood potential of a river basin and as a criterion for design of channel sections and other structures for local protection. It represents flood characteristics that may be expected from the most severe combination of meterologic and hydrologic conditions that are considered reasonable for the geographical region, excluding extremly rare combinations. The intense rainfall which accompanied the storm of August 1955 and produced record floods in much of southern New England did not extend over the North Nashua River basin. However, the probability of such an occurrence was considered in making the unit hydrograph analysis for the standard project flood development. A comparison of the magnitude of the standard project flood and major recorded floods at Fitchburg and Leominster are shown in Table 1.

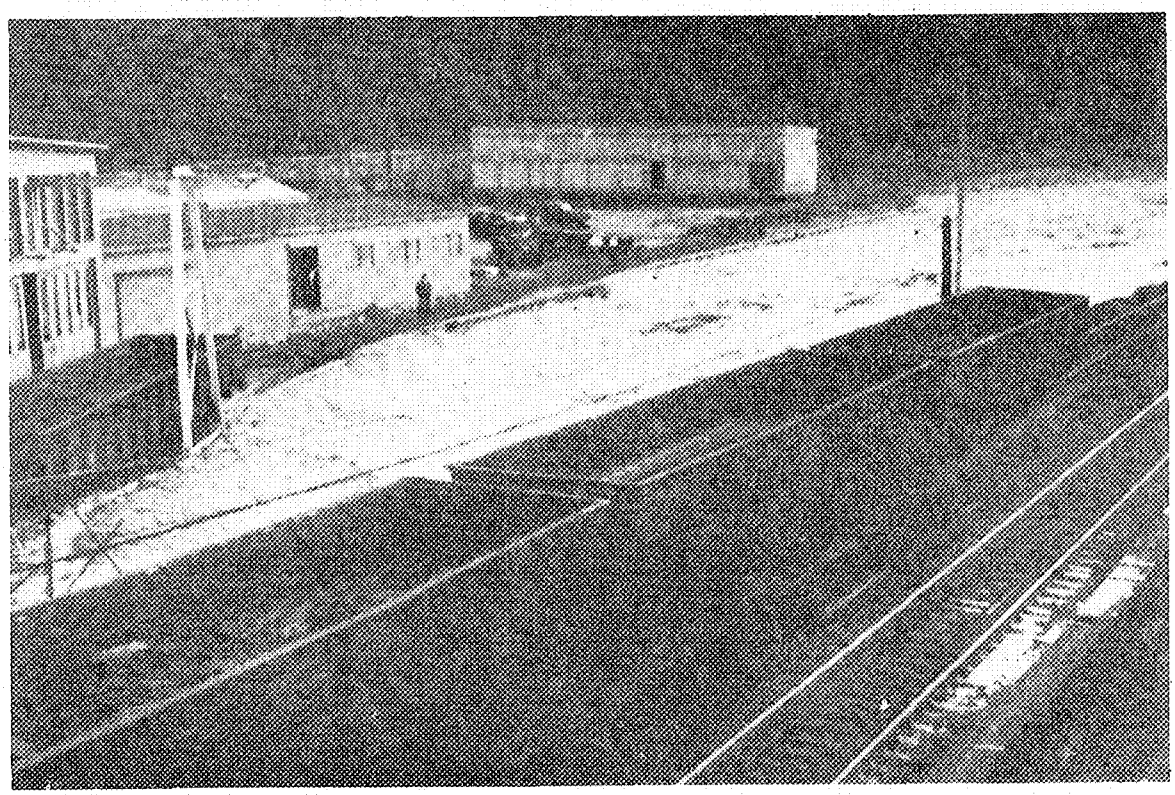
Table 1
Recorded Floods and Standard Project Flood
North Nashua River

	Arden Mill Dam Fitchburg (D.A. 63 sq. mi.)		U.S.G.S. Gage Leominster (D.A. 107 sq. mi.)	
Flood	Stage (ft.)	Discharge (cfs)	Stage (ft.)	Discharge (cfs)
March 1936	7.3	9,400	20.5	16,300
September 1938	7.1	8,900	14.6	10,300
October 1955	6.6	7,800	10.8	8,820
Standard Project Flood	11.0	20,000	25.8	24,000

1938 FLOOD - CHANNEL PROJECT IN OPERATION



General Electric Plant on left. Note flood levels approaching top of walls which were constructed as part of the 1937 project. Railroad bridge siding in foreground.



Picture taken downstream of General Electric Plant which is on left bank. Note crib walls on right bank, water is beginning to top crib walls built in 1937.

18. PROBABLE MAXIMUM FLOOD

The probable maximum flood was developed as a criterion for determining the spillway design flood for the proposed reservoirs in the North Nashua River basin. Data for the probable maximum storm were taken from Hydrometeorological Report No. 33, prepared jointly by the U.S. Weather Bureau and the Corps of Engineers. Unit hydrographs were derived from recorded floods and adjusted to simulate runoff conditions to be expected during a spillway design flood. The probable maximum flood at the reservoir sites have peak ordinates of about 1550 cubic feet per second per square mile of drainage area.

SECTION VI

WATER RESOURCE PROBLEMS

19. GENERAL

Present and projected use of the water resources of the North Nashua River and its tributaries create water management problems in four categories: flooding, water supply, pollution, and low-flow regulation of sustained yield. Foremost of the problems of present water usage in the study area from the viewpoint of economic losses is flooding. A comprehensive plan of water resource development can contribute to the solution of these problems in varying degrees. The problem categories are more fully discussed in the following sections.

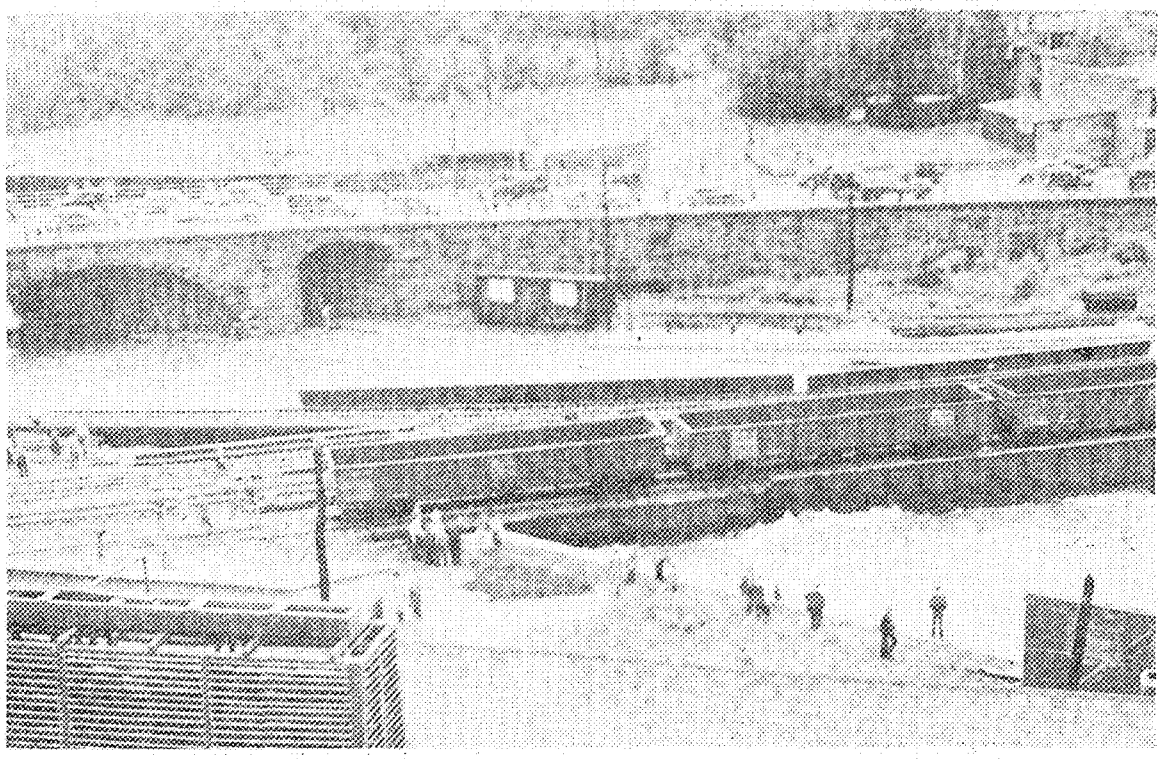
SECTION VII

THE FLOOD PROBLEM

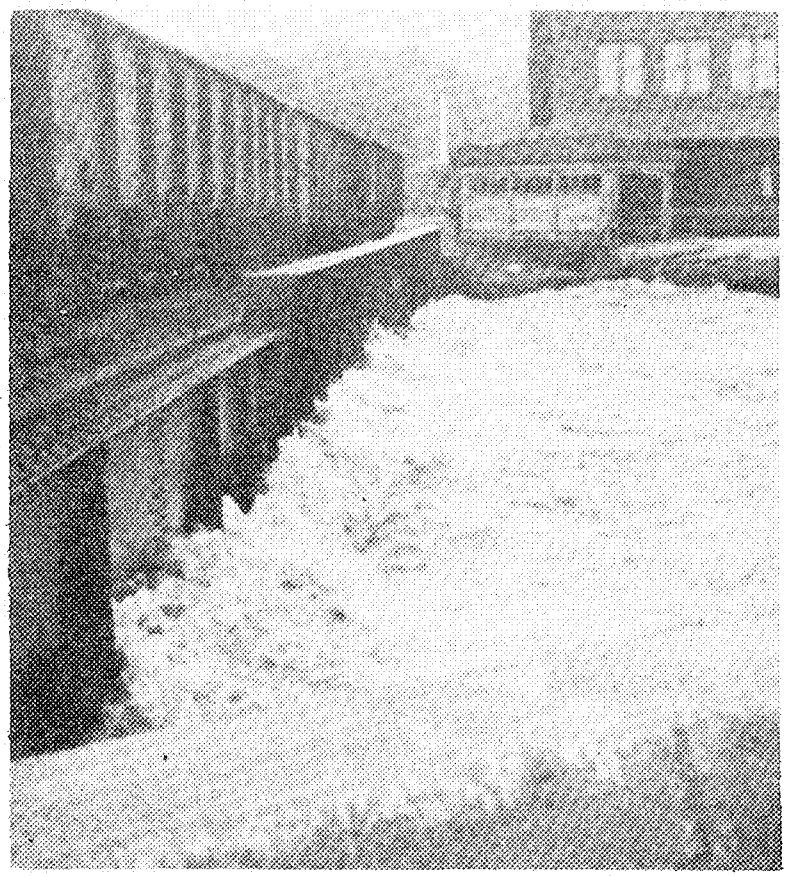
20. GENERAL

Over 2,800 acres of valley area along the North Nashua River and its tributaries have been subjected to severe and frequent flooding which have produced heavy flood damages by inundation, erosion and deposition of debris. The rocky and steep slopes of the valley in the upper reaches of the basin are conducive to rapid runoff, and flood waters may strike the communities without warning. Below Leominster the flood area is of somewhat different character. The valley begins to broaden, the stream bed has a flatter slope, and the flood plain becomes considerably wider. For this reach, the flood plain area covered by the flood of March 1936, was approximately 1,150 acres. It is significant that much of the growth

1938 FLOOD - CHANNEL PROJECT IN OPERATION



Boston and Maine Railroad Bridge upstream of Laurel Street. Note water surface surcharge against girder. Railroad cars are holding down bridge deck.



Same bridge as above, close-up view of water against bridge girder. Note entrance to pedestrian underpass in background which tunnels under North Nashua River.

and development in recent years has occurred in this flood plain. The geography of the area is such that the flood plain comprises the most suitable land available for further industrial expansion.

a. Fitchburg Business and Industrial Area. - Of paramount interest to the basin's economy is the ever present possibility of disastrous flooding in the business and industrial areas from flows exceeding the present capacity of the existing channel. Officials of the City of Fitchburg have become alarmed at the hazard from possible collapse of river bank local protection structures through undermining at broken, grouted riprap areas and where progressive deterioration of concrete crib walls has reached an advanced stage. If deterioration continues unchecked (see photographs), obstruction of the river from wall failures will aggravate the flood problem.

b. Existing Local Protection Project. - The local protection project at Fitchburg was originally designed for the record flood, or a discharge of about 9,000 cubic feet per second (c.f.s.). Deterioration over the past 28 years has reduced channel capabilities at some locations to below 6,500 c.f.s. During the floods of September 1938 and October 1955 flood waters (see photographs) nearly overtopped existing improvements arousing local concern as to the adequacy of the project.

c. Baker Brook. - The flood problem at Baker Brook watershed occurs primarily along the John Fitch Highway in the area known as the Fitchgate Shopping Plaza. Considerable land was inundated in 1936 but only minor damages were experienced at that time due to the undeveloped nature of the area. Owing to natural terrain this area has been partially developed and space exists for future growth. In recent years, new development has been stimulated by highway construction. Expansion and development in the flood plain of Baker Brook has substantially reduced the flow capabilities of the brook so that flooding occurs nearly annually.

d. Leominster Business and Industrial Area. - Monoosnoc Brook rises in the hills west of the city and flows in a general easterly direction bisecting the city for a distance of 8.7 miles to its confluence with the North Nashua River. Continuing downstream from Rockwell Pond for its lower 2.3 miles, Monoosnoc Brook passes under nine highway and one railroad bridges in its course through the heavily built up congested area of the city. Much of the stream between Pond and Water Streets has been walled in and in several areas is confined in conduits. Local interests are concerned with the inadequate capacity of the channel, which in previous flood periods has overtopped its banks and inundated the downtown business and industrial areas of the city.

21. EXTENT AND CHARACTER OF FLOODED AREA

Over 2,800 acres of flood-prone land lies along both sides of the North Nashua River and two of its larger tributaries, Baker Brook and Monoosnoc Brook, between Snows Mill Pond in Fitchburg and its confluence with the Nashua River in Lancaster. The flood plain in the lower reaches of the river in Lancaster and in the lower end of Leominster is principally meadow and swamp land. The plain is increasingly built over as one goes upstream in Leominster and in the City of Fitchburg, and with the exception of the mile of river which borders the airport just north of the Leominster line, the plain is completely built over.

The river front area in Fitchburg is completely developed with light and heavy industrial concerns, commercial establishments and tenement type housing. The main line of the Boston and Maine Railroad's Fitchburg Division follows the river valley through Fitchburg, crossing the river or its tributaries at nine points within the city and much of its trackage is also subject to flooding.

Industry established itself along the North Nashua River early in the 1800's being attracted first by the water power available and later by the availability of process water. Today, paper making, turbine manufacturing and the production of building hardware and carpentry tools account for a large segment of the total industrial employment with machine shops, foundries, textile plants, and plastic manufacturing plants accounting for the balance. Much of this industry is located in the flood-prone portion of Fitchburg along the main stem of the river. Over 800 acres of land is in this flood plain. On Baker Brook 240 acres of land in Fitchburg and 70 acres in Lunenburg are subject to flooding. Residential and recently developed commercial properties predominate in this area.

In Leominster some 580 acres of land are susceptible to flooding from the standard project flood. Over 70 acres of this is along Monoosnoc Brook in the built-up portion of the city, the remainder is on the North Nashua River. One large industrial plant and four smaller enterprises as well as some residential property are in the main river flood plain in the upper portion of the city; near its confluence with Monoosnoc Brook, the Leominster Sewage Plant and a new industrial park occupy the flood plain. Below the sewage plant the flood plain in Leominster has not yet been developed. On Monoosnoc Brook, four plastic manufacturing plants, 12 small industrial plants, numerous commercial properties and some residential property are subject to flooding.

The flood plain in Lancaster comprises 1,150 acres of meadow and swamp land.

Business Section downstream of Laurel Street. Note Fitchburg's Light and Power Company to the right. Area to be protected by upstream reservoirs. River flowing left to right.

22. EXPERIENCED FLOOD LOSSES

The record flood of March 1936 caused an estimated loss of over $2,100,000 in the North Nashua River Basin. The major portion of the loss was in the City of Fitchburg where normal community life was completely disrupted. Seven bridges were destroyed and four others damaged. All railroad service to the city ceased and most of the large industrial plants in the city were closed.

In Leominster, the principal losses came from the destruction of one bridge and damage to two others. Other main stem losses were to three industrial plants in North Leominster and to scattered rural properties. On Monoosnoc Brook the major losses were to commercial properties with bridge damage and industrial losses also contributing to the total. Main stem losses exceeded $100,000 while Monoosnoc Brook losses were in excess of $80,000.

Lancaster's losses were confined to bridges, a stretch of highway and the erosion of some farm land with total losses being less than $60,000.

The Lunenburg portion of the Baker Brook flood plain was undeveloped in 1936 and only minor damage occurred.

23. RECURRING LOSSES

A recurrence of the record flood levels of 1936 would cause losses of over $24,000,000 in the North Nashua River Basin under current conditions. In contrast to 1936, a period of depressed economic activity, with many plants in the basin on part-time operation and some completely closed down, the basin today is in sound economic health.

24. ANNUAL LOSSES

Estimated recurring losses for each of the studied sub-reaches of the North Nashua River and Baker and Monoosnoc Brooks were converted to average annual losses by correlation of stage damage and stage frequency relationships to produce damage frequency data. Average annual flood losses, so derived, are tabulated below.

PRESENT AVERAGE ANNUAL FLOOD LOSSES

North Nashua River	$ 1,280,600
Baker Brook in Fitchburg-Lunenburg	48,300
Monoosnoc Brook	90,000

As discussed in paragraph 11f, for Baker Brook and the Nashua River flood plain in Leominster above Mechanic Street the demand for land is expected to be such that the plain will be completely built over by 1970. Adjusting the annual losses to reflect conditions expected in 1970 increase losses by the following:

Baker Brook	$ 25,900
North Nashua River	44,200

25. EXISTING CORPS OF ENGINEERS' FLOOD CONTROL PROJECTS IN MERRIMACK RIVER

There are no authorized Federal flood control reservoirs in the North Nashua River Basin and no existing Federal reservoirs affect flood levels in the basin. One local protection project is located in Fitchburg. The present system of flood protection in the entire Merrimack River Basin includes the following:

Project Dams and Reservoirs	Present Status
Blackwater	Completed
Edward MacDowell	Completed
Franklin Falls	Completed
Hopkinton-Everett	Completed

Local Protection

Fitchburg	Useful Life Expended (see Par. 26)
Haverhill	Completed
Lawrence	Inactive
Lincoln	Completed Under Emergency Authority of P. L. 99, 84th Congress
Lowell	Completed
Nashua	Completed

26. EXISTING LOCAL PROTECTION PROJECT AT FITCHBURG

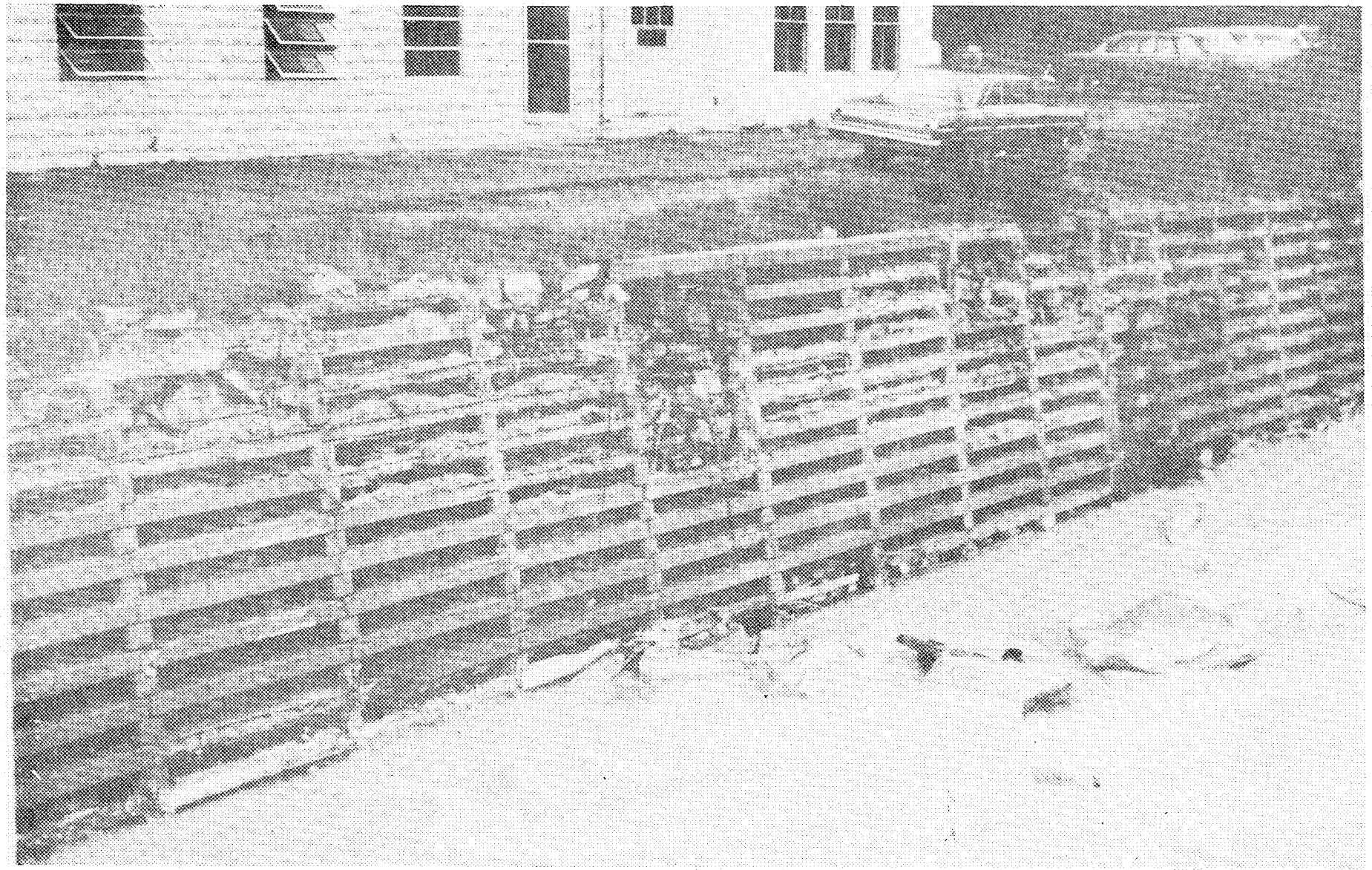
The existing protective works at Fitchburg were constructed following the disastrous flood of March 1936. The project extends along five miles of the North Nashua River from Cowees Dam (since removed) upstream of Oak Hill Road, downstream to the Fitchburg-Leominster Airport on Falulah Road just above the Leominster town line. The project was built at a total cost of $1,370,000. At several places earth banks were protected with concrete crib walls, at other locations the river bed and toes of the banks were protected against scour by grouted riprap. The work included channel enlargement, relocation of the outlet of Punch Brook, and removal of several abandoned dams. Under the assurances of local cooperation, the City of Fitchburg is responsible for operation and ordinary maintenance of the existing protection. Benefits attributed to the Fitchburg Local Protection since its completion in 1937 are estimated at approximately $6,000,000, or more than four times its initial cost. The project has physically deteriorated to the extent it no longer fulfills its design function.

a. Emergency Flood Relief - Significant losses occurred on the North Nashua River during the floods of 1955. Under the disaster relief authority of Public Law 875, 81st Congress, as amended, the Corps of Engineers restored the channel in some areas to its pre-flood condition, but no permanent improvements could be made under this authority. Gravel deposits and debris were removed from the stream bed and washed-out river bank slopes were filled. No repairs were made to deteriorated concrete cribbing.

27. IMPROVEMENTS BY OTHER FEDERAL AND NON-FEDERAL AGENCIES

No other Federal agencies have constructed projects for flood control or other beneficial use of water in the North Nashua River Basin. There are no existing projects for flood control or related purposes for the study area by non-Federal agencies.

CONDITION OF EXISTING PROJECT. Typical Grouted Rip-Rap Failures. Photograph taken in 1963.



CONDITION OF EXISTING PROJECT. Crib deterioration at Upper River St. Photograph taken in 1963.

28. IMPROVEMENTS DESIRED

A public hearing with respect to flood control and allied purposes for the study area was held in Fitchburg on 13 November 1962. Approximately 50 persons attended, including representatives of Federal, State and municipal governments, industrial and agricultural interests, civic organizations, and interested individuals. Municipal officials and industrial leaders of Fitchburg expressed the need for additional flood protective measures, the restoration of the existing local flood protection project, and for resource development to meet needs for water supply, recreation, and water quality control. The Massachusetts Department of Natural Resources, through its Water Resources Commission, expressed a strong desire for improvements for flood control and allied purposes and for development of related water resources, including water supply, general recreation, and fish and wildlife resources. A digest of the public hearing is included as Attachment I of Appendix J.

SECTION VIII

THE WATER SUPPLY PROBLEM

29. GENERAL

The cities of Fitchburg and Leominster and towns of Lunenburg and Shirley which comprise the Fitchburg-Leominster SMSA, each have their own separate municipal water supply system. Shirley and Lunenburg utilize groundwater sources which are adequate for their present needs. Fitchburg uses several surface water sources and Leominster utilizes both surface and groundwater sources. The water supply needs which are anticipated to be met by the Fitchburg and Leominster water supply systems have been considered in this report since the smaller communities, in general, have adequate water sources at this time.

The water which races through the North Nashua River in times of flooding is often in short supply to meet the growing demands of domestic and industrial water usage. In 1962, per capita consumption of 239 gallons in Fitchburg and 286 gallons in Leominster were the highest in the state, practically double the comparable rate for cities of similar size and industrial base. Present sources of water supply are inadequate to meet current demand. If the economies of Fitchburg and Leominster with their heavy industrial bases are to continue to prosper, additional sources of water supply must be developed. The North Nashua River and its tributaries furnish opportunities to provide additional surface water supplies. Discussion of proposed plans is contained in Section XIII.

30. INDUSTRIAL AND MUNICIPAL WATER REQUIREMENTS

Future water requirements for municipal, industrial and water quality control purposes in the North Nashua River basin have been estimated by the U. S. Public Health Service to the year 2020.

a. Fitchburg. - Fitchburg has four surface water sources of supply which provide a safe yield of 9.4 million gals. per day (mgd). The average water consumption in 1957 was 8.7 mgd, or 204 gal./cap./day, and in 1962 it was 10.3 mgd, or 239 gal./cap./day, representing a 17 percent increase in five years and resulting in a safe yield deficit of 0.9 mgd. Nine industrial plants in the City of Fitchburg alone account for over 1/3 of Fitchburg's 10 mgd public demand and the load would be much higher if the larger paper making producers did not have their own water supply. The anticipated water requirements for the City of Fitchburg is 333 gal./cap./day, or 17.0 mgd by the year 1970 and 378 gal./cap./day or 20.8 mgd by year 2020, which is 10.5 mgd more than the safe yield from existing sources. It is evident that the City of Fitchburg needs to develop new dependable sources of water supply in the immediate future.

b. Leominster. - Leominster has three surface sources of water supply and two ground-water sources. The surface water sources yield about 5.7 mgd and the ground-water sources have a safe draft of 1.9 mgd, which together provide the city with a safe yield of 7.6 mgd. The average daily consumption in 1962, under restricted water use, was 8.0 mgd or 286 gal./cap./day. Before restrictions were imposed, the average daily consumption was 10 mgd, with 14 mgd being the demand on the peak day. In 1957, the average daily consumption was 5.6 mgd, or 224 gal./cap./day, which shows an increase by 1962 of nearly 28 percent. The large per capita consumption of water and the increase in consumption are due to the heavy use of municipally supplied water for cooling and other processes by the plastics industry. The industrial use of water in Leominster accounted for approximately two-thirds of the average daily water production in 1962. In order to satisfy the demands for municipal water in Leominster, it is necessary to develop additional dependable water supply sources. The anticipated total demand for the years 2020 and 2070 are 16.8 and 22.7 mgd with corresponding per capita consumptions of 375 and 422 gals. per capita per day. This latter figure represents demands of 14.7 mgd greater than the dependable yield available in Leominster today.

c. Industrial Water from Other Sources. - The paper and allied products companies along the North Nashua River utilize the river flow for process water in the manufacture of their products. A substantial amount of the flow in the river during dry periods is supplied by the outflow from an industrial water supply source that has been developed by the Crocker-Burbank Paper Company. In the normal process of industrial expansion more water storage will be required in future years.

The proposed reservoir plan provides for maximum utilization of the surface water resources available in the proposed reservoir sites. This would develop more than one billion gallons of storage for municipal and industrial purposes. The dependable yield of this projected storage is an additional demand on the water resources of the North Nashua River basin. This demand is in addition to the municipal and industrial water projection previously cited for the cities of Fitchburg and Leominster.

SECTION IX

THE POLLUTION PROBLEM

31. PRESENT STREAM QUALITY

Although the waters entering from its tributaries are of good to excellent quality, the North Nashua River is grossly polluted. The primary cause of the condition is the discharge of industrial wastes, principally paper wastes along its upper and middle reaches. The New England-New York Inter-Agency Committee's Report on the Merrimack River Basin, issued in 1956, noted that this stretch of the river had the lowest water quality rating and stated that in critical periods of low flows and high temperatures, nuisance conditions prevail. Little or no improvement in water quality has occurred in the intervening period and today, even in times of normal flow, the water is multi-colored, turbid, and generally offensive. In the fall of 1962, the Massachusetts Department of Public Health published results on stream quality based upon an effluent survey and stream data. In a more recent evaluation of waste loadings to the North Nashua and Nashua Rivers, the National Council for Stream Improvement of the Pulp, Paper and Paperboard Industries, Inc., in conjunction with the Massachusetts Department of Public Health performed a study and published a report regarding the present and future conditions of the river. Classification studies are now underway under the supervision of the New England Interstate Water Pollution Control Commission. Documentation of the pollution problem is contained in Appendix G of this report.

32. EXISTING TREATMENT FACILITIES

Four municipalities along the North Nashua and Nashua Rivers between Snows Mill Pond and Pepperell have pollution abatement facilities that treat domestic sewage and some industrial wastes. They are Fitchburg and Leominster, Clinton and Ayer, each of which provides secondary treatment or its equivalent. In addition to this, there are several private institutions which discharge small amounts of treated wastes to the water course. In contrast, the majority of the industrial wastes along the North Nashua River are discharged in an untreated condition to the river. Wastes from the paper and allied products companies constitute the prime source of pollution in the area. Improvement of the water quality in the main stem North Nashua and Nashua Rivers thus depends principally on adequate treatment measures for industrial pollution.

33. POTENTIAL SECONDARY TREATMENT RESULTS

Based on the 1963 pollution loadings, it is expected that secondary treatment of all wastes from Snows Mill Pond on the Whitman River to East Pepperell on the Nashua River, would raise the water quality to a Class D condition if the river flow measured at the Leominster gage is maintained above 60 cfs at all times. A Class D water condition, as defined by the New England Water Pollution Control Commission, is "suitable for transportation of sewage and industrial wastes without nuisance, and for power, navigation, and certain industrial uses." Such water would contain dissolved oxygen, no objectionable oils and greases, no objectionable odors, scum, floating solids, and debris, no objectionable sludge deposits, color, and turbidity, and be free from toxic materials in dangerous concentrations, and be free from objectionable amounts of free acids and alkalies.

SECTION X

STREAMFLOW REGULATION FOR QUALITY CONTROL

34. GENERAL

Fourth of the problem categories in Fitchburg is inadequate flow in dry periods. Low flow is a contributing factor and magnifies two associated problem areas, water supply and pollution. At frequent intervals in the past, the flow in the river has diminished to the point where it was inadequate to carry off its load of wastes. When this occurs, suspended

solids deposit on channel bottoms and sides, bridge abutments and other exposed surfaces. If the low flow is coincident with periods of high temperature, nuisance conditions result. Industry along the river also suffers in periods of low flow through a deficiency in supply of water for cooling, power generation, processing and fire protection (sprinklers). While the total water withdrawn for these purposes is not great, diminution in the supply adversely affects the plant operation. Augmentation of flows by controlled releases from multiple-purpose reservoirs can, to a limited degree, help alleviate the deficiency in supply.

35. DILUTION WATER REQUIREMENTS

Based on preliminary calculations by the U. S. Public Health Service, it is estimated that secondary treatment of all wastes and a minimum flow maintained at 107 and 120 c. f. s. at Leominster U. S. G. S. gauge on the North Nashua River will be required for the year 2020 and 2070 respectively to raise the water quality to a Class C condition (suitable for recreational boating, habitat for wildlife) from Snows Mill Pond to East Pepperell. Additional improvements in water quality can also be expected as the accumulated sludge banks are flushed downstream and assimilated by natural stream recovery processes.

36. DEMAND ON STORAGE

Studies by the U. S. Public Health Service indicate a storage requirement of about 22,500 acre-feet in 2020 and 25,000 acre-feet in 2070 would be needed to provide the dependable flow needed at the Leominster gauge to raise the water quality to Class C. Site limitations restrict the inclusion of this amount of storage in considered reservoirs or in any other known available source within the basin.

SECTION XI

OTHER PROBLEMS AND NEEDS

37. RECREATION

With the continued trend toward a shorter work week, more time becomes available to participate in outdoor recreation. This increase brings greater pressure upon existing facilities and permits development of new recreation areas. Studies show that generally most people will drive to areas within about a 40-mile radius, or an hour's driving time for after

work and day-use activity. Areas adaptable to high density recreation are usually close to urban complexes. Based on a 1960 State Census, the number of persons residing within 10 miles of the study area has been recorded at 116,000, about 270,000 within 20 miles, and 1.8 million within 40 miles. Although there are some opportunities within a 40-mile radius of the study area, there are residents of many other cities competing for the use of these recreation areas. Little public recreation opportunity exists within 10 miles of the Fitchburg-Leominster SMSA. Municipal parks within the cities of Fitchburg and Leominster accommodate urban type recreation. Willard Brook State Forest has limited swimming and picnicking facilities and is located about six miles north of the City of Fitchburg. Mount Wachusetts Reservation and Leominster State Forest afford some land based recreation opportunities to the south. Several lakes and reservoirs in the North Nashua River Basin provide boating and fishing, primarily for privately-owned development. No areas exist in the North Nashua River Basin, Baker or Monoosnoc Brook tributaries which offer public outdoor recreation. The construction of water resources structures provide opportunities for development of the recreation resources. In this connection, investigations made by the National Park Service reveal opportunities exist for the inclusion of recreation as a project purpose in considered reservoir projects.

38. FORESTATION AND SOIL CONSERVATION

The paper industries within the study area are engaged in manufacturing processes concerned primarily with finished paper products. Consequently, ground wood pulp is imported from outside suppliers and there is little demand upon local forest resources. The projected expansion of the local paper industries will be adequately supported by large groundwood suppliers in the States of Maine, New Hampshire and Vermont. Department of Agriculture studies indicate that in view of the urbanized nature of the watershed, there is little need or opportunity for construction of retention structures for the purpose of land conservation. Reservoirs for flood control and allied purposes considered in this report will, in fact, reduce erosive flood flows.

39. FISH AND WILDLIFE

Wildlife species in the North Nashua Basin area consist principally of cottontail, grey squirrel, pheasant, ruffed grouse, and woodcock. White tail deer also occur within the project area. The U. S. Fish & Wildlife Service reports that wildlife resources in the study area will not be adversely

affected by the construction of upstream reservoirs nor by channel improvements. There are no significant opportunities for the enhancement of wildlife resources. Phillips Brook tributary in the Towns of Ashburnham, Westminster and the city of Fitchburg is stocked annually on a "put-and-take" basis with about 3,100 brook trout and 360 brown trout. Phillips Brook supports approximately 4,000 man-days of fishing annually. Stocking of the Whitman River tributary was discontinued after 1956 because of extensive land posting. The Falulah Brook tributary of Baker Brook is stocked annually below Greens Pond in Fitchburg with 500 brook trout. Other streams in this drainage area have negligible fishery values. At the present time, the North Nashua River in the business sections of Fitchburg and Leominster is virtually without sport fishery. The pollution problem is of sufficient magnitude to prevent such establishment at this time. Investigations performed by the U. S. Fish and Wildlife reveal that proposed dams would not adversely affect the existing "put-and take" trout fishery of Phillips Brook because stocking is confined to stream locations above proposed sites.

40. HYDROELECTRIC POWER

Electric power requirements in the area are supplied by the Fitchburg Gas and Electric Company and the Massachusetts Electric Company. Hydroelectric power development of the conventional type at available sites in the study area is impractical because of the small drainage area, head, and streamflows.

SECTION XII

SOLUTIONS CONSIDERED

41. SOLUTION TO THE FLOOD PROBLEM

Alleviation of the flood problem could be accomplished through construction of flood control reservoirs; channel diversion and relocation; levees and improved channels for the protection of local damage centers; or a combination of reservoirs and local protection works. Restrictive zoning measures or evacuation of the flood plain are impractical due to the highly developed nature of the flood plain.

a. Flood Control Reservoirs. - A total of 10 sites having topographic features which favor the construction of reservoirs of sufficient capacity to effectively modify flood flows were investigated. Four of the

sites were found to provide opportunity for development on the basis of their topography, geology, accessibility, storage capacity and costs. The four sites are located as follows: One on the Whitman River about five miles west of the center of Fitchburg on South Ashburnham Road; two on Phillips Brook, one about 2-3/4 miles north of Fitchburg center on Route 12, the other about 1/2 mile north of the confluence of the North Nashua River, also adjacent to Route 12; and one on Monoosnoc Brook about 1-1/2 miles west of Leominster and 3-3/4 miles southeast of Fitchburg. These reservoirs were studied in relation to the flood stage reductions provided by each, singly and in various combinations.

In addition, three reservoir sites were studied on the Baker Brook watershed which offer opportunity for future development. One reservoir is located on Pearl Hill Brook in Lunenburg about 1-3/4 miles northeast of the center of Fitchburg; and two on Falulah Brook, the first four miles northwest of the city on Rindge Road, and the second on an unnamed tributary stream of Falulah Brook about $2\frac{1}{2}$ miles north of the city adjacent to Route 31.

b. Local Protection Work. - Studies demonstrated the desirability of three local protection projects located as follows, and described more fully in Paragraph 54.

(1) Rehabilitation of Project Constructed with Work Relief Funds - Complete reconstruction of channel works.

(2) Channel Improvements on Baker Brook - At two zones extending for a distance of 6,800 feet.

(3) Channel Improvements on Monoosnoc Brook - At two zones extending for a distance of 3,600 feet.

c. Alternate Plans - North Nashua River. - All practicable means of solving the flood problem in the study area were considered. These included construction of physical measures such as reservoirs, channel improvement and construction of dikes and flood walls. Evacuation of the flood plain and flood plain zoning procedures are deemed impractical due to the extensive and costly development of the flood plain. The only method found worthy of detailed study consisted of upstream reservoirs in combination with channel restoration. Construction of sufficient upstream reservoirs on the North Nashua River to reduce flood stages to channel capacity in a project design flood was found to have a high flood control benefit-to-cost ratio, as well as providing an opportunity to maximize the use of the water resources through development for water supply and other purposes.

42. SOLUTION TO THE WATER SUPPLY PROBLEM

a. Fitchburg's Existing Domestic and Industrial Water Supply. - Water use in the North Nashua River watershed has increased at a greater rate than the population growth. Continuation of this trend is anticipated due to the proposed expansion of paper and plastic industries. Distribution through the Fitchburg Water Department system has quadrupled in the past 25 years, and the U. S. Public Health Service forecasts a continued increase in water usage. The water supply problem is heightened by the fact that there are insufficient untapped surface sources available in the watershed to meet this forecast need. Without the industrial water storage that is in existence, owned and operated by the paper industries, the municipal water department could not meet the needs of other local industries, many of which would be forced to suspend operations. The greatest needs for industrial water supply are required by the paper industries which hold in reserve their own supply of about 1,500 million gallons and use about 12 mgd from this source. Industrial water supply is also provided by the Fitchburg Water Department for industries other than paper manufacturing. Fitchburg's demand has already exceeded the safe minimum yield of its water sources and expansion of supplies is necessary. Approximately 50,000 people obtain their water from ground and surface sources. Fitchburg and two nearby towns, Westminster and Shirley, are served by the Fitchburg Water Department which furnishes an average supply of about 10 mgd. There is insufficient domestic water to permit the extension of this service to other nearby towns, or to meet anticipated further demands of the existing supply area.

b. Leominster Water Supply. - Major portions of the existing ground and surface water supplies are utilized by the plastic industry, with future projections indicating an evern greater need for water by these industries. Leominster is currently exceeding its safe yield and is contemplating entering the system of the Metropolitan District Commission which could provide existing and a portion of future needs.

c. Dams and Reservoirs. - Studies indicated the suitability of five sites for water supply, all multiple-purpose containing flood control storage. Insufficient flood control benefits are, however, available at this time for the two water supply sites referred to as Shattuck and Pearl Hill, to permit Federal participation. These areas should be reserved for water supply purposes for later consideration. Multiple-purpose development for water supply and flood control purposes appears warranted at this time at Nookagee, Whitmanville, and Monoosnoc sites. The safe dependable yield from water supply storage provided by these latter three reservoirs would exceed

10 m. g. d. and would increase to 13 m. g. d. with the inclusion of Shattuck and Pearl Hill reservoirs. The five considered multi-purpose reservoirs which could contribute significantly in the solution of the water supply problem are listed below.

(1) Nookagee - Includes features for flood control, water supply and recreation. Water supply storage would provide a safe yield at 90 and 98% dependability of 3. 8 and 3. 5 m. g. d. respectively.

(2) Whitmanville - Includes provision for flood control and water supply storage which would provide a safe yield at 90 and 98% dependability of 2. 4 and 2. 2 m. g. d. respectively.

(3) Monoosnoc - Includes features for flood control, water supply and recreation. Water supply storage would provide a safe yield at 90 and 98% dependability of 1. 5 and 1. 4 m. g. d. respectively.

(4) Shattuck and Pearl Hill - Offer opportunity for future development for flood control and water supply with combined storage affording a safe yield at 90 and 98% dependability of 2. 5 and 2. 3 m. g. d. respectively.

43. WATER QUALITY IMPROVEMENT

The two possible methods of reducing the pollution load in the North Nashua River are by treatment of wastes at their source and by dilution of the discharge waste through increased stream flow.

a. Treatment at Source. - The treatment of wastes at their source is an essential element of pollution reduction and is the responsibility of local agencies. Present technology permits a high degree of treatment of domestic sewage and many industrial wastes. Further treatment of these wastes could, at a considerable cost, virtually eliminate these pollutants from the stream. A few years ago primary treatment units were installed at several paper mills, however, this type of treatment has been found to be inadequate. Pilot plant improvement studies are presently in progress but certain colored wastes and persistent chemicals typical of paper mill discharges and acid mine wastes are not susceptible to existing or foreseeable practical methods of treatment according to a study made by the U. S. Public Health Service.

b. Incidental Dilution from Water Supply. - Dilution is often a practical method of controlling nuisance from the colored wastes and persistent chemicals discharged into water courses. In controlling these factors,

dissolved oxygen objectives of the existing and contemplated stream standards are also reached if secondary treatment is accomplished at major pollution sources. On this basis, water quality improvement becomes largely a water supply problem. Water supply storage will, because of its release during dry periods, have some beneficial effect on low-flow discharges. Because of the location of the paper industries with relation to the proposed water supply storage at Nookagee and Whitmanville Reservoirs, the prime beneficiary of this supply is the determinable factor and consequently, local cost sharing is considered equitable.

c. Dilution from Low-Flow Augmentation. - Existing storage in the North Nashua River above the U. S. G. S. gage station at Leominster indicates low flows based on 90 and 98 percent dependability, of 34 and 32 c. f. s. respectively. Studies by the U. S. Public Health Service indicate that the storage volumes needed to provide stream flows for adequate dilution to effect a major change in stream classification cannot be satisfied from the total of the proposed and deferred Federal projects in the basin. However, applying releases from proposed water supply storage of recommended projects based on 90 and 98 percent dependability will increase flows at the gage to 85 and 75 c. f. s. respectively.

44. OTHER PROBLEM SOLUTIONS

a. Recreation. - Provisions for recreation facilities, such as beaches, boat-launching ramps, camping areas, sanitary facilities and picnic areas on the land bordering a reservoir, will create opportunities for many recreation activities. Investigations of the recreation opportunities offered by reservoirs were made by Corps' personnel augmented with studies by the National Park Service.

b. Soil Conservation. - Owing to the limited agricultural area within the watershed studies and the urbanized character of the protected area, there are no retention structures included for soil conservation purposes. The Department of Agriculture has reported that the proposed resource plan will have no adverse affect upon their program.

c. Fish and Wildlife. - Investigations made by the U. S. Fish and Wildlife Service in cooperation with the Massachusetts Fish and Game Agency, indicate that the reduction of pollution and the increase in low flow provided by reservoirs would improve existing fisheries. The fishing resources downstream of studied reservoirs are practically non-existent owing to the polluted waters. Upstream of the proposed dams, the greater reservoir areas will promote 11,600 fisherman-days, divided among Nookagee and Monoosnoc Reservoirs.

d. Hydroelectric Power. - Owing to the small drainage areas there are no economic conventional hydroelectric power sites.

45. MULTIPLE-PURPOSE SOLUTIONS

The basic requirements for water supply and recreation all depend on the maintenance of stream flow and water surface area, and they can be readily combined. In plans for flood control, consideration was given to all related water resource improvements that might be affected by the plan or coordinated with the proposed works. All reservoirs studied for a single-purpose were also analyzed as multiple-purpose projects. On the Whitman River and Phillips Brook tributaries of the North Nashua River it was possible to incorporate flood control storage and industrial water supply. In addition, recreational development is a desirable purpose at Nookagee Reservoir. On the Baker Brook tributary, it was possible to incorporate flood control, municipal water supply and recreation. Reservoir projects in the Baker Brook watershed are proposed for future construction owing to insufficient need of the flood control component at this time. At Monoosnoc Brook Reservoir, it is possible to incorporate features for flood control, recreation and water supply. Multiple-purpose development of reservoir sites results in the maximum utilization of the water resources of the North Nashua River.

SECTION XIII

WATER RESOURCE PLAN

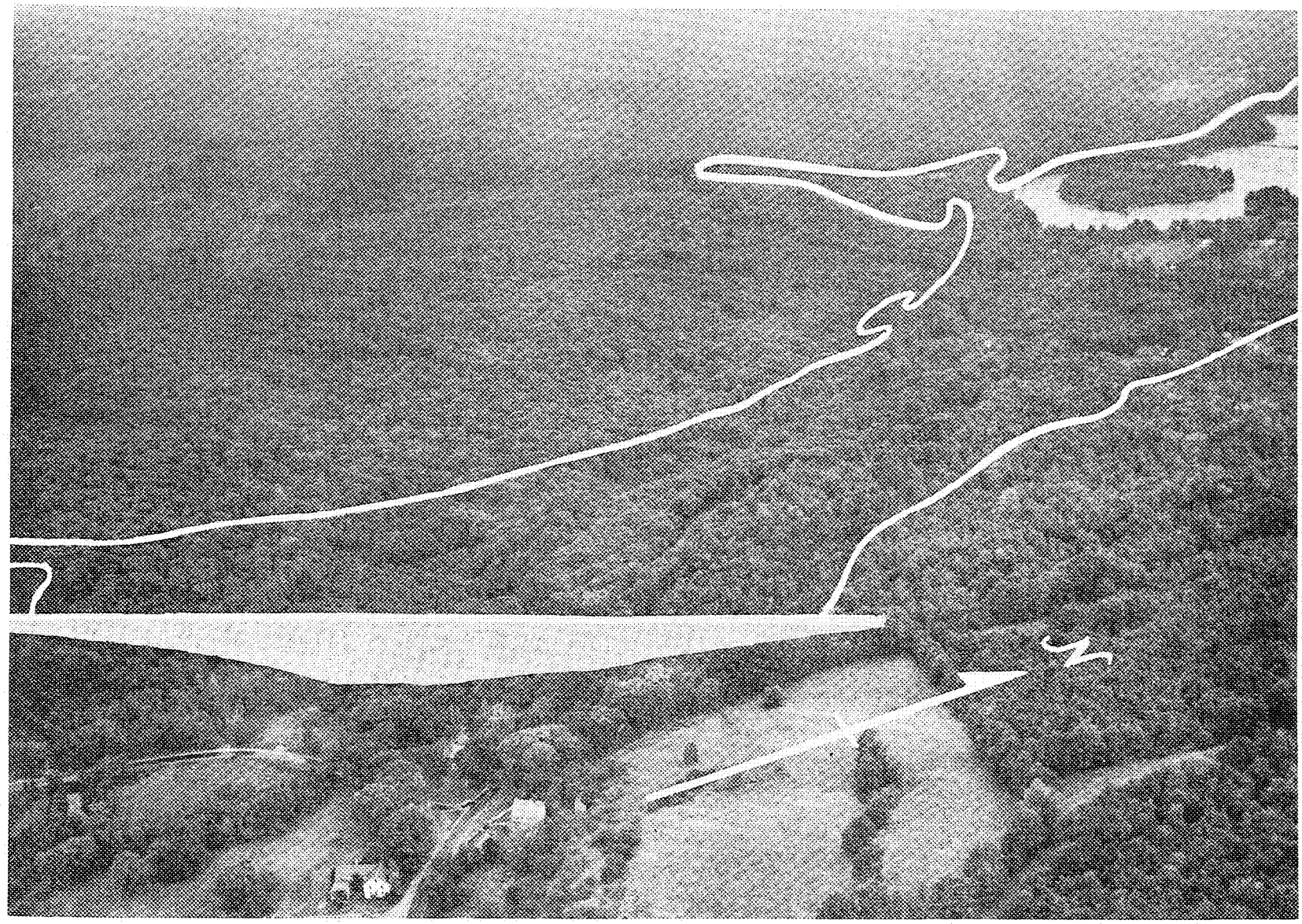
46. GENERAL

The proposed water resource development plan consists of seven dams and three channel projects located in the North Nashua River, Baker and Monoosnoc Brooks, all tributaries of the Merrimack River Basin. The improvements are divided into ten separate work areas. Plate No. 1 shows the location of the reservoirs and local protection projects, and a summary of data pertinent to the reservoir projects is given on Table 2 and 3. The water resource plan would provide protection from floods of standard project magnitude along the industrialized portion of the North Nashua River basin and along a $2\frac{1}{2}$ mile reach of Baker Brook in Fitchburg. In addition, the plan would provide protection from a flood greater than the flood of record for two miles along Monoosnoc Brook in Leominster. The plan would also fully develop the proposed reservoir sites for other uses including municipal and industrial water supply, recreation, and fish and wildlife, and would provide for the rehabilitation of the existing flood control project, which during its life span of 28 years has prevented damages equal to three times the cost of its construction.

TABLE 2
PERTINENT DATA
RESERVOIR PROJECTS PROPOSED FOR IMMEDIATE CONSTRUCTION

Feature	Whitmanville	Nookagee	Phillips	Monoosnoc
Purpose (1)	FC & WS	FC, WS& R	FC	FC, WS & R
Drainage Area (Net)	17.5	11.0	5.0	2.5
Elevations (ft., msl)				
Top of Dam	860	848	690	583
Flood Control Pool				
(spillway crest)	845	835	675	573
Surface Area, Acres	420	295	105	90
Water Supply Pool				
(spillway crest)	824	815	-	563
Surface Area, Acres	200	170	-	57
Recreation Pool				
(spillway crest min.)	-	790	-	563
Surface Area, (min.) acres	-	50	-	57
Dam				
Type of Dam	Earth Fill	Earth Fill	Earth Fill	Earth Fill
Length of Dam, ft.	1,470	2,150	1,700	2,000
Max. Height, ft.	76	106	48	71
Top Width, ft.	20	25	25	25
Spillway				
Type	Chute	Side Chan.	Chute	Chute
Location	Lf. Abt.	Lf. Abt.	Lf. Abt.	Saddle
Crest Length, ft.	200	205	200	90
Design Discharge, cfs	25,200	15,900	24,700	3,800
Outlet Conduits				
Flood Control				
Length	26	200	260	200
Inside Diameter	4' x 3'	48"	54"	24"
Water Supply				
Length	310'	470'	-	512'
Inside Diameter	24"	24"	-	-
Reservoir Storage				
Flood Control, ac. ft.	6,700	4,700	1,600	800
Water Supply, ac. ft.	2,650	2,600	-	1,200
Recreation, ac. ft.	-	800	-	-
Flood Control, runoff	7.2"	8.0"	6.0"	6.0"
Water Supply, runoff	2.8"	4.4"	-	9.0"
Recreation, runoff	-	1.4"	-	-

(1) FC = Flood Control; WS = Water Supply; R = Recreation



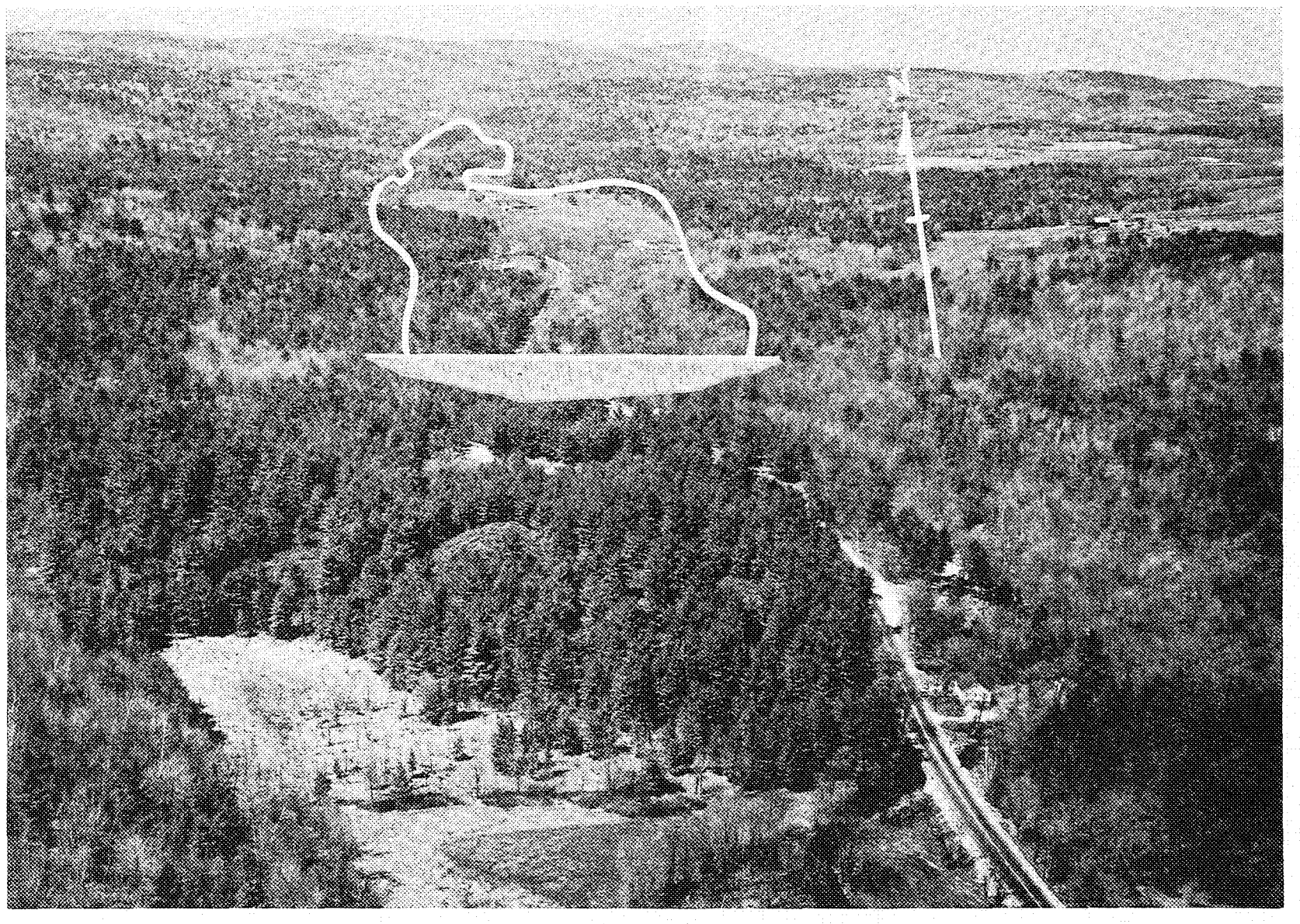
Whitmanville Dam and Reservoir
Looking upstream

47. WHITMANVILLE DAM AND RESERVOIR

The Whitmanville Dam site, located on the Whitman River in Westminster about 2.8 miles north of the Village of Westminster and five miles west of the center of Fitchburg, will control a tributary drainage area of 17.5 square miles. The reservoir at spillway crest (elevation 845 m. s. l.) will have a surface area of approximately 420 acres and will extend upstream about $2\frac{1}{2}$ miles. It will inundate an existing industrial water supply dam and reservoir, referred to as Westminster Reservoir, located about 3/4 mile upstream of the proposed Whitmanville Dam. The existing Westminster Dam structure will be removed. The dual-purpose reservoir will have a storage capacity of 9,350 square feet of which 2,650 acre-feet (including replacement of 1,120 acre-feet of existing water supply storage) equivalent to 2.8 inches of runoff, will be utilized for industrial water supply; and 6,700 acre-feet, or 7.2 inches of runoff will be reserved for flood control. The dam, with a top elevation of 860 feet will be of rolled earth fill construction, approximately 1,500 feet long(in cluding spillway) with a maximum height of 76 feet. A concrete chute spillway having an ogee weir 200 feet long and a crest elevation at 845 m. s. l. will be founded on rock at the left bank. An ungated 4'x3' conduit formed integrally with the spillway serves a flood control outlet and also maintains the water supply pool at elevation 824. An intake tower with two 2'x2' gated outlets at elevation 785 and 790 regulates the water supply outflow. A single 4'x7' emergency gate capable of being operated at the same level will be located within the intake structure immediately upstream from the service gates. South Asburnham Road, which will be intersected by the dam and inundated by the reservoir, will be relocated along the left bank of the reservoir. Construction of a flank dike along the right bank of the dam about 300 feet long having a maximum height of four feet will also be required. Total estimated cost is $3,840,000.

48. NOOKAGEE DAM AND RESERVOIR

The Nookagee Dam site is located on Phillips Brook in the northeast corner of Westminster about 3.6 miles northwest of Fitchburg center and three miles southeast of Asburnham and controls a tributary drainage area of 11.0 square miles. The multi-purpose reservoir plan provides storage for flood control, industrial water supply, and includes a day-use, park-type recreation development containing facilities for swimming, picnicking and fishing. The reservoir at elevation 835 m. s. l. will have a surface area of approximately 300 acres at spillway crest and extend about 1.5 miles up Phillips Brook. The water supply pool with a surface elevation of 815 feet m. s. l., and a surface area of 170 acres will have a storage

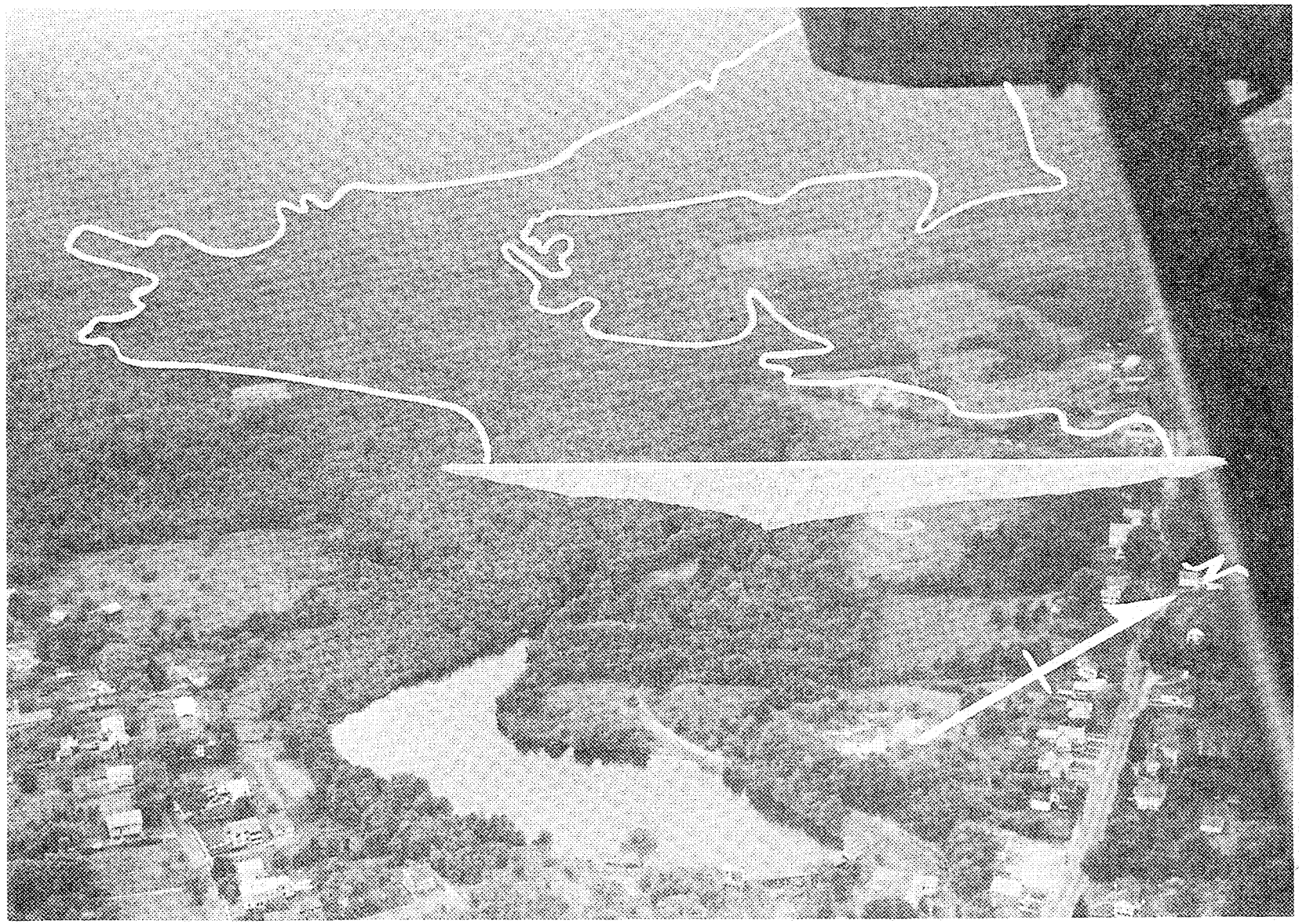


Nookagee Dam and Reservoir
Looking Upstream

capacity of 2,600 acre-feet, equivalent to 4.4 inches of runoff. The flood control storage capacity will be 4,700 acre-feet, equivalent to 8.0 inches of runoff. In addition, a minimum of 1.4" of runoff equivalent to 800 acre-feet will be available for recreational development. The dam, with a top elevation of 848 feet, will be of rolled, earth-fill construction approximately 2,150 feet long (including spillway) with a maximum height of 106 feet. A concrete side channel spillway with an ogee weir 205 feet long at elevation 835 will be founded on rock at the left bank. At elevation 815 feet m.s.l. a concrete drop inlet structure with a 48-inch reinforced concrete pipe will serve as an uncontrolled outlet maintaining the water supply pool at that elevation. An intake tower with two 2-foot gated outlets having invert elevations of 765 and 770 will regulate the water supply outflow. A single 4-foot by 7-foot emergency gate capable of being operated at the same level will be located within the intake structure immediately upstream from the service gate. Asburnham Street (Massachusetts Route 12) will be relocated along the left bank for a distance of approximately 1-3/4 miles. The Nookagee Reservoir will provide for substantial recreation use as an integral part of the water resource development of the water supply pool. Based on an analysis of past flows of record at Phillips Brook, it is anticipated that the water surface would be maintained above elevation 810 (140 acres) in an average year during the summer recreation season of June, July and August. Total estimated cost is $5,430,000.

49. PHILLIPS DAM AND RESERVOIR

The Phillips Dam site is located on Phillips Brook in West Fitchburg about ½ mile north of its confluence with the North Nashua River and about two miles south of Nookagee Dam. The dam at spillway crest, elevation 675, will create a reservoir about 3/4 mile upstream and provide a surface area of about 105 acres at that elevation. The reservoir will have a storage capacity of 1,600 acre-feet, the equivalent of six inches of runoff from a net drainage area of five square miles. The dam, with a top elevation of 690 feet m.s.l., will be of rolled, earth fill construction approximately 1,700 (including spillway) feet long having a maximum height of 48 feet. At elevation 675, a chute spillway with an ogee weir 200 feet long will be founded on rock on the left bank. A concrete inlet structure with an ungated 54-inch opening having an invert elevation of 643, will conduct normal river flows. A portion of Route 12 will be raised and incorporated into the main dam. Total estimated cost is $2,320,000.



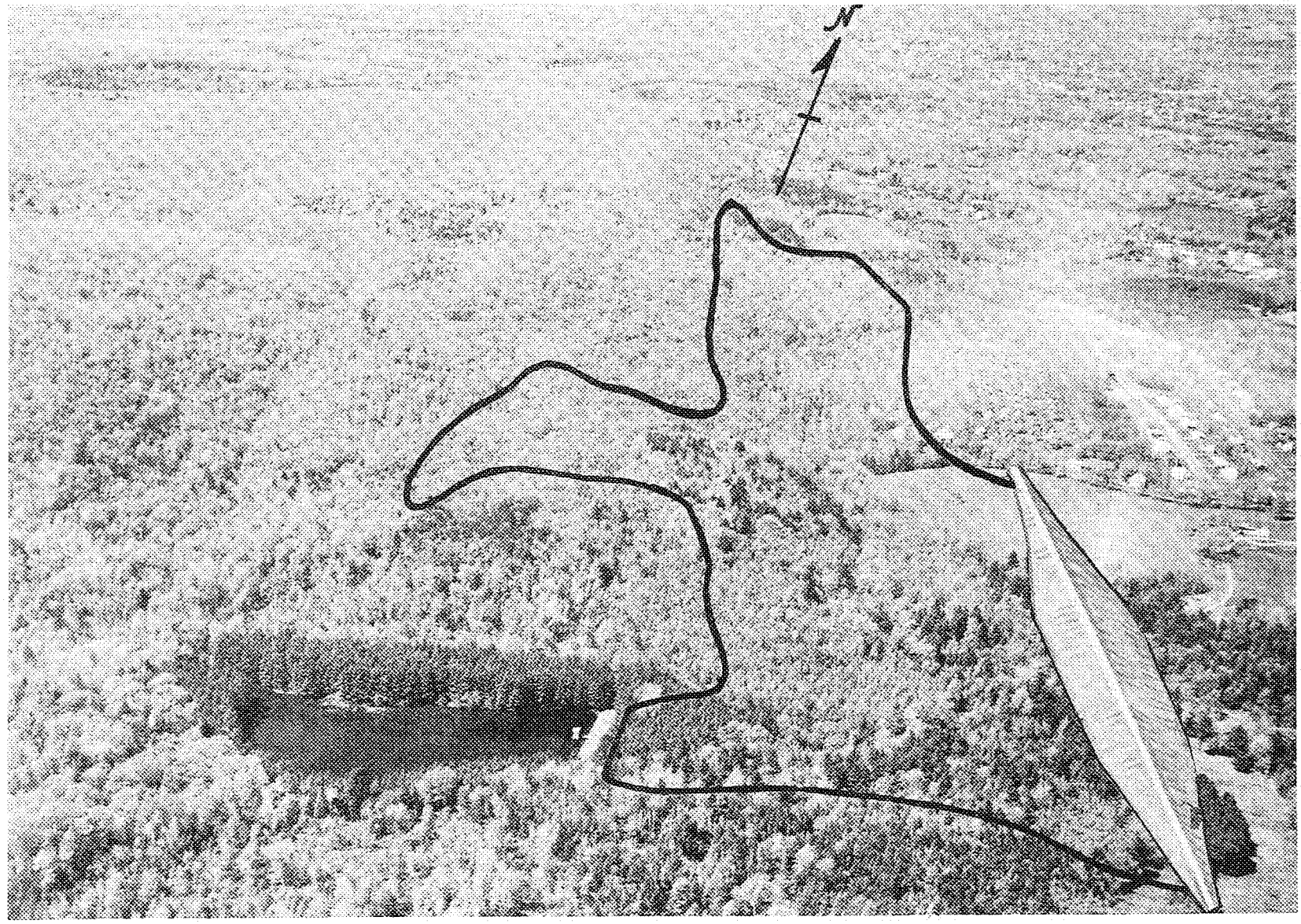
Phillips Dam and Reservoir
Looking Upstream

50. MONOOSNOC DAM AND RESERVOIR

The Monoosnoc Dam site is located on a tributary stream of Monoosnoc Brook in Leominster about $1\frac{1}{2}$ miles west of the city proper. The multiple-purpose flood control, recreation, and water supply reservoir will extend about 1.2 miles upstream and at the spillway crest elevation of 573 m. s. l. will have a surface area of approximately 90 acres. The reservoir will provide a storage capacity of 2,000 acre-feet of which 1,200 acre-feet equivalent to nine inches of runoff and affording a surface area of 57 acres at elevation 563 m. s. l., will be jointly utilized for recreation and water supply storage. The remaining 800 acre-feet, equivalent to six inches of runoff, will be reserved for flood control. The 57-acre permanent pool offers opportunity for development of public outdoor recreation and includes day-use, park-type recreation containing facilities for swimming, picnicking, and fishing. Drawdown for water supply purposes will be utilized as warranted. The normal maximum draw would be about three feet during the summer recreation season. Monoosnoc Dam will control a tributary drainage area of 2.5 square miles with a top elevation of 583 feet m. s. l. and be of rolled, earth fill construction approximately 2,000 feet long (main dam) with a maximum height of 71 feet. A concrete chute spillway having an ogee weir 90 feet long at elevation 573 feet m. s. l. will be founded on till in the natural saddle between North Monoosnoc Hill and Carter Hill. At elevation 563, a concrete drop inlet structure with an ungated 24-inch reinforced concrete pipe will discharge through the dam and serve as a flood control outlet, maintaining the recreation and water supply pools at that elevation. An intake tower with a 24-inch gated outlet at elevation 513 for draining the recreation pool and for regulating outflow for water supply purposes is included. Construction of a flank dike about 150 feet long with a maximum height of eight feet at the upstream end of the reservoir will also be required. Total estimated cost is $2,610,000.

51. SHATTUCK DAM AND RESERVOIR

A multi-purpose flood control and municipal water supply dam is proposed for future construction at this site. The Shattuck site is located on Falulah Brook about 3.5 miles north of Fitchburg center and 1.3 miles north of the existing Lovell Reservoir Dam, which is currently a part of the domestic water supply system for the City of Fitchburg. The reservoir at spillway crest, elevation 931, would extend about 3,100 feet upstream with a surface area of about 90 acres and would provide a storage capacity of 2,340 acre-feet. Of this amount, 1,080 acre-feet, equivalent to 5.4 inches of runoff, would be utilized for water supply, and 1,260 acre-feet, or 6.3



Monoosnoc Hill Dam and Reservoir
Looking North

inches of runoff, for flood control storage. At elevation 912 feet m. s. l. the water supply pool would have a surface area of 54 acres. Shattuck Dam would control a tributary drainage area of 3.8 square miles. The dam, with a top elevation of 946 feet m. s. l., would be of rolled, earth-fill construction 1,970 feet long, (including spillway) and have a maximum height of 78 feet. A concrete chute spillway with an ogee weir 60 feet long at elevation 931, would be founded on rock at the right bank. At elevation 912, a concrete drop inlet and a 48-inch reinforced concrete pipe would serve as an uncontrolled outlet and would maintain the water supply at that elevation. A 24-inch gated outlet at elevation 870 would regulate the water supply outflow. Portions of Rindge Road would be relocated along the right side of the reservoir. Total estimated cost is $2,170,000.

52. PEARL HILL DAM AND RESERVOIR

A multi-purpose water supply and flood control dam is proposed for future construction at this site. Studies indicate that the dam site could be developed for multiple-purpose water supply and flood control storage as economic conditions dictate. Pearl Hill Dam would be located on Pearl Hill Brook in the Town of Lunenburg about two miles northeast of the center of Fitchburg. The reservoir at spillway crest, elevation 468, would extend about 1.3 miles upstream and have a surface area of about 90 acres, providing a storage capacity of 1,230 acre-feet. Of this amount, 610 acre-feet, equivalent to 5.5 inches of runoff, could be utilized for water supply storage. The remaining 620 acre-feet would be reserved for flood control storage. The maximum water surface for the water supply pool would be about 50 acres at elevation 458.2. Pearl Hill Dam would afford control for a tributary drainage area of 2.1 square miles and would have a top elevation of 478 feet m. s. l. constructed of rolled, earth fill approximately 1,170 feet long (including spillway) with a maximum height of 40 feet. A concrete chute spillway at elevation 468, with an ogee weir 80 feet long would be founded on rock at the left bank. A 48-inch reinforced concrete pipe with inlet would serve as an uncontrolled outlet and at elevation 458.2 would maintain the water supply pool. A 24-inch gated outlet at elevation 440 would regulate the water supply outflow. A portion of Northfield Road, located about 3,800 feet upstream of the dam site, would be raised and provided with culverts so that flood flows would not overtop this portion of the roadway. Total estimated cost is $950,000.

53. SAIMA DAM AND RESERVOIR

A multi-purpose dam and reservoir for flood control and recreation is proposed for future construction at this site. The site is located on an unnamed tributary of Falulah Brook about 2.3 miles north of Fitchburg and

TABLE 3
PERTINENT DATA
RESERVOIR PROJECTS PROPOSED FOR DEFERRED CONSTRUCTION

Feature	SHATTUCK	PEARL HILL	SAIMA
Purpose (1)	FC & WS	FC & WS	FC & R
Drainage Area	3.8	2.1	1.7
Elevations (ft., msl)			
Top of Dam	946	478	693
Flood Control Pool (spillway crest)	931	468	684
Surface Area, Acres	90	90	75
Water Supply Pool (spillway crest)	912	458.2	-
Surface Area, Acres	54	50	-
Recreation Pool(min) (spillway crest)	-	-	670
Surface Area, Acres	-	-	25
Dam			
Type of Dam	Earth fill	Earth fill	Earth fill
Length of Dam, ft.	1,970	1,170	420
Maximum Height, ft.	78	40	46
Top Width, ft.	25	25	25
Spillway			
Type	Chute	Chute	Chute
Location	Rt. Abt.	Lf. Abt.	Lf. Abt.
Crest Length, ft.	60	80	100
Outlet Conduits			
Flood Control			
Length	300	230	160
Inside Diameter	48"	48"	48"
Water Supply			
Length	300	230	-
Inside Diameter	24"	24"	-
Reservoir Storage			
Flood Control, ac. ft.	1,260	620	710
Water Supply, ac. ft.	1,080	610	-
Recreation, ac. ft.	-	-	180
Flood Control, runoff	6.3"	5.5"	8.0"
Water Supply, runoff	5.4"	5.5"	-
Recreation, runoff	-	-	2.0"

(1) FC = Flood Control; WS = Water Supply; R = Recreation

3/4 mile upstream of its confluence with Falulah Brook. The reservoir at spillway crest elevation 684 would extend some 4,000 feet upstream and provide a surface area of 75 acres. A permanent recreation pool at elevation 670 would afford a surface area of 25 acres. The reservoir would have a storage capacity of 890 acre-feet of which 180 acre-feet, equivalent to two inches of runoff, would be assigned for the permanent recreation pool, and 710 acre-feet, equivalent to eight inches of runoff, for flood control. Saima Dam would provide control for a tributary drainage area of 1.7 square miles. It would have a top elevation of 693 feet m. s. l. and be of rolled, earth-fill construction approximately 420 feet long and have a maximum height of 46 feet. A natural rock spillway with an ogee weir 100 feet long at elevation 684 would be founded on rock at the left bank. At elevation 670, a 48-inch opening integral with the spillway would serve as an uncontrolled outlet and would maintain the recreation pool at that elevation. A gated bottom discharge outlet would be provided to pass flow for cold water fish control and also permit drawdown of the pool for maintenance purposes. Construction of a flank dike along the left bank would be required. The dike, 1,170 feet in length, would parallel Ashby State Road (State Route 31) and would have a top elevation of 693 feet m. s. l. and a maximum height of 33 feet. Billings Road, located about 1,100 feet upstream of the proposed dam site, would be provided with culverts to pass normal river flows, and would be raised and relocated for a distance of about 1,000 feet. Richardson Road, of which a portion is within the reservoir limits, would be abandoned. Total estimated cost is $1,040,000.

54. CHANNEL IMPROVEMENTS

a. North Nashua River. - Channel improvement and rehabilitation of the existing walls and cribs will extend for a distance of five miles. This work will provide a channel with a safe carrying capacity of 9,000 c.f.s., equivalent to the Standard Project Flood, as reduced by the proposed upstream reservoirs, Whitmanville, Nookagee and Phillips. The work includes channel deepening, bank and slope protection and removal of obstructions. Due to high channel velocities during flood periods, banks will be protected to prevent erosion and consequent deposition in the improved channel. The plan which contains four primary features has a total estimated cost of $700,000, and provides the following:

(1) Walls and Cribs

Sites 1 and 2 - River Street bridge - two areas downstream of bridge abutment walls.

Site 3 - Circle Street - immediately downstream of the bridge.

Site 4 - Vicinity of General Electric Company - upstream of Putnam Street.

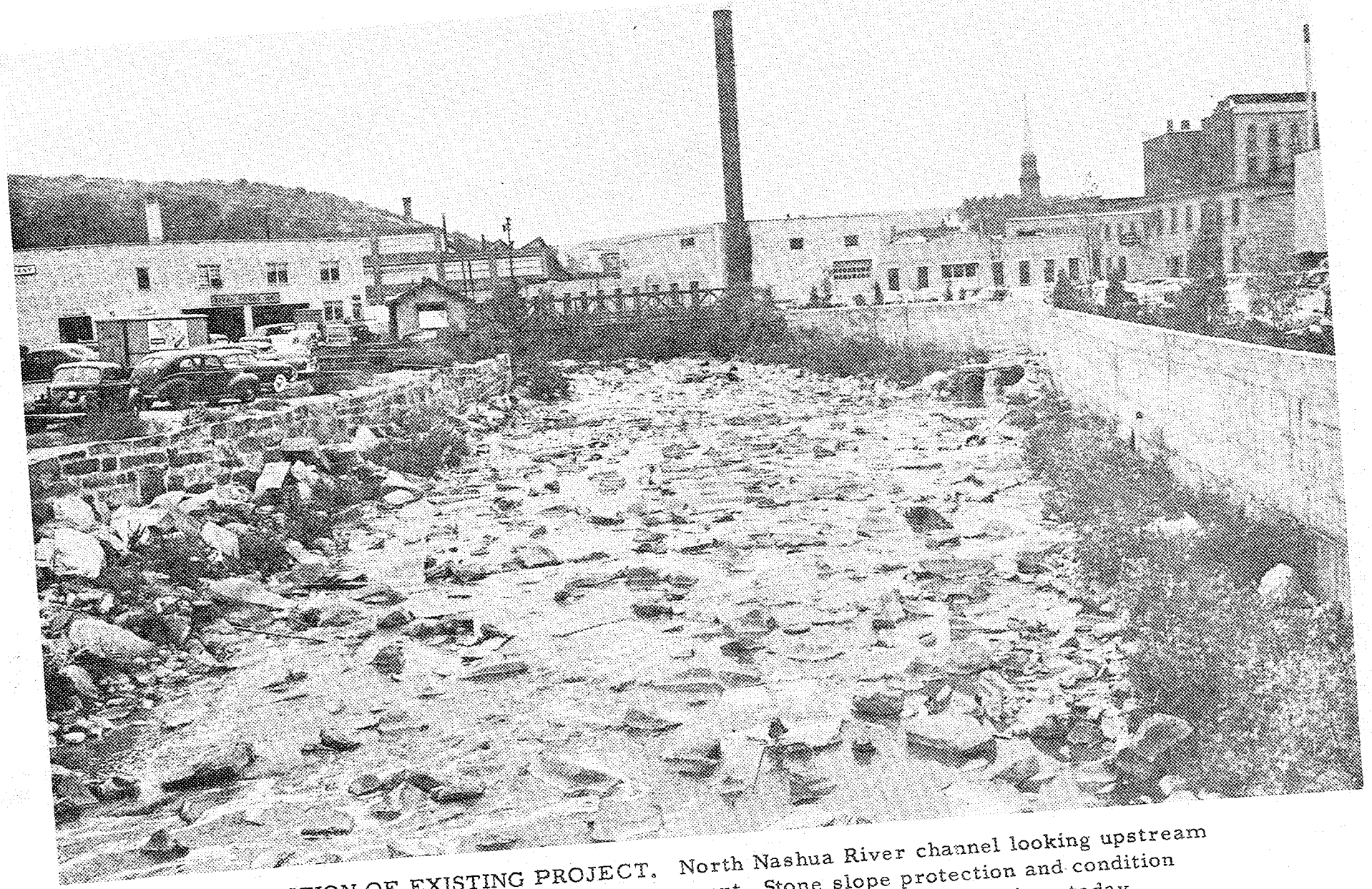
Sites 5 and 6 - Laurel Street - upstream and downstream of the Boston and Maine Railroad Bridge.

Site 7 - Immediately upstream of Water Street Bridge.

(2) Rehabilitation of slope protection - Restoration will be made of grouted riprap toes at bridge piers, wall footing, and at other critical locations. In various areas from Oak Hill bridge downstream to the Falulah Road bridge, existing deteriorated riprap will be replaced with stone protection of adequate size.

(3) Channel excavation - Since the completion of the Work Relief Project in 1937 there has been considerable deposition in that reach of the North Nashua River between the Boston and Maine Railroad bridge located upstream of the General Electric Company plant and the Laurel Street viaduct. In addition to these deposits, several restrictions produced by bridge piers and the alignment of the channel have reduced the effective capacity of the channel. Because of the excessive cost that would be involved in changing the alignment of the channel or widening the channel at the bridge, limited channel deepening will be accomplished to accommodate flood flows. Beginning 130 feet above the Boston and Maine Railroad bridge at the General Electric Plant, downstream to a point 100 feet below Laurel Street, a distance of 2,260 feet, about 20,000 c.y. will be excavated from the channel.

(4) Removal of channel obstructions and depositions. Boulders, stone and debris now obstructing the channel will be removed. Considerable scouring of riprap has occurred from Oak Hill Road to Laurel Street along the North Nashua River. Movement of stone has been caused by past floods. Deposition of this stone impedes channel flows by greatly increasing friction values along the channel. The plan of improvement calls for the removal of this stone and replacement of riprap where necessary between Daniel and Water Streets. Stone slope protection will be provided to prevent further



CONDITION OF EXISTING PROJECT. North Nashua River channel looking upstream from Cushing Street bridge. Note movement, Stone slope protection and condition [illegible] taken in 1949 is representative of conditions today.

erosion and undermining of the banks during future floods. Approximately 12,000 c.y. of stone would be removed and restored on the channel bottom and side slopes.

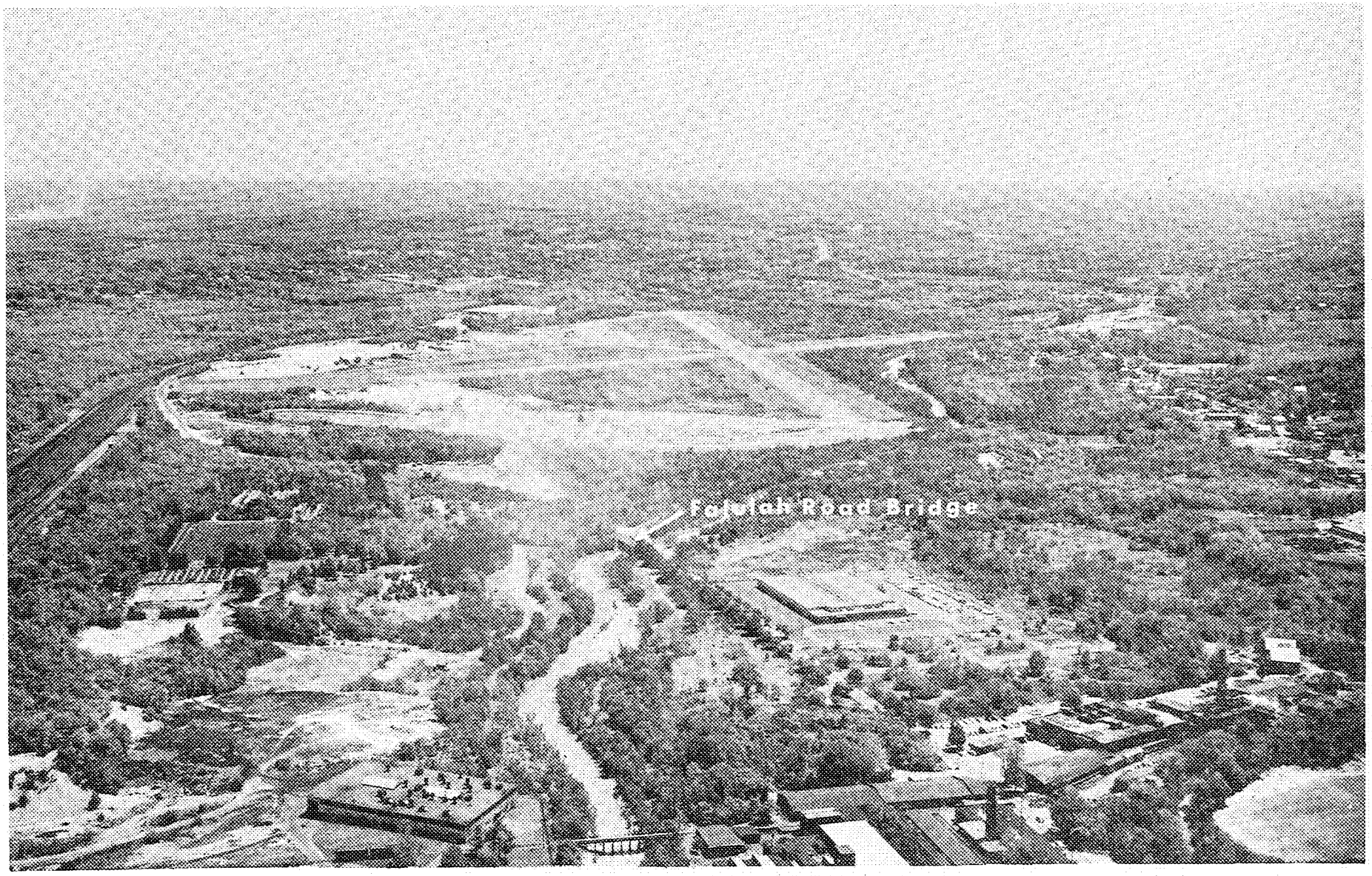
Deposits of silt, sand and gravel accumulated from Oak Hill Road downstream to Falulah Road, reduce the effective capacity of the channel and the flow capabilities of the stream. Removal of deposition where required will be accomplished.

b. Baker Brook. - Protection for the area susceptible to flood damage from Baker Brook includes channel improvement at four zones, and has an estimated total cost of $900,000, including the following:

ZONE I - Channel improvement beginning about 1,000 feet downstream from Townsend Street bridge and extending downstream for about 700 feet to the Lunenburg Street bridge. The channel will be deepened and widened to a bottom width of 40 feet with stone slope protection on 1 on 2 side slopes. The restrictive bridge at Lunenburg Street will be replaced.

ZONE II - From the downstream side of Lunenburg Street, channel improvements will continue in a southerly course about 1300 feet to the northeast corner of the Fitchgate Shopping Plaza. From this point, the existing channel continues in a southeasterly direction and is joined by Pearl Hill Brook, a major tributary of Baker Brook. To the rear of the shopping plaza the channel improvements maintain a southeasterly course for approximately 650 feet, and thence follow a southwesterly direction parallel to the Fitchburg-Lunenburg boundary line for a distance of 3550 feet. In this reach of 5500 feet from the Lunenburg Street bridge to the Lunenburg Town Line, the channel will be deepened, widened and straightened. The new channel will have an average width of 40 feet with 1 on 2 side slopes, protected by 18 inches of stone. A low earth dike 2,550 feet long will be included along the right bank of Baker Brook at the rear of the Fitchgate Shopping Plaza.

ZONE III - Downstream of the Lunenburg Town Line, the channel will be improved for about 500 feet, terminating in the now drained Baker Pond. The channel will have a bottom width of 40 feet with 1 on 2 side slopes. A flood gate structure at Intervale Road, as it crosses under the Boston and Maine Railroad bridge, is included. The gate will prevent Baker Brook flood waters from entering the Simond Saw and Steel Company property.



FITCHBURG-LEOMINSTER AIRPORT

Looking east at airport, note Falulah Road crossing the North Nashua River in foreground - Baker Brook hidden by trees, enters at left, about 2,000 feet downstream of Falulah Bridge.

ZONE IV - Channel improvements in this area, proposed for construction by the Massachusetts Department of Public Works, extend from the Fitchburg-Leominster boundary downstream along Baker Brook for about 2,100 feet to a point approximately 350 feet upstream of its confluence with the North Nashua River. In this reach the channel will be widened to a bottom width of 40 feet, straightened, and deepened with 1 on 2 side slopes. The abandoned bridge at Falulah Road will be removed and a new bridge constructed at Crawford Street to replace three existing 48-inch pipe culverts.

c. Monoosnoc Brook. - Channel improvements on portions of Monoosnoc Brook are under design by the Leominster Housing Authority, to be included in an Urban Renewal Project which calls for 2,400 feet of channel relocation. Channel improvements have been divided into four zones. Zones II and III are to be included as part of the Renewal Project. Protective works for Zone I upstream and Zone IV downstream of the renewal project are included as segments of the Water Resources Plan and have a total estimated cost of $290,000. A description of work to be accomplished for the four zones is as follows:

ZONE I - Channel improvements extend from the Cotton Street Bridge downstream approximately 950 feet to the Pleasant Street bridge. Improvements consist of channel excavation, removal and replacement of the existing walls adjacent to the Standard Pyroxoloid Company, construction of about 100 feet of concrete wall on the right bank opposite the Commonwealth Plastics Company, and the capping of the existing stone wall on the left bank located about 250 feet upstream of the Standard Pyroxoloid Company. Stone slope protection will be placed on all new slopes. The remains of a dam immediately upstream of Cotton Street will be removed.

ZONES II and III - The City of Leominster's Urban Renewal Project will relocate 2400 feet of channel and remove four undersized bridges with replacement of three bridges. In Zone II, Pleasant Street to Central Street, the new channel will have a bottom width of 30 feet with 1 on 2 side slopes. In Zone III, the channel will have a bottom width of 20 feet with 1 on 2 side slopes, from Central Street to Mechanic Street; 1 on 1.5 side slopes from Mechanic Street to the New York, New Haven and Hartford Railroad bridge. Work in Zones II and III will be accomplished by local interests. Channel improvement in these zones is an integral portion of the flood damage prevention project for Monoosnoc Brook.

TABLE NO. 4

PERTINENT DATA
PROPOSED CHANNEL PROJECTS

	Baker Brook	Monoosnoc Brook	North Nashua River
Purpose	Overbank flood control of Baker Brook	Overbank flood control of Monoosnoc Brook.	Overbank flood control of North Nashua River.
Location	Channel improvement upstream and downstream of Pearl Hill Brook.	Channel improvement from the Cotton Street bridge downstream to Whitney Street.	Channel improvement and rehabilitation of existing walls and cribs.
Type of Improvement	Dike, channel excavation, rock slope protection, drop structure, flood gate structure, and the removal and replacement of inadequate sized bridges.	Dike, channel excavation and relocation; removal, replacement and capping of the existing walls; stone slope protection and the removal of a dam.	Repairs to walls and cribs, rehabilitation of slope protection, channel excavation, removal of channel obstructions and depositions.
Hydrology			
Maximum flood of record	3,600 c.f.s.	2,000 c.f.s.	9,400 c.f.s.(2)
Project design flood	6,200 c.f.s. upstream of Pearl Hill and 7,700 c.f.s. downstream.	2,500 c.f.s. (as modified by upstream reservoir).	9,000 c.f.s. (as modified by proposed Whitmanville, Nookagee and Phillips Reservoirs).
Drainage Area	15.8 square miles (at Baker Brook)	11.5 square miles	132 square miles (at confluence of Nashua River).
Length	6,700 feet	Zone I - 950 feet Zone II & III - 2,400 feet (1) Zone IV - 2,400 feet	Five miles(length of improvement).
Bottom Width	40 feet.	Varies from 20 to 40 feet.	Controlled by existing project.

(1) To be constructed by Urban Renewal Authority; (2) Leominster gauge.

ZONE IV - Channel improvement will extend from the New York, New Haven and Hartford Railroad bridge downstream to Whitney Street, a distance of about 2400 feet. Improvements provide for enlarging the opening under the Tilton Cook Company, the removal of Rochdale Dam just downstream of Water Street, and general clearing and realignment of the existing channel.

55. HYDROLOGIC AND HYDRAULIC CONSIDERATIONS

a. General. - Hydrologic analyses of the major floods, namely; March 1936, September 1938 and October 1955 were made to determine the discharge contributions of the tributaries to flood peaks at the principal damage centers in order to evaluate the flood characteristics and potentialities of the various streams and the effectiveness of proposed flood control projects. These studies indicate that Whitman River and Phillips Brook are the major contributors to flood flows at the damage areas along the North Nasha River. Flooding in the Baker Brook watershed results from high flows in either Falulah or Pearl Hill Brook, and Baker Brook discharges affect stages in the North Nashua River at damage areas below Fitchburg. Although Notown Reservoir has sufficient surcharge storage to effectively reduce and delay peak flows from its drainage area except for extremely rare events, floods on Monoosnoc Brook are largely produced by the uncontrolled drainage areas.

b. Flood Frequencies. - The frequency or percent-chance of occurrence of peak discharges was determined from records at the U. S. G. S. gaging stations in the North Nashua River and adjacent river basins. The frequency analyses were made in accordance with ER 1110-2-1450, "Hydrologic Frequency Estimates", dated 10 October 1962. A skew coefficient of 0.8 was adopted for the North Nashua River and tributaries from a regional analyses.

c. Standard Project Floods. - The standard project floods on the North Nashua River at Arden Mill Dam in Fitchburg, Baker Brook at Summer Street Bridge, and Monoosnoc Brook at the mouth in Leominster, have natural peak discharges of 20,000 c.f.s., 7,700 c.f.s., and 5,000 c.f.s., respectively. The proposed system of reservoirs would reduce these discharges in the North Nashua River and Monoosnoc Brook to 8,900 c.f.s. and 3,700 c.f.s., respectively.

d. Spillway and Outlet Capacities -

(1) Spillway capacities have been determined in accordance with EM 1110-2-1405, "Flood-Hydrograph Analyses and Computations", dated 31 August 1959.

(2) Ungated outlets were selected to satisfy the following criteria: (a) pass the normal stream flow without utilizing excessive reservoir storage; (b) obtain outlet discharges equivalent to the downstream safe channel capacity with the reservoir full to spillway crest elevation; and (c) be sufficiently restrictive to use reservoir storage effectively, yet large enough to empty the reservoir in a reasonable period of time.

e. Channel Capacities - The present minimum channel capacity of the North Nashua River is estimated to range from about 4,000 to 6,000 c.f.s. above Oak Hill bridge, and from 7,000 to 9,000 c.f.s. from above Oak Hill Road bridge downstream to the mouth of Baker Brook. Below Baker Brook through the Towns of Leominster and Lancaster the channel capacity is estimated to be about 10,000 c.f.s. Channel improvement and restoration will provide a safe channel capacity through the Fitchburg reach of about 9,000 c.f.s., equivalent to the standard project flood modified by the proposed Whitmanville, Nookagee and Phillips reservoirs.

The present channel capacity in Baker Brook is limited (600-800 c.f.s.) due to recent commercial developments adjacent to the brook above Baker Pond. The proposed channel improvements in Baker Brook will provide a capacity of 6,200 to 7,700 c.f.s. from Lunenburg Street bridge to the mouth.

The existing capacity of Monoosnoc Brook in Leominster varies from about 1,200 c.f.s. at Water Street to about 1,700 c.f.s. through the downtown commercial area, between Pleasant Street and the New York, New Haven and Hartford railroad tracks. The proposed channel improvements including Urban Renewal Relocation Plan will provide a minimum channel capacity of about 2,000 c.f.s., including modification at the Pyroxoloid Plant located just upstream of Pleasant Street which has a present capacity of about 1,500 c.f.s.

56. RESERVOIR REGULATION

Regulation of Whitmanville, Nookagee, Phillips, and Monoosnoc Reservoirs would be automatic and flood crests would be substantially reduced on the North Nashua River and Monoosnoc Brook. Reductions would also be effected on the Nashua River below the confluence with the South Branch.

TABLE 5

Effect of Proposed Reservoir System on Record Flood and Standard Project Flood

North Nashua River

	Arden Mill Dam Fitchburg, Mass. (D.A. 63 sq. mi.)		U.S.G.S. Gage Leominster, Mass. (D.A. 107 sq. mi.)	
Flood	Natural	Modified	Natural	Modified
March 1936				
Stage (ft)	7.3	4.3	20.5	15.9
Discharge (cfs)	9,400	4,100	16,300	10,600
Standard Project Flood - Stage (ft)	11.0	7.3	25.8	20.2
Discharge (cfs)	20,000	8,900	24,000	16,000

During major floods the North Nashua River reservoir system would also effect a reduction of about 0.5 feet in the Nashua River at the East Pepperell gage and about 0.3 feet above Jackson Mill Dam at Nashua, New Hampshire. It is further estimated that the system would reduce the stage during major floods developing uniformly over the Merrimack River basin by about 0.1 foot in the Merrimack River at the Nashua-Hudson bridge in Nashua. Because of the reservoirs general effectiveness over a widespread area, it is considered equitable that they be constructed, operated, and maintained at Federal expense, subject to local assumption for costs allocated to water supply.

57. DEGREE OF PROTECTION

The existing channel on the North Nashua River would be improved to enable it to handle safely the residual releases from upstream reservoirs, plus the flood flow from the uncontrolled drainage area. All protective works described in this report would provide protection against the standard project flood with a minimum of three feet of freeboard, except in the Monoosnoc Channel where physical limitations make it impractical to provide protection to the standard project level. Channel improvement along Monoosnoc Brook would be designed to provide protection against floods 70 percent greater than the flood of record (18 March 1936).

58. PROVISIONS AGAINST ENCROACHMENT

Local interests should be required to provide assurances that they will establish encroachment lines downstream from the recommended dams to permit non-damaging releases and reasonably efficient reservoir operation. In connection with channel projects, local interests should be required to establish ordinances which will safeguard and prevent obstruction or encroachment in the improved channels.

SECTION XIV

ESTIMATES OF FIRST COSTS AND ANNUAL CHARGES

59. FIRST COSTS

The total estimated cost of the four reservoirs and three channel projects considered for immediate construction in the North Nashua Water Resources Development plan is $16,090,000, based on June 1964 price levels. Evaluations of property are based on real estate studies and information from local officials, reflecting values in recent sales in the area. All costs include an allowance for contingencies. The estimated costs for engineering and overhead are based on knowledge of the site and experience on similar projects. A summary of construction costs for the individual reservoirs and channel projects are presented in Tables 6 and 7.

60. ANNUAL CHARGES

Average annual costs, also summarized in Tables 6 and 7 are based on interest rates of 3.125 percent for Federal and non-Federal costs. Investment costs for reservoirs are amortized over a 100-year assumed life. Channel projects are amortized over a 50-year economic life. Loss of taxes for those land areas to be inundated by reservoirs has not been included as it is expected that enhancement of lands along the periphery of the proposed reservoir will offset any tax loss on land to be inundated. Allowances for maintenance, operation and interim replacement of equipment have been included in annual charges.

TABLE 6

Summary of First Costs and Annual Charges for Reservoirs

(1964 Price Level)

First Costs	Whitmanville	Nookagee	Phillips	Monoosnoc	Total Reservoirs
Lands and Damages	$ 515,000	$ 375,000	$ 100,000	$ 190,000	
Highway Relocations	625,000	750,000	11,000	62,500	
Reservoir Clearing	62,000	95,000	15,000	26,200	
Dams and Appurtenance	1,922,000	3,033,000	1,644,000	1,598,100	
Access Road	15,000	13,000	0	0	
Building, Grounds and Utilities	0	62,000	0	0	
Recreation Facilities Equipment	0	162,000	0	168,700	
Total Direct Cost	$ 3,139,000	$ 4,490,000	$ 1,770,000	$ 2,045,500	
Engineering & Design	446,000	580,000	355,000	356,700	
Supervision and Administration	255,000	360,000	195,000	207,800	
Total First Cost	$ 3,840,000	$ 5,430,000	$ 2,320,000	$ 2,610,000	$14,200,000
Annual Charges					
Interest	$ 120,200	$ 169,700	$ 72,500	$ 81,400	
Amortization	5,800	8,300	3,500	3,800	
Maint. & Operation	5,600	15,500	3,500	12,400	
Interim Replacements	400	4,500	500	4,400	
Total Annual Charges	$ 132,000	$ 198,000	$ 80,000	$ 102,000	$ 512,000

TABLE NO. 7

SUMMARY OF FIRST COSTS AND ANNUAL CHARGES FOR LOCAL PROTECTION

(50-Year Project Life)

	North Nashua River	Baker Brook	Monoosnoc Brook	Total Local Protection
1. CONSTRUCTION EXPENDITURES				
Federal Project Investment	$700,000	$692,000	$224,000	$1,615,000
Non-Federal Project Investment	0	208,000	66,000	275,000
Total	$700,000	$900,000	$290,000	$1,890,000
2. ANNUAL CHARGES				
Interest on Investment, 3-1/8%	$ 21,900	$ 28,100	$ 9,100	$ 59,100
Amortization of investment (.00854)	6,000	7,700	2,500	16,200
Operation and Ordinary Maintenance	7,000	4,500	1,300	12,800
Total	$ 34,900	$ 40,300	$ 12,900	$ 88,100

SECTION XV

ANNUAL BENEFITS

61. FLOOD DAMAGE PREVENTION BENEFITS

a. General. - Tangible flood damage prevention benefits were derived as the difference in annual losses in the various affected reaches of the North Nashua River Basin under conditions expected in 1970(the assumed date of project completion) without the project and annual losses remaining after construction of the recommended projects. Benefits so derived are tabulated below and summarized with other tangible benefits in Table 8. Reservoir benefits accrue at all downstream communities on the North Nashua, Nashua and Merrimack Rivers, as indicated in Paragraph 56.

North Nashua River	Annual Benefit
Channel Restoration	$ 40,000
Whitmanville, Nookagee and Phillips Reservoirs as System:	983,000
Baker Brook	
Channel Only	57,800
Monoosnoc Brook	
Monoosnoc Reservoir	43,000
Monoosnoc Channel	27,000

b. Enhancement Benefits. - In addition to flood damage prevention benefits, the project will realize benefits from stimulating the development of currently idle flood plain land in Lancaster. At present, the land is susceptible to flooding by a flood of 20-year frequency; construction of the recommended projects would prevent damage from all floods with a frequency less than 60 years, and even the 100-year event would cause only minor flooding. The current value of land in the area is $400 an acre. With protection and development, an ultimate value of $4,000 an acre for residential lots will be attained. Development costs are estimated at $1,600 an acre, so a net increase in value of $2,000 an acre for 320 acres will be realized.

At an interest rate of $5\frac{1}{2}\%$, the current rate on residential real estate development in the area, the gross increase in value of $640,000 would mean an annual return of $35,200. As the development is not expected to start until 1980 and to take place over a 15-year period thereafter, the benefit was discounted to an annual average equivalent value using an interest rate of 3-1/8%. The benefit so derived amounts to $20,700 annually and is credited to the system of three reservoirs.

62. RECREATION BENEFITS

Recreation benefits expected to accrue from the proposed water resource developments at Monoosnoc and Nookagee Dams were evaluated into two categories of general recreation and fishing.

1. General Recreation. - A survey of the recreational values of the areas affected by the proposed reservoirs was made by Corps' personnel augmented with studies by the National Park Service. The estimated average annual general recreation benefits, exclusive of fishing is $126,000 attributable to the proposed Nookagee and Monoosnoc reservoirs. Estimates are based on projected annual attendance and use of the recreation facilities to be provided.

2. Benefits from Fish and Wildlife. - A survey of the fish and wildlife values of the areas affected by the proposed projects was made by the U.S. Fish and Wildlife Service. Benefits from Nookagee and Monoosnoc reservoirs attributable to enhancement of sport fishery resources were determined by comparing the human utilization of these resources expected to occur without the projects and that expected to occur with the projects in operation. The total estimated average annual benefits to fishery resources from the proposed plan are $35,000. Detrimental effects of the wildlife resources as produced by the development plan are expected to be minor and were not considered.

63. WATER SUPPLY BENEFITS

The water supply nenefits would accrue from increased quantities made available as a result of the Nookagee, Whitmanville and Monoosnoc reservoirs. The estimated total average annual water supply benefits of $243,000 are based on June 1964 price levels. Benefits were measured as the cost of obtaining the same quantity of water by the cheapest alternative means that would most likely be developed in absence of the Federal projects.

64. INTANGIBLE BENEFITS

Certain intangible benefits which are not susceptible to direct monetary evaluations would be realized by the water resource plan. Releases from water supply storage will substantially increase flow to downstream communities and thereby tend to improve water quality. Flood control provided by the reservoirs and channel improvements would benefit the public welfare by decreasing the threat to injury and loss of life. The flash floods prevalent in the basin strike without warning. Such floods would be reduced in magnitude by the proposed reservoirs and contained by the channel improvement. The dependable supply of water afforded by Nookagee, Whitmanville and Monoosnoc dams would promote an expansion of the industrial base in the area. In addition, the growth of the industrial base which is now located in the flood plain and currently threatened by disastrous floods, would be assured by the removal of this threat, thereby stimulating the local and national economy. Benefits to the general welfare, economy and security of the people in the basin area such as those enumerated cannot be predetermined or evaluated in monetary terms.

SECTION XVI

COST ALLOCATION

65. ALLOCATION OF COSTS AMONG PURPOSES

Allocation of costs of the multiple-purpose reservoirs projects to the purposes of flood control, water supply, and recreation were made by the separable costs-remaining benefit method. Details of the cost allocation are presented in Appendix D. The annual costs and percentage of total annual project costs allocated to reservoirs proposed for immediate construction are shown in Table 10.

66. APPORTIONMENT OF COSTS

A division of project costs between Federal and non-Federal interests of the water resources development plan has been made, based upon allocation of costs for Whitmanville, Nookagee and Monoosnoc dams, and on presently applicable laws and regulations governing cost-sharing practices. Table 11 shows the apportionment to non-Federal and Federal interests of first costs, investment, annual operation, maintenance and replacements costs, and annual charges.

TABLE 8

Summary of Average Annual Tangible Benefits
(1964 Price Level)

Benefit	Reservoirs				Channel Projects		
	Whitman-ville	Nookagee	Phillips	Monoosnoc	North Nashua River	Monoosnoc Brook	Baker Brook
Flood Control	$ 464,000	$357,000	$ 162,000	$ 43,000	$40,000	$ 27,000	$57,800
Water Supply	58,000	130,000	0	55,000	0	0	0
Recreation							
General	0	74,000	0	52,000	0	0	0
Fishing	0	16,000	0	19,000	0	0	0
Total Tangible Benefits	$ 522,000	$577,000	$ 162,000	$169,000	$40,000	$ 27,000	$57,800

TABLE 9

Summary of Cost, Annual Charges, and Benefits
(June 1964 Price Level)

	Dams				Channel Improvement			
	1	2	3	4	5	6	7	
	Whitman-ville	Nookagee	Phillips	Monoosnoc	North Nashua River	Baker Brook	Monoosnoc Brook	Total
First Costs								
Federal	$2,710,000	$ 3,450,000	$ 2,320,000	$ 1,890,000	$ 700,000	$692,000	$224,000	$ 11,986,000
Non-Federal	1,130,000	1,980,000	0	720,000	0	208,000	66,000	4,104,000
Total First Costs	$ 3,840,000	$ 5,430,000	$ 2,320,000	$ 2,610,000	$ 700,000	$900,000	$290,000	$ 16,090,000
Annual Charges								
Federal	$ 92,500	131,000	$ 80,000	$ 76,900	$ 27,900	$ 27,600	$ 8,900	$ 444,800
Non-Federal	39,500	67,000	0	25,100	7,000	12,700	4,000	155,300
Total Annual Charges	132,000	$ 198,000	$ 80,000	$ 102,000	$ 34,900	$40,300	$ 12,900	$ 600,100
Annual Benefits	$ 522,000	$ 577,000	$ 162,000	$ 169,000	$ 40,000	$57,800	$ 27,000	$ 1,554,800
Benefit-Cost Ratio	3.9	2.9	2.0	1.7	1.2	1.4	2.1	2.6

Dams are amortized for 100-year life; channel improvements for 50-year life.

TABLE 10

Allocation of Annual Project Costs for Reservoirs Proposed for Immediate Construction

	Whitmanville		Nookagee		Phillips		Monoosnoc	
	Cost	Percent	Cost	Percent	Cost	Percent	Cost	Percent
Flood Control	$92,500	70.1	$80,000	40.4	$80,000	100.0	$35,300	34.6
Water Supply	39,500	29.9	67,000	33.8	0	0	25,100	24.6
Recreation	0	0	51,000	25.8	0	0	41,600	40.8
Total Annual Project Costs	$ 132,000	100.0	$198,000	100.0	$80,000	100.0	$102,000	100.0

TABLE 11

SUMMARY OF COST APPORTIONMENT (1)

	Whitmanville		Nookagee			Monoosnoc		
	Federal Flood Control	Non-Federal Water Supply	Federal Flood Control	Federal Recreation	Non-Federal Water Supply	Federal Flood Control	Federal Recreation	Non-Federal Water Supply
Specific First Costs	$ 6,300	166,000	89,700	244,000	134,000	25,000	305,000	85,000
Allocated Joint-Use First Costs	2,703,700	964,000	2,260,000	856,000	1,846,000	975,000	585,000	635,000
% of Allocated Joint-Use First Costs	73.7%	26.3%	45.6%	17.2%	37.2%	44.5%	26.6%	28.9%
Annual Investment Cost	88,800	37,200	77,000	36,100	64,900	32,800	28,900	23,500
% of Annual Investment Cost	70.5%	29.5%	43.2%	20.3%	36.5%	38.5%	33.9%	27.6%
Specific O.M.&R. Costs	0	600	0	14,200	400	0	11,300	300
Allocated Joint-Use O.M.&R.	3,799	1,700	2,900	700	1,700	2,500	1,400	1,300
% of Allocated Joint-Use O.M.&R.	68.5%	31.5%	55.5%	13.0%	31.5%	48.0%	27.0%	25.0%

(1) Since Phillips Dam is single-purpose, flood control, cost apportionment is 100% Federal.

a. Apportionment of Flood Control Costs. - Costs allocated to flood control were apportioned to Federal and non-Federal interests in accordance with the Flood Control Act of 1936, as amended.

b. Apportionment of Water Supply Costs. - In accordance with the Water Supply Act of 1958, as amended, costs of providing water supply storage for immediate and anticipated future use are apportioned to non-Federal interests. All construction, operation and maintenance, replacement and interest costs incurred by the Federal Government and allocated to water supply are to be repaid by the water users. No interest will be charged on the investment costs up to 30 percent of total project costs allocated to future water supply until use is initiated, but such interest-free period shall not exceed ten years. No payment will be required for the cost allocated for current interest charges on the unpaid balance after the interest-free period. However, all costs for future water supply including interest incurred after the interest-free period must be repaid within 50 years after use is initiated.

c. Apportionment of Water Quality Costs. - It is considered that any water quality improvement provided by the proposed resource plan would have widespread benefits throughout the North Nashua and Nashua River Basins. As such, the cost allocated to water quality improvement would be considered a Federal responsibility. However, water supply storage proposed at Whitmanville, Nookagee and Monoosnoc Reservoirs would primarily benefit industry in the upper reaches of the North Nashua River. The increased supply would permit expansion in industrial use of water and it would be impractical to pass reservoir releases through the head ponds of the industrial plants. It is considered equitable that the cost of the added storage should be borne by the principal beneficiaries.

d. Apportionment of General Recreation Costs. - In accordance with existing Federal policy, minimum basic facilities including maintenance and operation of such facilities, would be provided at Federal cost. The cost of additional facilities required to fully develop recreational potential of the proposed Nookagee and Monoosnoc projects including operation and maintenance thereof, are considered to be non-Federal.

e. Apportionment of Fish and Wildlife Costs. - Public Law 86-624 approved 12 August 1958, provides that an appropriate share of project costs may be allocated for purposes of recreation development, and improvement of fish and wildlife resources. For purposes of cost-sharing, general recreation and fish and wildlife recreation are considered to be synonomous. A limitation on Federal assumption of costs is established by administrative policy as stated in H. R. 9032, 88th Congress.

SECTION XVII

SUMMARY AND DISCUSSION

67. PROJECT FORMULATION AND ECONOMIC JUSTIFICATION

In the formulation of the water resource plan, consideration was given to all available means of fulfilling the existing or prospective water needs of the North Nashua Basin. The water resources plan, as described in earlier paragraphs, provides a basis for major improvement of the water problems in the North Nashua Basin. The immediate needs for flood protection, industrial and municipal water supply, and recreation can be met in part by the construction of the four reservoirs, supplemented with channel improvements. All practicable methods for solving the flood problem areas of the basin were considered, including construction of dikes and flood walls, improvement of channels and diversion of flood waters. Alternate plans were studied in detail for each considered project to assure the best use of the available water resources.

In all cases, the average annual benefits for units of the proposed plan exceed the annual costs. Each of the reservoirs included in the plan was considered individually and in various sequences of development. In addition, Whitmanville, Nookagee and Phillips have also been tested as last added in the system, and on this basis are found to be justified. For purposes of benefit evaluation, Nookagee and Phillips Reservoirs are considered inseparable, because site limitations make it more economical to construct two low dams on Phillips Brook in lieu of one higher dam.

The following benefit-cost ratios have been determined for the seven segments of the proposed water resource plan.

Dams & Reservoirs	Total Annual Benefits	Total Annual Cost	Benefit Cost-Ratio
Whitmanville, Nookagee and Phillips as a System	$1,261,000(1)	$ 410,000	3.1
Monoosnoc Dam	169,000(1)	102,000	1.7
Channel Improvements			
North Nashua River	40,000	34,900	1.2
Baker Brook	57,800	40,400	1.4
Monoosnoc Brook	27,000	12,900	2.1

(1) Includes Ann. Ben. Flood Control, Water Supply and Recreation

68. SUMMARY OF NEEDS

a. The need for flood protection in the North Nashua River Basin has long been recognized. The floods of 1936 and 1938 caused widespread damage to industrial, commercial and residential property. Four major floods have occurred in the past 30 years. The flood of 1955 caused great damage to the existing project in Fitchburg which in its 28-year life has greatly deteriorated. Rehabilitation of the work, although essential, will provide only a low degree of protection in the Fitchburg area and leave other locations in the city and downstream communities without protection. It is estimated that in Fitchburg alone, a recurring 1936 flood even with the existing project restored would cause damages in excess of $10,000,000 for that five-mile reach of the city. The estimated frequency for such an event is more than once in 50 years, further high-lighting the potential flood threat.

b. The demand for water supply for domestic consumption has exceeded the safe yield. Present planning by the municipalities indicates that the large supplies expected to be needed in the future will be sought by diversion from other watersheds, and through development of the limited ground and surface water sources in the basin. The present study shows that all available sources within the basin will be needed. The dependable flow of the North Nashua River in its present state of development is utilized primarily by paper industries now taking water from the river. Industrial expansion now underway or planned will require additional dependable flow and expensive recirculation equipment. Inclusion of water supply storage for municipal and industrial purposes at proposed dams will relieve pressures on existing supplies and permit expansion of the economy.

c. The pollution of the North Nashua River by industrial wastes is of serious concern to the area. Treatment by known methods will not be adequate to restore the stream for all types of usage. Dilution of wastes by additional flows would tend to improve stream conditions.

d. The growth of the immediate and surrounding metropolitan and industrial areas and decreasing working time has resulted in increased leisure time and greater disposable income which, in turn, has increased the need for recreational opportunities. Attractive developments require facilities for water sports and fishing and for outdoor activities such as camping and picnicking. Studies by the National Park Service indicate that existing recreation facilities are used to capacity and that additional facilities are needed.

69. LOCAL COOPERATION

As attested by exhibit letters in Appendix J, responsible local and State organizations in the area have indicated a strong interest and support of project improvements as well as a willingness to meet required items of local cooperation at the appropriate time.

a. In connection with the reservoirs included in the water resource plan, local interests should be required to provide the following:

(1) Repay all costs allocated to water supply, as determined by the Chief of Engineers, in accordance with the provisions of the Water Supply Act of 1958, as amended in 1961. The repayments shall reimburse the Government for specific costs as well as for joint-use costs for construction, operation, maintenance and major replacements attributable to water supply. Such costs will be determined by actual costs for construction and estimated costs for operation, maintenance and major replacements. The percentages given in Table 11 for these reservoirs will be used to determine the applicable share of joint-use costs in each case. Cost of water supply storage is presently estimated at $3,830,000 for construction and $6,000 annually for operation, maintenance and major replacements.

(2) Repay that portion of the construction costs allocated to recreation, including the recreational aspects of fish and wildlife in accordance with the cost sharing policy outlined in H. R. 9032, 88th Congress.

(3) Establish encroachment lines downstream of the dams to permit efficient reservoir operation.

b. That, prior to construction of each of the local protection channel improvements projects, responsible non-Federal interests give assurances satisfactory to the Secretary of the Army that they will:

(1) Provide without cost to the United States all lands, easements and rights-of-way necessary for the construction of the projects; provide necessary relocations and alterations to highways, roads and highway bridges; relocate all utilities; and construct necessary interior drainage ditches.

(2) Hold and save the United States free from damages due to the construction works.

(3) Maintain and operate all works after completion in accordance with regulations prescribed by the Secretary of the Army.

(4) Prevent encroachment on improved channels.

70. CONCLUSIONS PRESENTED BY OTHER FEDERAL AND NON-FEDERAL AGENCIES

The Water Resource Development Plan has been reviewed by the Regional offices of Federal agencies and by State and local agencies as well as industrial officials. Federal and state agencies have concluded that the project will provide important flood protection benefits, enhance flood-prone areas, provide important water supply sources, afford much needed recreation, and enhance the fish and wildlife resources in the area. The project would not be detrimental to mineral resources in the area nor effect future development of hydroelectric power. State and local officials, including industrial leaders, have voiced support for the plan and a desire for its immediate implementation. Detailed views and replies from agencies and local interests are contained in Appendix J.

SECTION XVIII

CONCLUSIONS AND RECOMMENDATIONS

71. CONCLUSIONS

Because of the magnitude of the water resource problems in the North Nashua River Basin, extensive studies were made to determine a plan of improvement which would satisfy the needs for flood control, water supply, water quality control, recreation and other purposes. The proposed plan provides for a portion of the needs. It provides an efficient vehicle for reducing future flood damages, for satisfying some of the demands for increased water supply and increased recreational facilities. The future needs of the basin for water supply and water quality storage are so great that no means exist within the basin to satisfy these needs. The plan of water resource development will provide widespread relief from extensive flood damages. A recurring flood of 1936 magnitude would cause damages of over $24 million in the North Nashua River Basin under current economic conditions. The plan practically eliminates these damages. In addition, the water supply features of the plan will provide water for municipal and industrial expansion and promote the economic growth of the basin.

Massive pollution problems exist through the basin. The elimination of nuisance conditions will require expansion of the present municipal waste systems and programs for primary and secondary treatment of industrial discharges. Present and future prospective flow regimes in the

TABLE 12

SUMMARY
WATER RESOURCE DEVELOPMENT PLAN
NORTH NASHUA RIVER BASIN
RECOMMENDED FOR IMMEDIATE CONSTRUCTION

Project	Federal	Water Supply Non-Federal	Total Project Cost
Whitmanville	$2,710,000	$1,130,000	$ 3,840,000
Nookagee	3,450,000	1,980,000	5,430,000
Phillips	2,320,000	0	2,320,000
Monoosnoc	1,890,000	720,000	2,610,000
Sub-Total	$ 10,370,000	$ 3,830,000	$ 14,200,000
Channels		Lands, Damages Relocations	
North Nashua River	$ 700,000	0 (1)	$ 700,000
Baker Brook	692,000	208,000	900,000
Monoosnoc Brook	224,000	66,000	290,000
Sub-Total	$ 1,616,000	$ 274,000	$ 1,890,000
TOTAL	$ 11,986,000	$ 4,104,000	$ 16,090,000

(1) Permanent easements obtained by local interest for existing project are sufficient.

RECOMMENDED FOR DEFERRED CONSTRUCTION

		Water Supply	
Shattuck (2)	$ 1,170,000	$ 1,000,000	$ 2,170,000
Pearl Hill (2)	554,000	396,000	950,000
Saima (3)	1,040,000	0	1,040,000
Total Deferred	$ 2,764,000	$ 1,396,000	$ 4,160,000
Total North Nashua Basin Projects			$ 20,250,000

(2) Multiple-purpose projects; i. e. flood control and domestic water supply at Shattuck and Pearl Hill; (3) multi-purpose flood control and reereation at Saima.

river are inadequate to cope with expected future waste loading without adequate treatment at all discharge points. The available surface water resources of the basin are needed to meet priority needs for municipal and industrial water supply. The large volume of storage required for improvement of stream quality cannot be provided from any known source and therefore the plan makes no specific provision for water quality storage, although the release of proposed water supply storage will tend to provide some improvement in downstream water conditions.

Public recreation opportunities are inadequate within and nearby the basin. Opportunities exist for development of water-based recreational facilities at two of the reservoirs proposed for immediate construction, Nookagee and Monoosnoc. The development proposed will provide needed facilities. The nature and widespread effects of benefits from the plan of development warrant Federal participation in the costs of development. Three reservoir projects in the plan, Shattuck, Pearl Hill and Saima Dam sites, although not warranted for immediate development, should be reserved for future construction, to be undertaken at such time as the Chief of Engineers determines sufficient need, based on redetermination of benefits and costs. See Summary, Water Resources Development Plan, Table 12.

72. RECOMMENDATIONS

The Division Engineer recommends:

a. That the water resource plan for the North Nashua River Basin, a tributary of the Merrimack River, Massachusetts, be authorized essentially as described in this report, with such modification thereof as in the discretion of the Chief of Engineers may be advisable, at a total estimated cost of $20,250,000 for construction, exclusive of preauthorization costs. The plan provides: (1) Seven reservoirs at a total estimated cost of $18,360,000, and (2) Three local protection projects for urban and industrial areas at a total estimated cost of $1,890,000.

b. That four of the reservoirs, designated as Whitmanville, Nookagee, Phillips and Monoosnoc, and the three local protection projects be authorized for immediate construction for the purposes of flood control, water supply, recreation, and fish and wildlife conservation, as applicable, generally in accordance with plans contained herein and with such modifications as in the discretion of the Chief of Engineers may be advisable, at a total estimated cost of $16,090,000, of which $15,816,000 would be Federal cost and $4,104,000 the non-Federal cost including reimbursable costs of $3,830,000 for water supply features. The net Federal cost is $11,986,000. Annual costs for maintenance and operation are estimated at $58,600 of which $40,800 would be Federal costs and $18,800 non-Federal costs.

c. That immediately following authorization of the seven reservoir projects, detailed site investigation and designs be made for the purpose of accurately defining the project lands required; that subsequently advance acquisition be made of such title to such lands as may be required to preserve the sites against incompatible developments; and that the Chief of Engineers be authorized to participate in the construction or reconstruction of transportation and utility facilities in advance of project construction, as required to preserve such areas from encroachment and avoid increased costs for relocations.

d. That prior to construction of the Whitmanville, Nookagee, Phillips and Monoosnoc reservoir projects, responsible non-Federal interests give assurances satisfactory to the Secretary of the Army that they will:

(1) Repay all the costs allocated to water supply, as determined by the Chief of Engineers, in accordance with the provisions of the Water Supply Act of 1958, as amended in 1961. The repayments shall reimburse the Government for specific costs as well as for joint-use costs for construction, operation, maintenance and major replacements attributable to water supply. Such costs will be determined by actual costs for construction and estimated costs for operation, maintenance and major replacements. The percentages given in Table 11 for these reservoirs will be used to determine the applicable share of joint use costs in each case. Cost of water supply storage is presently estimated at $3,830,000 for construction and $6,000 annually for operation, maintenance and major replacements.

(2) Repay that portion of the construction costs allocated to recreation, including the recreational aspects of fish and wildlife in accordance with the cost sharing policy outlined in H. R. 9032, 88th Congress.

(3) Establish encroachment lines downstream of the dams to permit efficient reservoir operation.

e. That prior to construction of each of the local protection channel improvement projects, responsible non-Federal interests give assurances, satisfactory to the Secretary of the Army that they will:

(1) Provide, without cost to the United States, all lands, easements, and rights-of-way necessary for the construction of the projects; provide necessary relocations and alterations to highways, roads and highway bridges; relocate all utilities; and construct necessary interior drainage ditches.

(2) Hold and save the United States free from damages due to the construction works.

(3) Maintain and operate all works after completion in accordance with regulations prescribed by the Secretary of the Army.

(4) Prevent encroachment on improved channels.

P. C. HYZER
Brigadier General, USA
Division Engineer

ACKNOWLEDGEMENTS AND IDENTIFICATION OF PERSONNEL

1. The preparation of this report was administered by:

Brigadier General P. C. Hyzer, USA, Division Engineer
John Wm. Leslie, Chief, Engineering Division
Edward L. Hill, Chief, Planning & Reports Branch

2. This report was prepared under the direction of Joseph L. Ignazio, Chief, Small Projects Section.

3. The U. S. Army Engineer Division, New England, is appreciative of the cooperation rendered in connection with this study by personnel of other Federal Agencies, municipalities and industries, particularly the following:

U. S. Fish and Wildlife Service
U. S. Public Health Service
National Park Service
Massachusetts Water Resources Commission
City Officials, Fitchburg
City Officials, Leominster
Industrial Officials, North Nashua River Basin

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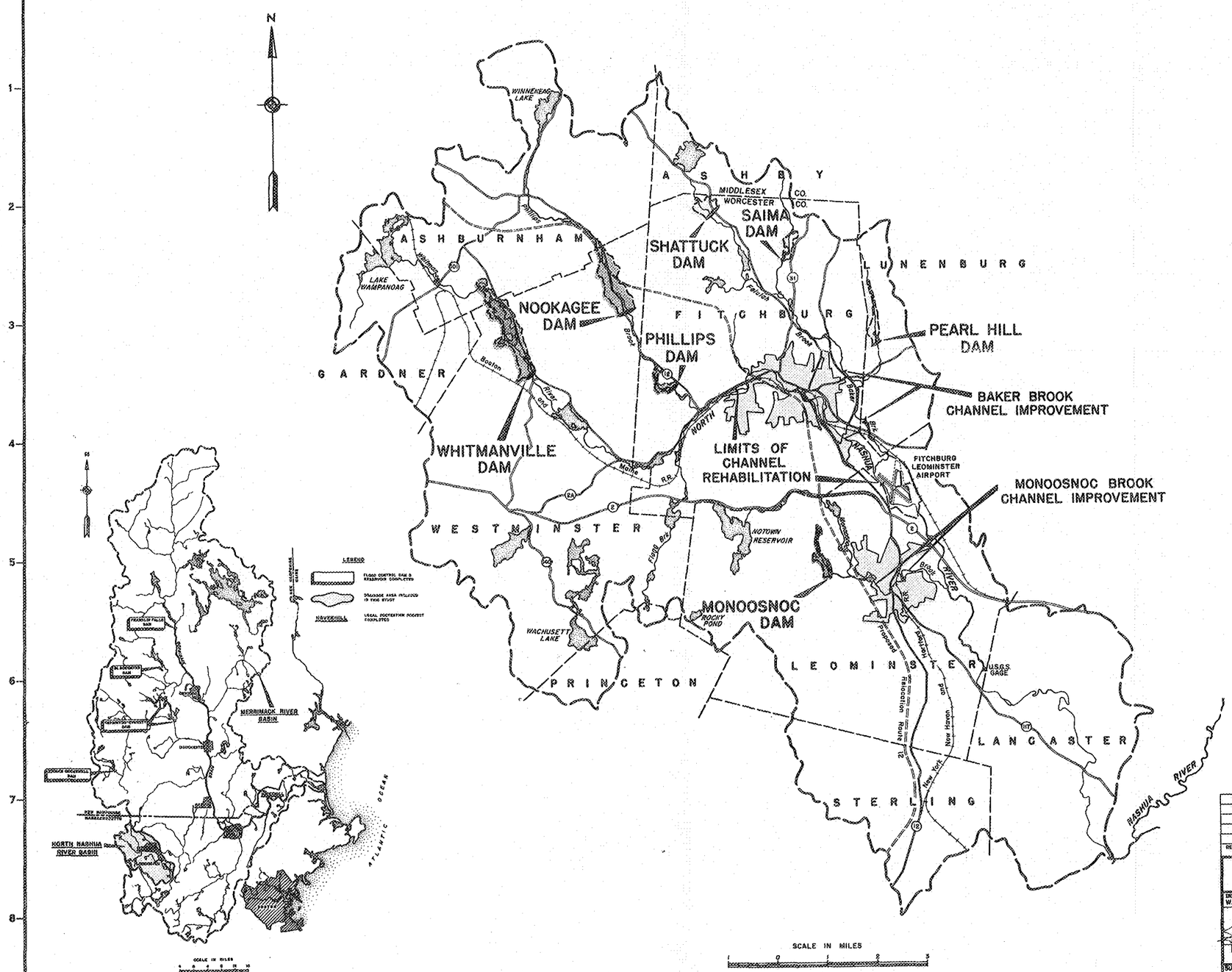

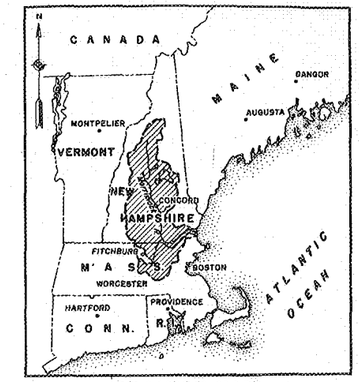

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U.S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS
WALTHAM, MASS.

DES. BY W.J.W. DR. BY H.S. CK. BY

PROJECT ENGINEER

SUBMITTED BY CHIEF, PLANN & RPTS BRANCH

APPROVED CHIEF, ENGINEERING DIVISION

DATE JAN. 1965

WATER RESOURCE DEVELOPMENT PLAN NORTH NASHUA RIVER BASIN

MERRIMACK RIVER BASIN MASSACHUSETTS

TO ACCOMPANY REPORT DATED: 25 JAN. 1965

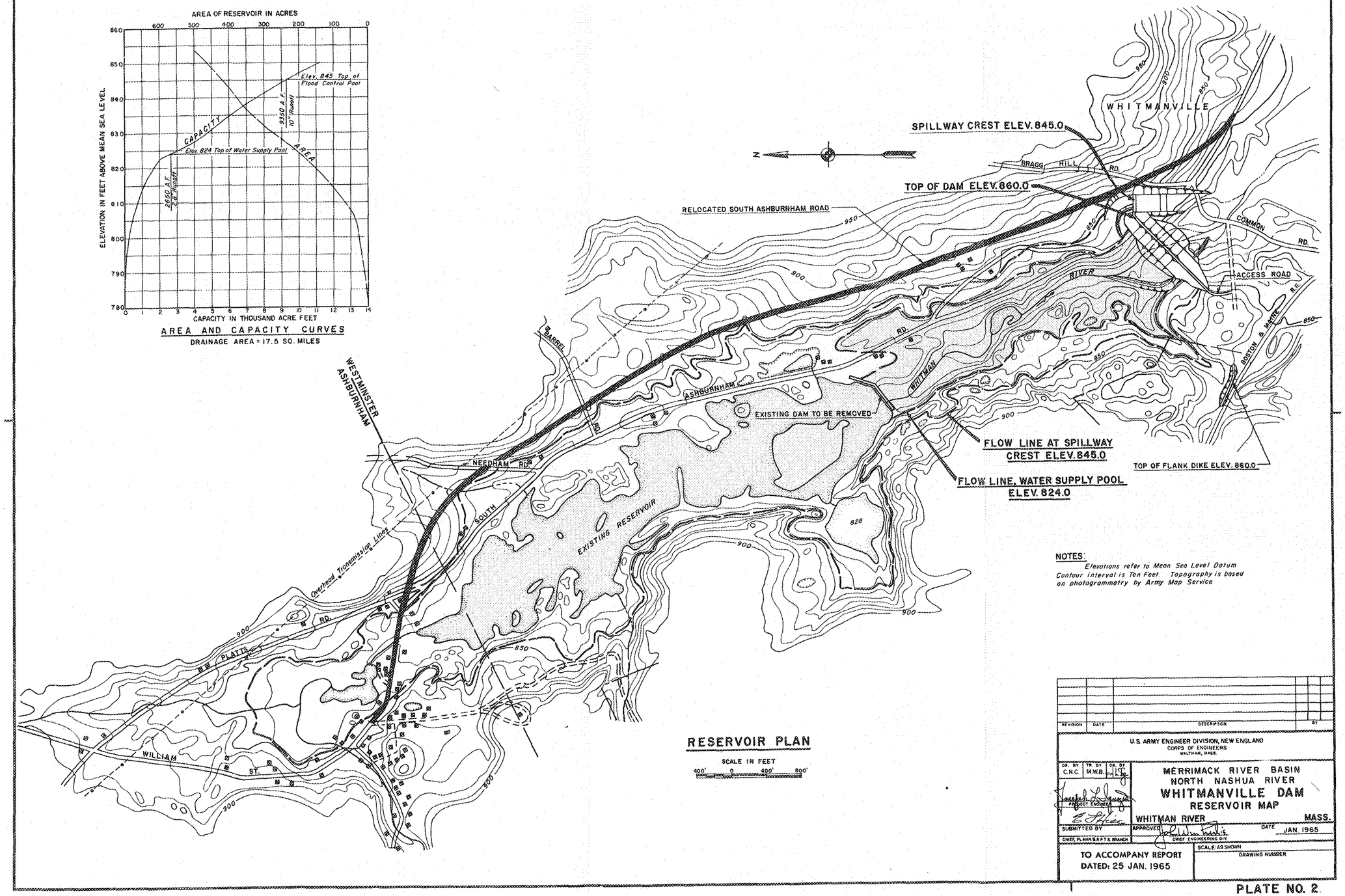
SCALE AS SHOWN

DRAWING NUMBER

PLATE NO. 1

AREA AND CAPACITY CURVES

DRAINAGE AREA = 17.5 SQ. MILES



NOTES:
Elevations refer to Mean Sea Level Datum
Contour interval is Ten Feet. Topography is based on photogrammetry by Army Map Service

RESERVOIR PLAN

SCALE IN FEET
400' 0 400' 800'

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DR. BY C.N.C. | TR. BY M.W.B. | CK. BY

MERRIMACK RIVER BASIN
NORTH NASHUA RIVER
WHITMANVILLE DAM
RESERVOIR MAP
WHITMAN RIVER MASS.

PROJECT ENGINEER

SUBMITTED BY
CHIEF, PLANN. & R.P.T.S. BRANCH

APPROVED
CHIEF ENGINEERING DIV.

DATE JAN. 1965

SCALE: AS SHOWN

TO ACCOMPANY REPORT
DATED: 25 JAN. 1965

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PLATE NO. 2

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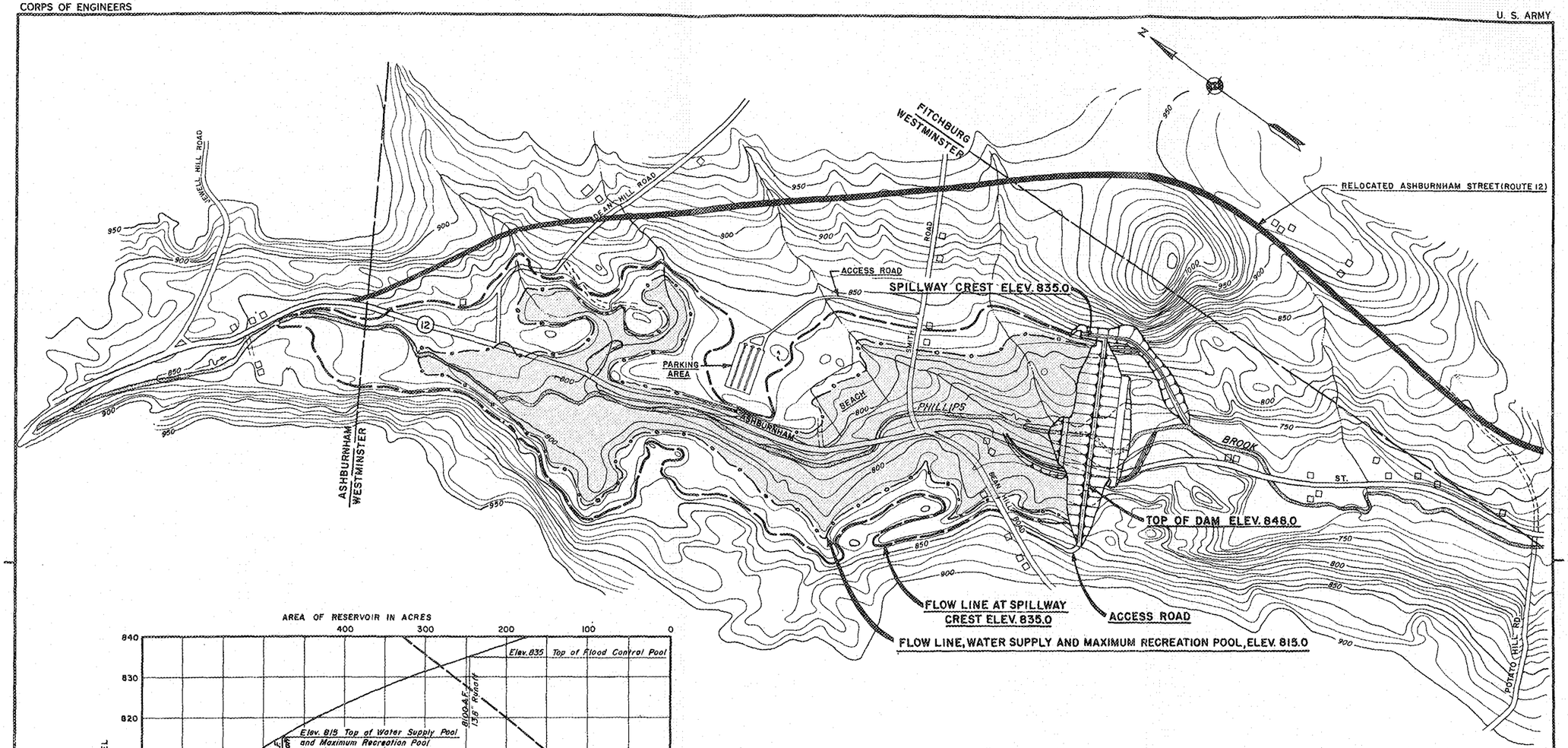

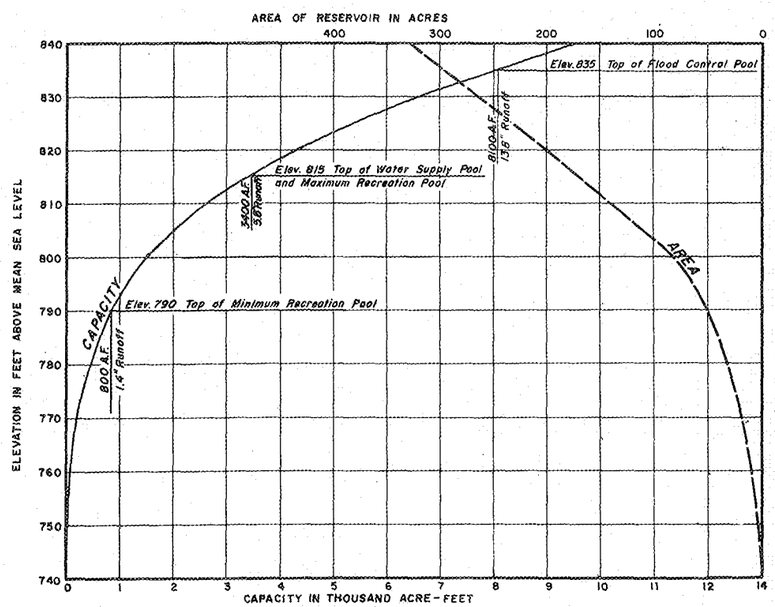

AREA AND CAPACITY CURVES

DRAINAGE AREA 11.0 SQ. MILES

RESERVOIR PLAN

SCALE IN FEET

400' 0 400' 800'

NOTES:

Elevations refer to Mean Sea Level Datum

Contour interval equals ten feet.

Topography by Army Map Service

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W.J.W.	M.W.B.	

PROJECT ENGINEER

SUBMITTED BY

CHIEF, PLANN. & RPTS. BRANCH

MERRIMACK RIVER BASIN
NORTH NASHUA RIVER
NOOKAGEE DAM
RESERVOIR MAP

PHILLIPS BROOK MASS.

APPROVED

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DATE JAN. 1965

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SCALE AS SHOWN

DRAWING NUMBER

SHEET

PLATE NO. 3

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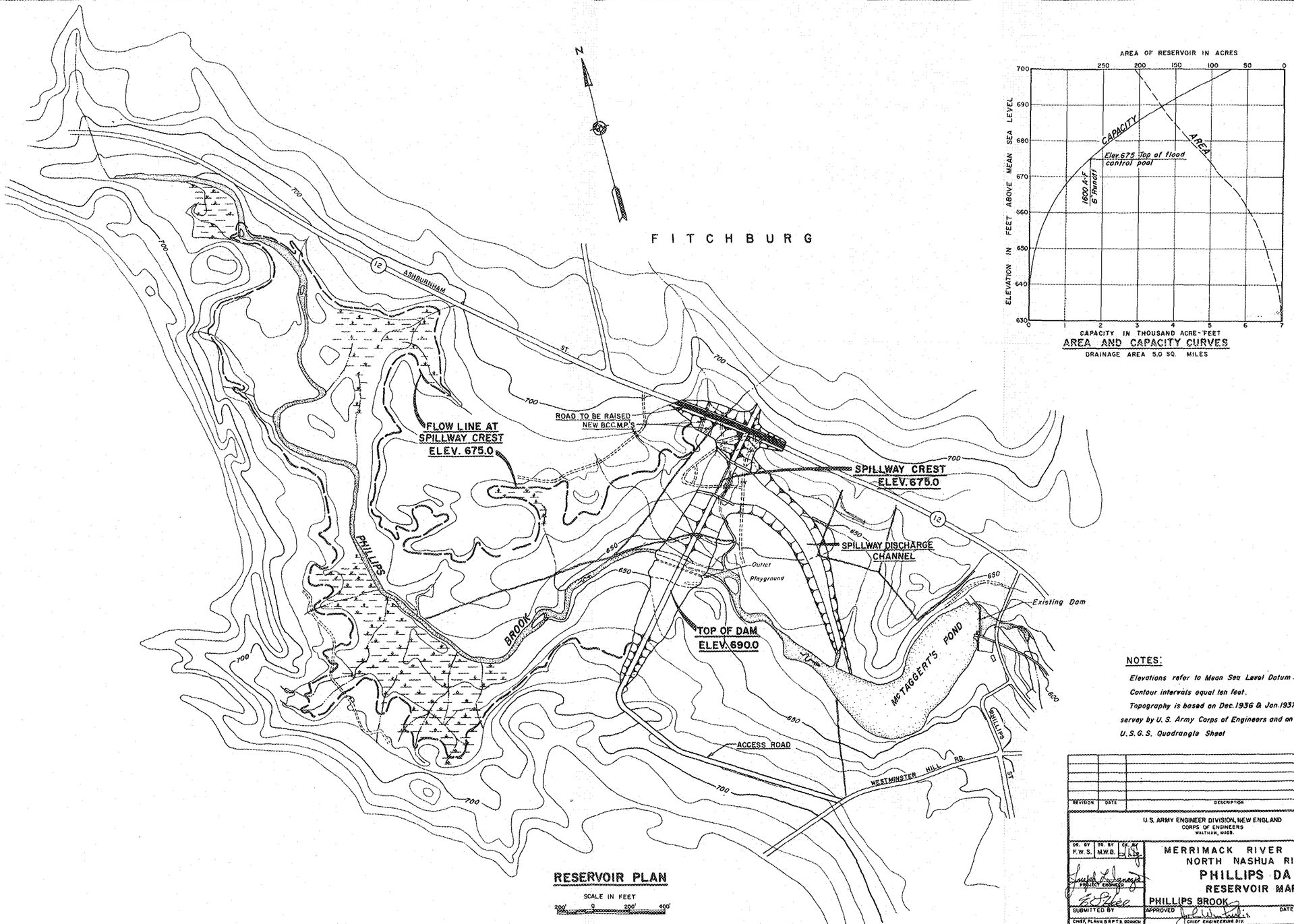

NOTES:

Elevations refer to Mean Sea Level Datum.

Contour intervals equal ten feet.

Topography is based on Dec. 1936 & Jan. 1937 survey by U. S. Army Corps of Engineers and on U.S.G.S. Quadrangle Sheet

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F.W.S.	M.W.B.	L.S.B.

PROJECT ENGINEER

SUBMITTED BY

CHIEF, PLANNING & RPTS. BRANCH

MERRIMACK RIVER BASIN
NORTH NASHUA RIVER
PHILLIPS DAM
RESERVOIR MAP

PHILLIPS BROOK MASS.

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DATE JAN. 1965

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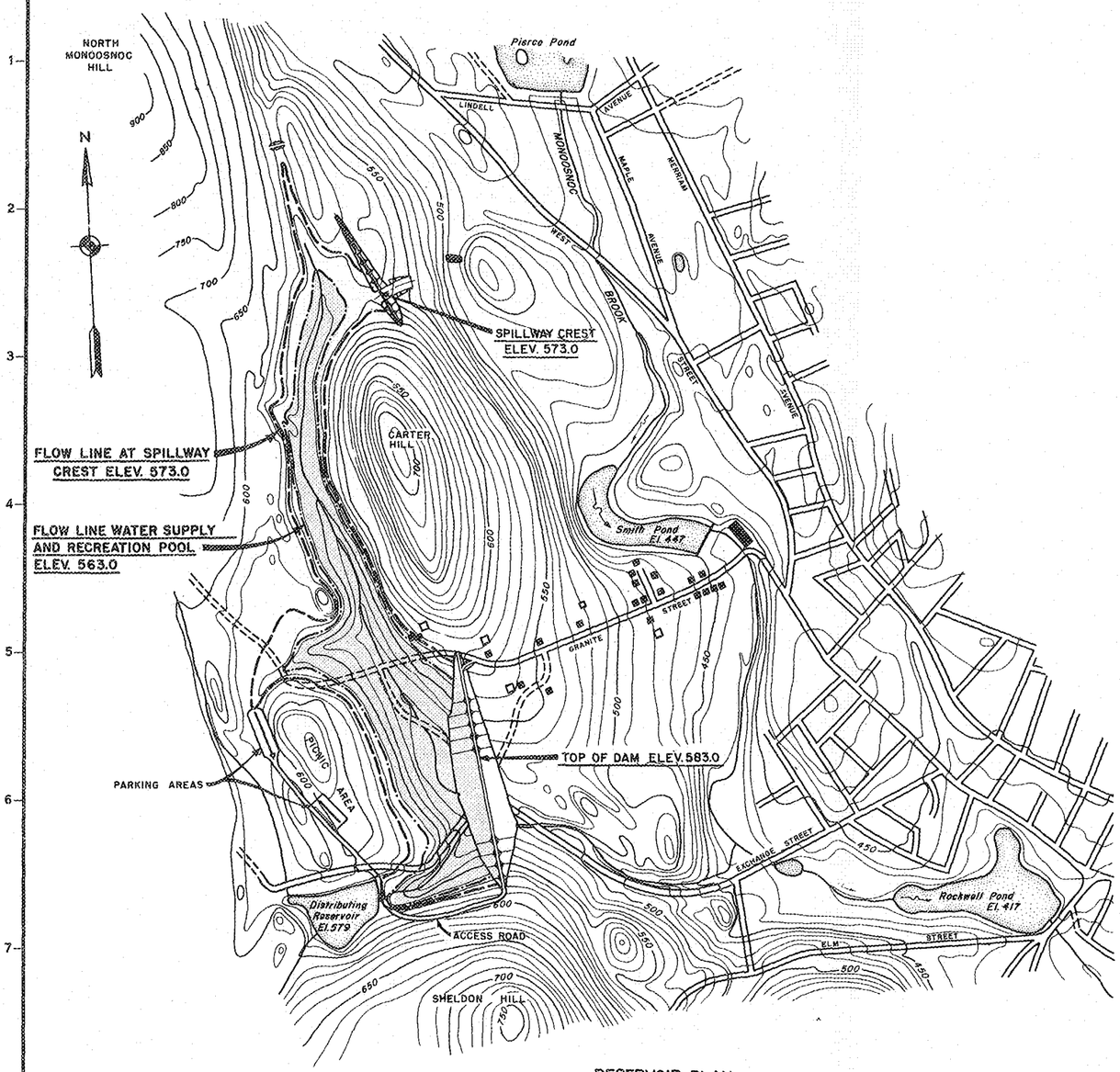
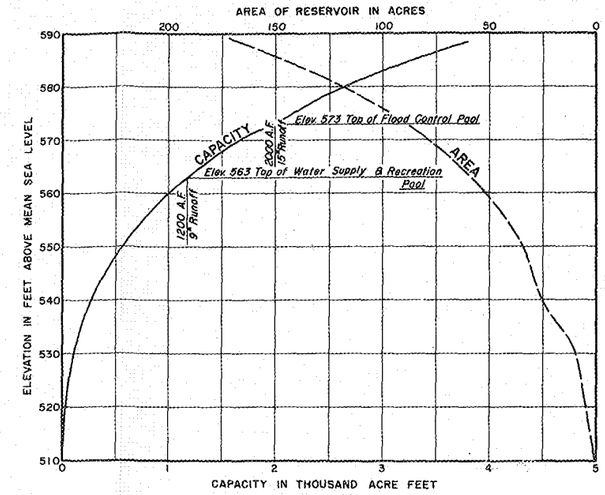


RESERVOIR PLAN

SCALE IN FEET

400' 0 400' 800'



AREA AND CAPACITY CURVES

DRAINAGE AREA 2.5 SQ. MILES

NOTES:

Elevations refer to Mean Sea Level Datum

Contour Interval equals ten feet

Topography by U.S.G.S.

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MERRIMACK RIVER BASIN
NORTH NASHUA RIVER
MONOOSNOC DAM
RESERVOIR MAP

MONOOSNOC BROOK — MASS.

SUBMITTED BY — CHIEF, PLANN & RPTS BRANCH

APPROVED — CHIEF, ENGINEERING DIVISION

DATE JAN. 1965

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SCALE AS SHOWN

DRAWING NUMBER

SHEET

PLATE NO. 5

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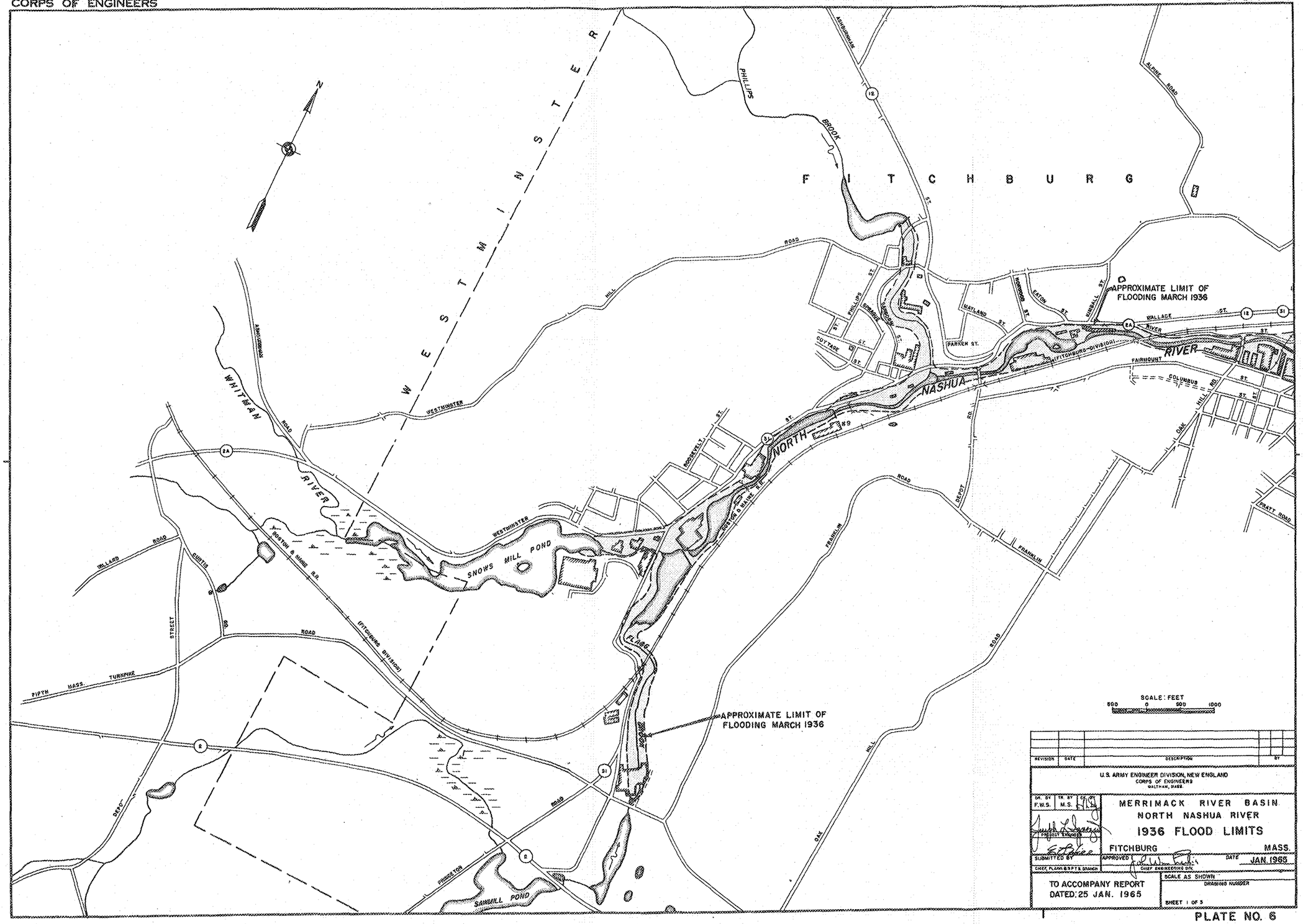

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PROJECT ENGINEER

SUBMITTED BY

CHIEF, PLANN. & R.P.T.S. BRANCH

MERRIMACK RIVER BASIN
NORTH NASHUA RIVER
1936 FLOOD LIMITS

FITCHBURG MASS.

APPROVED

CHIEF ENGINEERING DIV.

DATE JAN. 1965

SCALE AS SHOWN

DRAWING NUMBER

SHEET 1 OF 3

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DATED: 25 JAN. 1965

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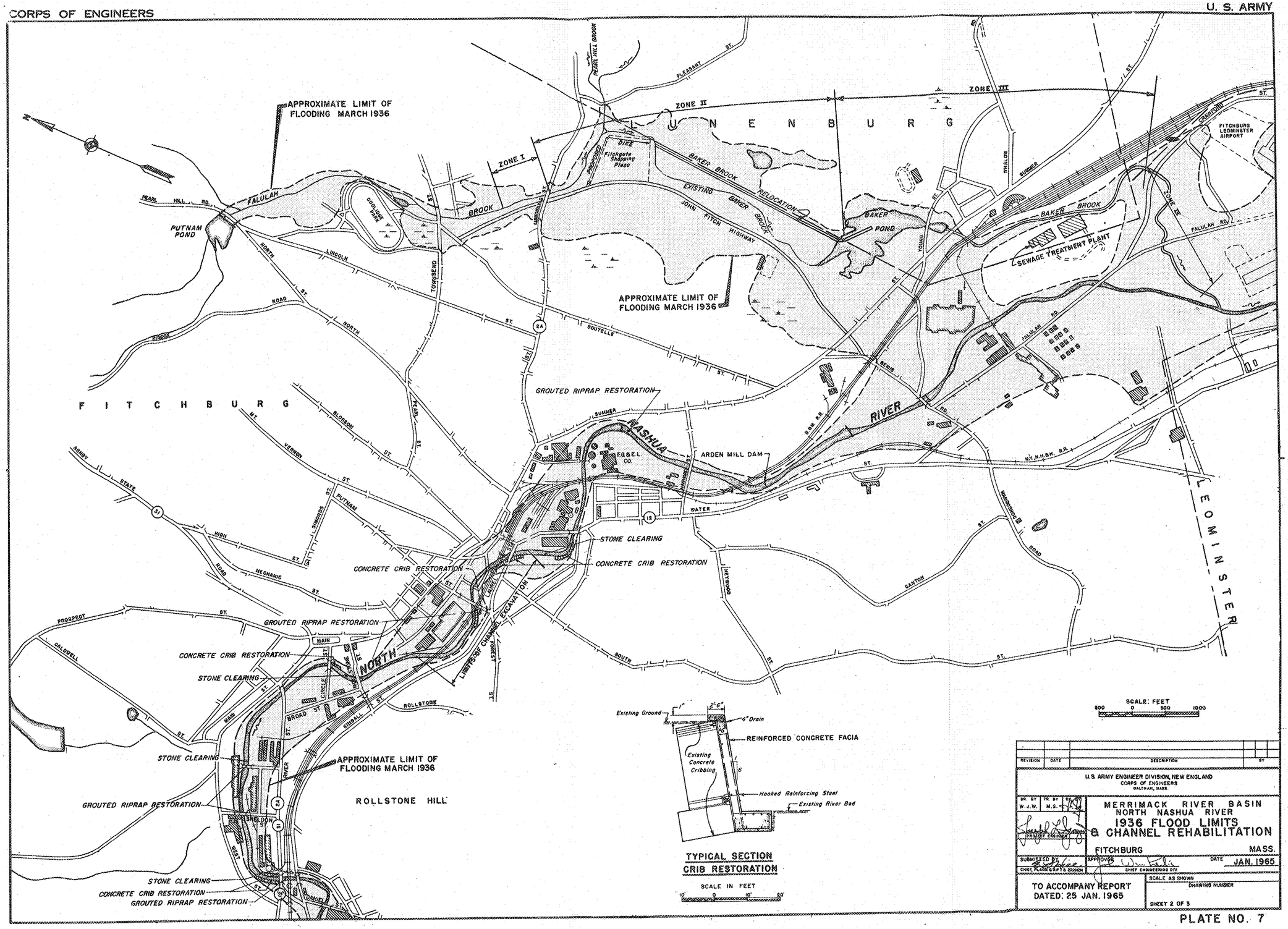
CORPS OF ENGINEERS

U. S. ARMY



REVISION	DATE	DESCRIPTION	BY

U.S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS
WALTHAM, MASS.

DR. BY W.J.W. | TR. BY M.S. | CK. BY

PROJECT ENGINEER

MERRIMACK RIVER BASIN
NORTH NASHUA RIVER
1936 FLOOD LIMITS
& CHANNEL REHABILITATION

FITCHBURG MASS.

SUBMITTED BY: CHIEF, PLANN. & RPT. & ENGINEER

APPROVED: CHIEF, ENGINEERING DIV.

DATE JAN. 1965

TO ACCOMPANY REPORT
DATED: 25 JAN. 1965

SCALE AS SHOWN

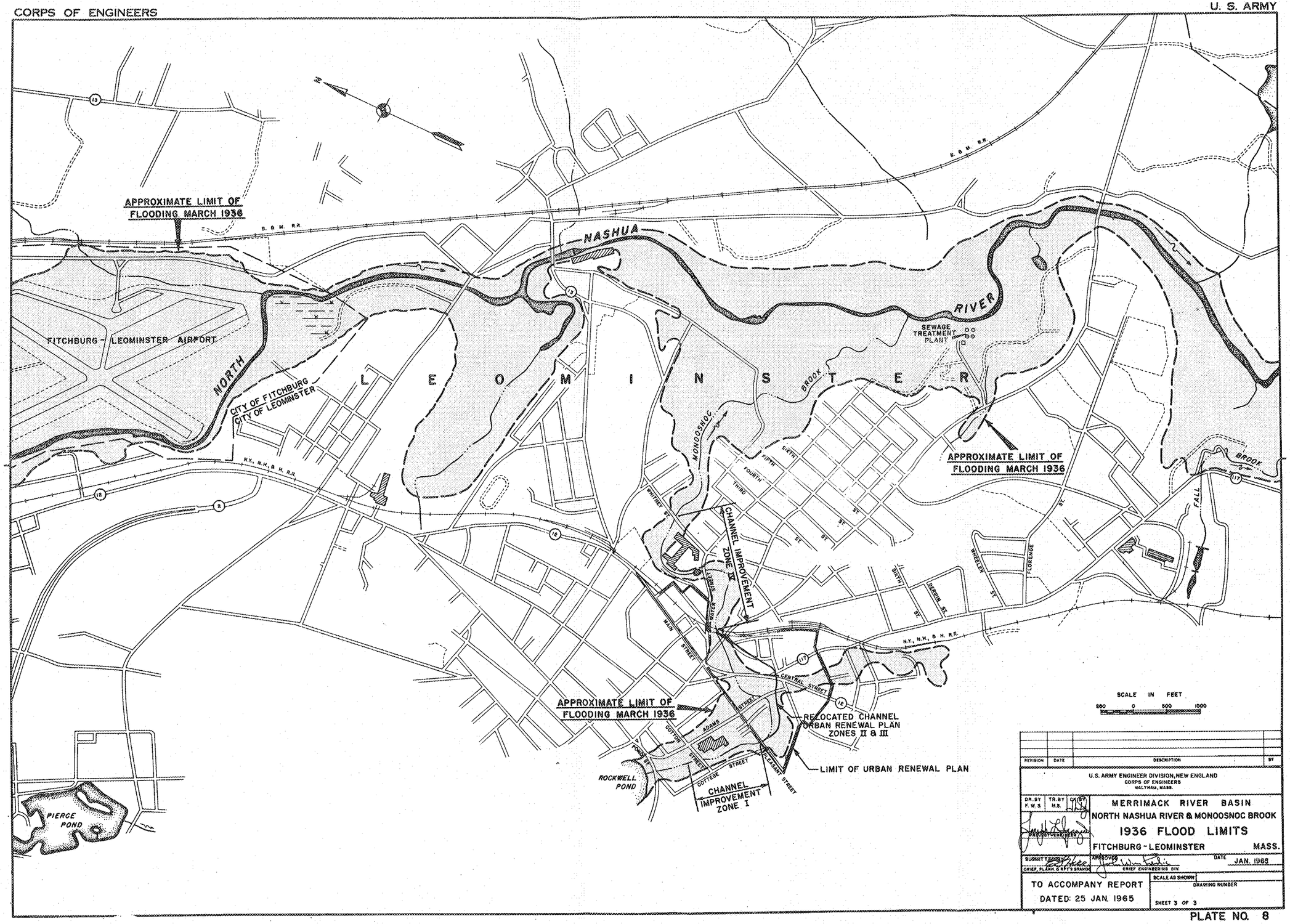
DRAWING NUMBER

SHEET 2 OF 3

PLATE NO. 7

CORPS OF ENGINEERS

U. S. ARMY



REVISION	DATE	DESCRIPTION	BY

U.S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS
WALTHAM, MASS.

DR. BY F.W.S. | TR. BY M.S. | CK. BY

PROJECT ENGINEER

MERRIMACK RIVER BASIN
NORTH NASHUA RIVER & MONOOSNOC BROOK
1936 FLOOD LIMITS
FITCHBURG - LEOMINSTER MASS.

SUBMITTED BY: CHIEF, PLANN. & RPT'S BRANCH
APPROVED: CHIEF ENGINEERING DIV.
DATE JAN. 1965

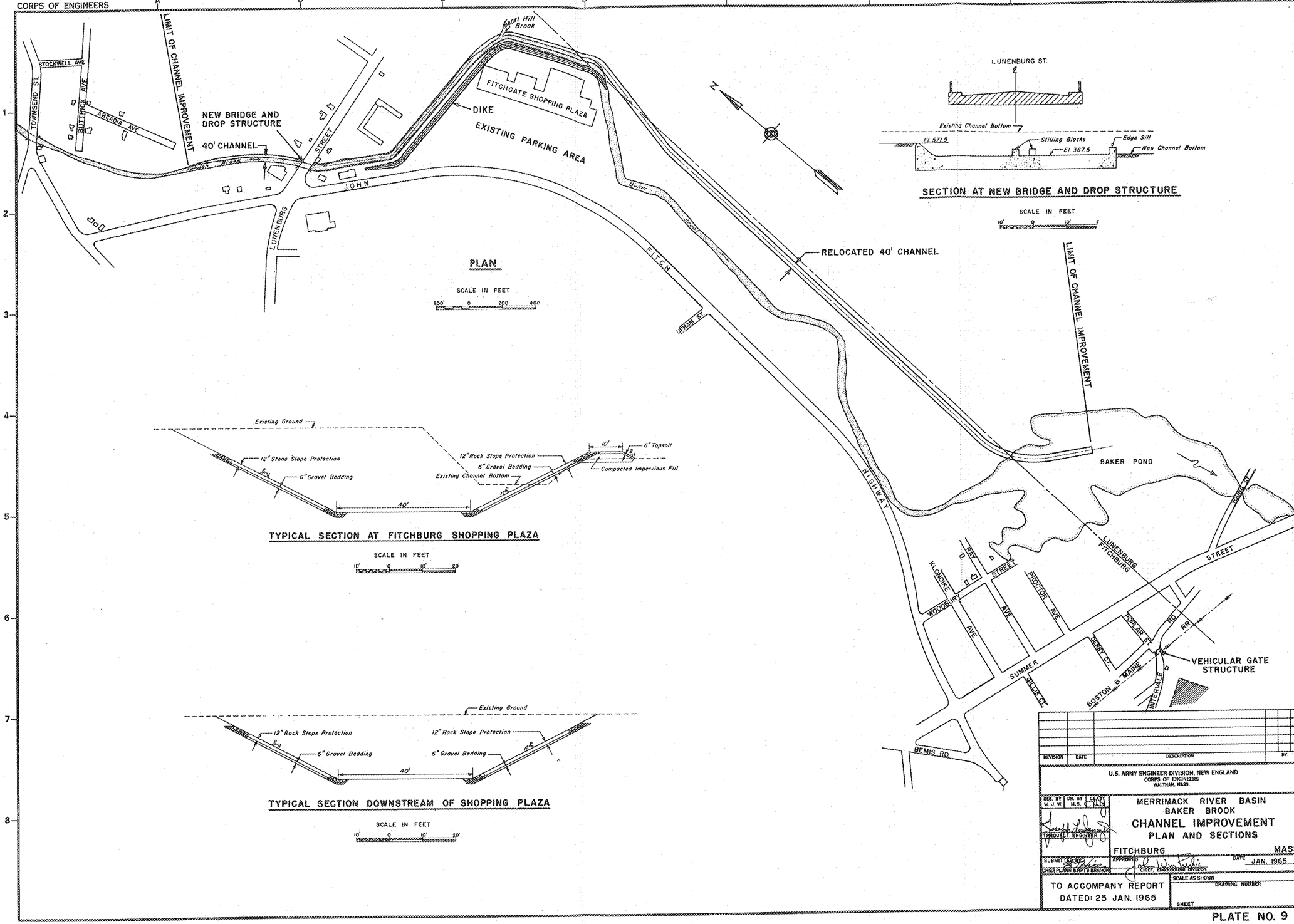
TO ACCOMPANY REPORT
DATED: 25 JAN. 1965

SCALE AS SHOWN
DRAWING NUMBER
SHEET 3 OF 3

PLATE NO. 8

CORPS OF ENGINEERS

U. S. ARMY



REVISION	DATE	DESCRIPTION	BY

U.S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS
WALTHAM, MASS.

DES. BY W. J. W. | DR. BY M. S. | CK. BY

PROJECT ENGINEER

MERRIMACK RIVER BASIN
BAKER BROOK
CHANNEL IMPROVEMENT
PLAN AND SECTIONS

FITCHBURG MASS.

SUBMITTED BY: CHIEF, PLANN. & RPTS. BRANCH

APPROVED: CHIEF, ENGINEERING DIVISION

DATE JAN. 1965

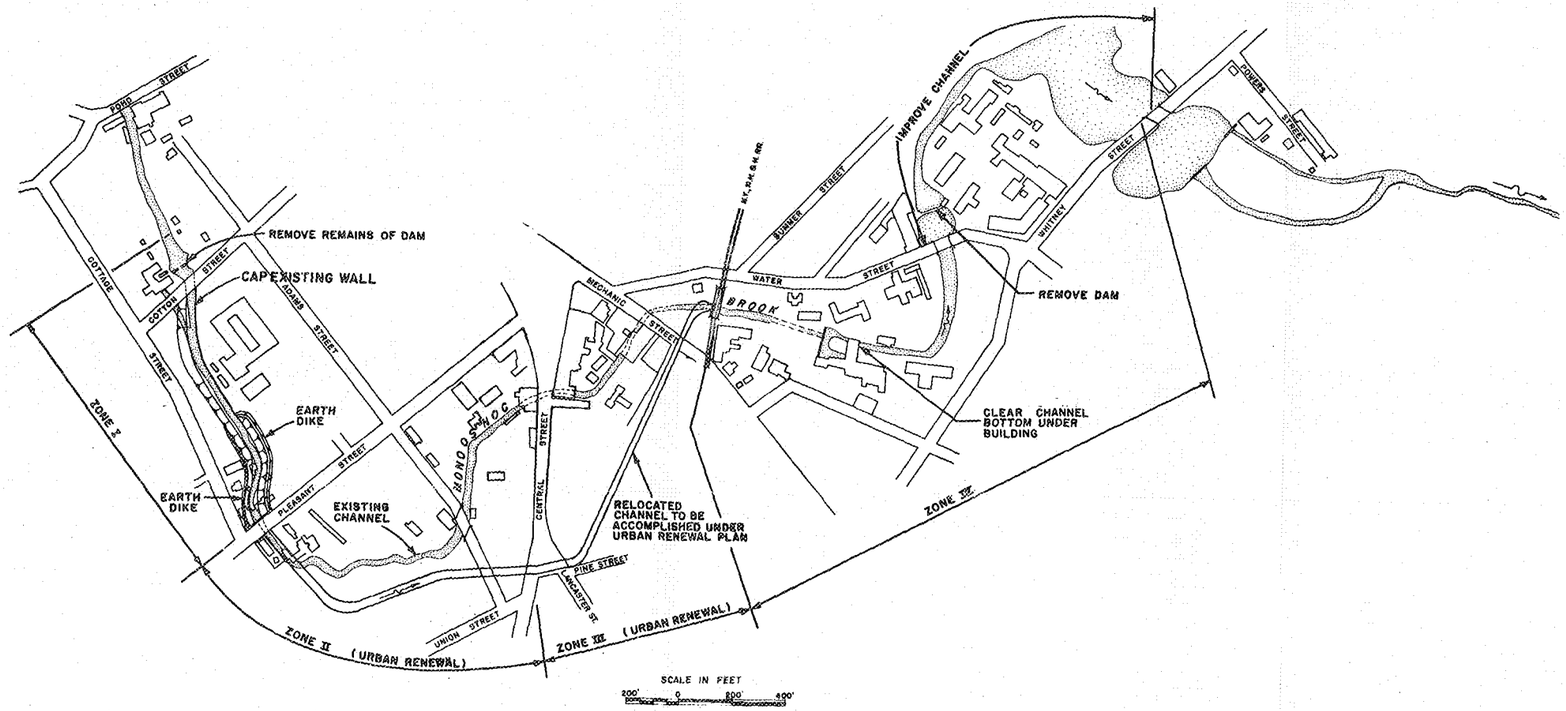
SCALE AS SHOWN

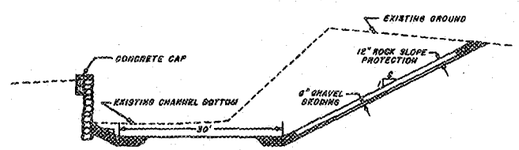
TO ACCOMPANY REPORT
DATED: 25 JAN. 1965

DRAWING NUMBER

SHEET

PLATE NO. 9

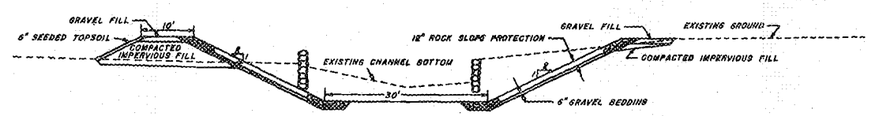




TYPICAL SECTION

FROM COTTON STREET BRIDGE
DOWNSTREAM 580 FEET

SCALE IN FEET
10' 0 10' 20'



TYPICAL SECTION

FROM PLEASANT STREET BRIDGE
UPSTREAM 390 FEET

SCALE IN FEET
10' 0 10' 20'

REVISION	DATE	DESCRIPTION	BY

U.S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS
WALTHAM, MASS.

DR. BY W.J.W. | TR. BY R.S. | CK. BY

PROJECT ENGINEER

MERRIMACK RIVER BASIN
MONOOSNOC BROOK
CHANNEL IMPROVEMENT
PLAN AND SECTIONS

LEOMINSTER MASS.

SUBMITTED BY CHIEF, PLANS & RPTS BRANCH

APPROVED CHIEF ENGINEERING DIV.

DATE JAN. 1965

TO ACCOMPANY REPORT
DATED: 25 JAN. 1965

SCALE AS SHOWN

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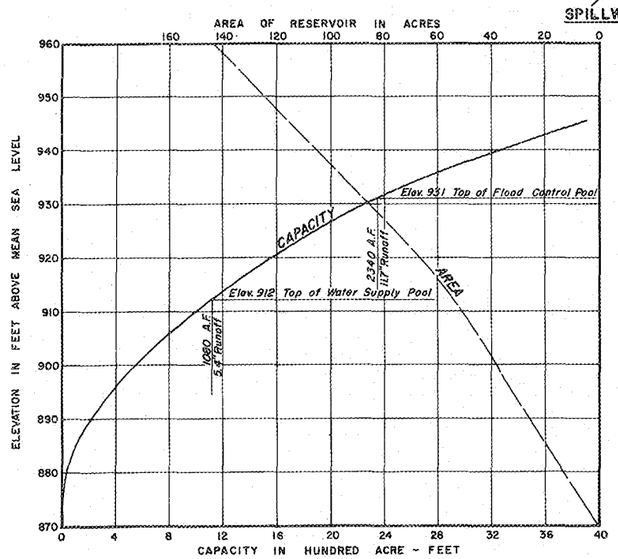


AREA AND CAPACITY CURVES

DRAINAGE AREA 3.8 SQ. MILES

RESERVOIR PLAN

SCALE IN FEET

400' 0 400' 800'

NOTES:

Elevations refer to Mean Sea Level Datum

Contour interval equals ten feet.

Topography by Army Map Service

REVISION	DATE	DESCRIPTION	BY

U.S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS
WALTHAM, MASS.

DR. BY F.W.S. | TR. BY M.W.B. | CK. BY

PROJECT ENGINEER

MERRIMACK RIVER BASIN
NORTH NASHUA RIVER
BAKER BROOK TRIBUTARY
SHATTUCK DAM
RESERVOIR MAP

FALULAH BROOK MASS.

SUBMITTED BY — CHIEF, PLANN. & RPTS. BRANCH

APPROVED — CHIEF, ENGINEERING DIV.

DATE JAN. 1965

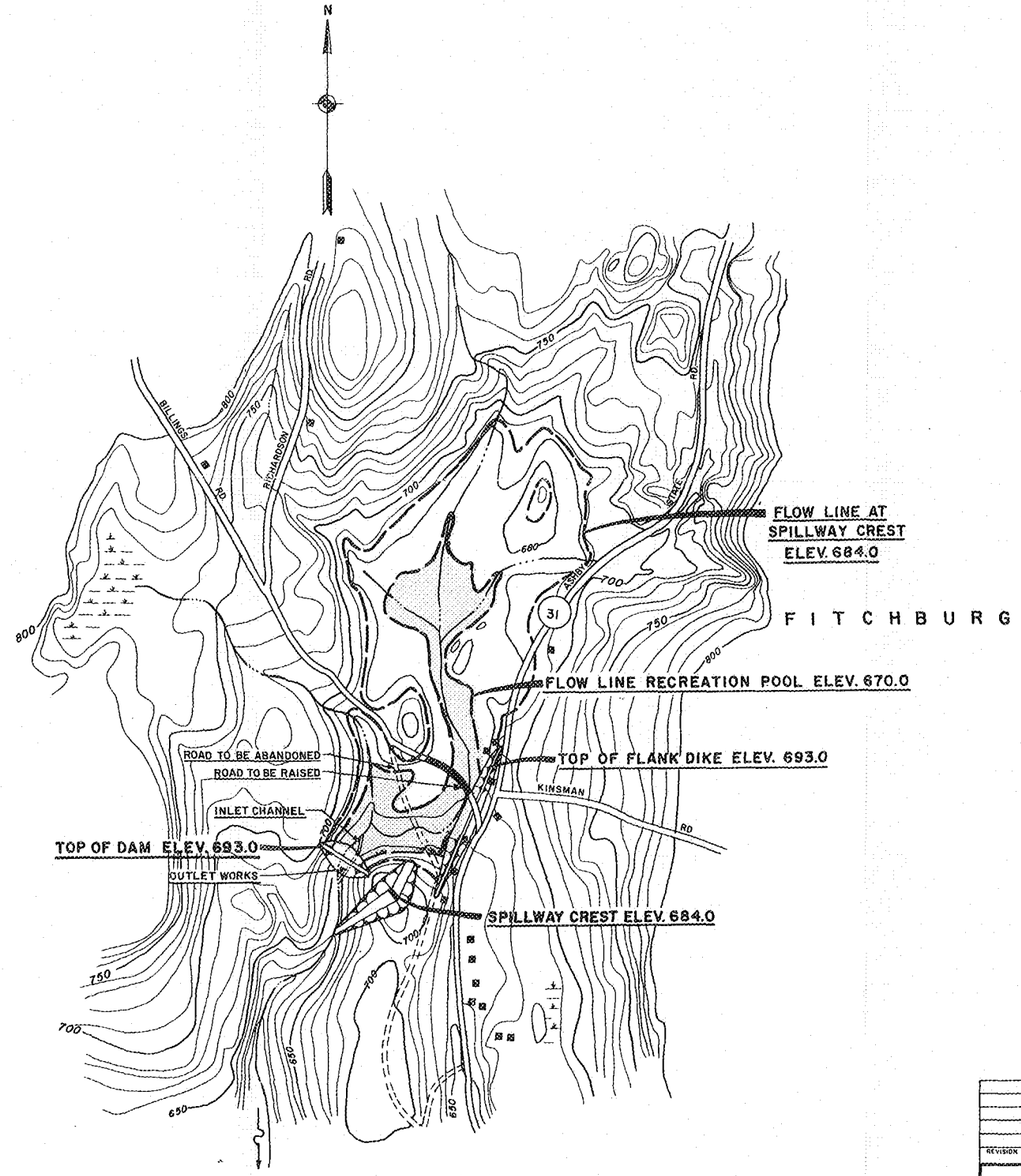
TO ACCOMPANY REPORT
DATED: 25 JAN. 1965

SCALE: AS SHOWN

DRAWING NUMBER

SHEET

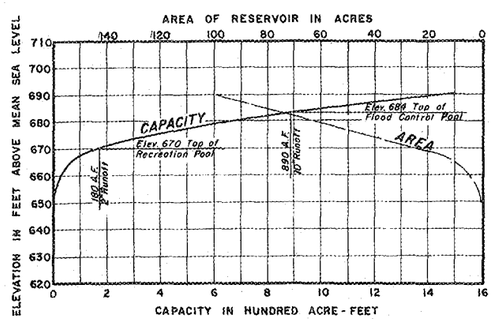
PLATE NO. 11



RESERVOIR PLAN

SCALE: IN FEET

400' 0 400' 800'



AREA AND CAPACITY CURVES

DRAINAGE AREA 1.7 SQ. MILES

NOTES:

Elevations refer to Mean Sea Level Datum

Contour interval equals ten feet.

Topography by Army Map Service

REVISION	DATE	DESCRIPTION	BY

U.S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS
WALTHAM, MASS.

DR. BY F.W.S. | TR. BY M.W.B. | CK. BY

MERRIMACK RIVER BASIN
NORTH NASHUA RIVER
BAKER BROOK TRIBUTARY
SAIMA DAM
RESERVOIR MAP
FALULAH BROOK MASS.

PROJECT ENGINEER

SUBMITTED BY — CHIEF, PLANN. & R.P.T.S. BRANCH

APPROVED — CHIEF ENGINEERING DIV.

DATE JAN. 1965

TO ACCOMPANY REPORT DATED: 25 JAN. 1965

SCALE: AS SHOWN

DRAWING NUMBER

SHEET

ATTACHMENT I

WATER RESOURCES DEVELOPMENT PLAN

NORTH NASHUA RIVER BASIN

Information Called for by
Senate Resolution 148, 85th Congress, 1st Session
Adopted 28 January 1958

ATTACHMENT I

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U. S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS
424 TRAPELO ROAD
WALTHAM, MASS. 02154

ATTACHMENT 1

to

INTERIM REPORT ON NORTH NASHUA RIVER BASIN REPORT
MERRIMACK RIVER, MASSACHUSETTS, DATED 25 JANUARY 1965

ADDITIONAL INFORMATION ON RECOMMENDED AND
ALTERNATIVE PROJECTS CALLED FOR BY SENATE RESOLUTION
148, 85th CONGRESS, 1st SESSION,
ADOPTED 28 JANUARY 1958

1. INTRODUCTORY STATEMENT

The information in this supplement is furnished in response to Senate Resolution 148, 85th Congress, 1st Session, adopted 28 January 1958. This resolution requires information in addition to that now submitted in support of the project recommended for authorization and on possible alternatives thereto. Reasons are given why alternatives are rejected in favor of the recommended project and the effects of alternative standards of evaluation, economic analysis, and cost allocation on project feasibility, scope and cost-sharing arrangements.

2. PROJECT DESCRIPTION AND ECONOMIC LIFE

The Water Resource Development Plan recommended for the North Nashua River Basin provides for beneficial uses of water resources combining (1) flood control, (2) municipal and industrial water supply, (3) recreation, (4) fish and wildlife, and related improvements. The plan provides for three multi-purpose dams and reservoirs, one single-purpose flood control dam, and three separate channel projects, located on the North Nashua River, and Baker and Monoosnoc Brook tributaries. The plan of improvements include the relocation of South Ashburnham Road and Ashburnham Street (Mass. Route 12), construction of independent water supply outlets and construction of recreation facility areas providing for fish and wildlife use as well as areas for bathing, boating and

picnicking. The project would primarily protect highly developed industrial areas along the North Nashua River and its tributaries, including the cities of Fitchburg and Leominster and eight neighboring communities which together comprise a population of approximately 116,000 persons. Project studies revealed the desirability of construction at a future date, three multiple-purpose dams and reservoirs on the Baker Brook tributary, referred to as Shattuck Dam, flood control and water supply; Saima Dam, flood control and recreation; and Pearl Hill Dam, flood control and water supply. The plan is described in further details in Section XIII of this report and in Appendix D. The economic life used in the project analysis is 100 years for reservoirs and 50 years for channel improvements.

3. PROJECT COSTS

The estimates of first costs and annual charges have been prepared on the basis that local interests would: For Local Protection Projects (1) furnish all lands, easements and rights-of-way necessary for the construction of the local channel improvements as well as accomplish all necessary modifications to bridges, sewerage and drainage facilities and relocations of utilities and structures in connection with channel improvements; (2) operate and maintain the project and For Reservoirs repay the allocated costs of water supply and recreation.

Project first costs are based on average bid prices for similar work in the same general area, adjusted to 1964 price levels. Annual charges in the report are based on interest on the investment and amortization over the assumed project life, to which are added amounts for maintenance and operation of the project, interim replacement of equipment having an estimated life of less than the economic life. Interest rates are 3.125 percent for Federal and non-Federal costs. First costs and annual charges are detailed in Appendix I.

4. BENEFIT-COST RATIOS

Table 1 presents a summary of economic data for the water resources development plan. The ratio of annual benefits to annual costs is given for both a 50 and 100-year project life. Benefits are based on tangible benefits as given in Paragraphs 61 to 63 of the basic report. Annual costs consisting of interest on investment, amortization and maintenance and operation and allowance for major replacement costs, are reported in Paragraphs 59 and 60 of the report. The benefit-cost ratio for the plan of a 100-year project life is substantially the same for each of the

three methods of cost allocation used, and the same holds true of the plan for a 50-year project life. The benefit-cost ratio for the 100-year project life is significantly greater than that of the 50-year project life.

5. INTANGIBLE PROJECT EFFECTS

In addition to the tangible benefits included in Paragraphs 61-63, important unevaluated tangible and intangible benefits would accrue to the recommended project since it would provide an atmosphere of greater stability and confidence in the productive hearts of the cities of Fitchburg and Leominster. Threats of disease, emergency evacuation measures, and much of the threat of life posed by severe flooding would be virtually eliminated. In addition, protection would be provided for Fitchburg and Leominster's major industries, which are not only important contributors to the national defense but account for approximately 60 percent of the total employment of their respective cities. The water supply storage (industrial) will provide for normal and anticipated use as well as the future expansion of the industrial demand. The recreation improvements are designed to provide for normal anticipated use.

6. PHYSICAL FEASIBILITY AND COST OF PROVIDING FOR FUTURE NEEDS

The measures to control flooding and to provide related water resources improvement fully develop site potentials. Expansion of the proposed facilities can be readily made as later demands warrant, by consideration of Saima, Pearl Hill and Shattuck Dams and reservoirs.

7. ALLOCATION OF COSTS

Allocation of costs were computed by (1) the separable cost-remaining benefits method, (2) the priority of use method, and (3) the incremental cost method for project economic lives of 50 and 100-years. The cost allocation summaries are shown in Tables 2, 3 and 4.

8. EXTENT OF INTEREST IN PROJECT

The recommended plan received the approval of State and City officials and many of the local citizens at a public hearing and subsequent meetings. Copies of letters commenting on the project and abstracts of statements given at the hearing are contained in Appendix J.

9. REPAYMENT SCHEDULES

There are reimbursable features incorporated in the recommended plan. Any required cash contribution or reimbursement by non-Federal interests would be made in accordance with applicable Federal law.

10. PROPOSED INCREASES IN APPROPRIATIONS

The project recommended for immediate construction would increase the necessary Federal appropriations required for the construction of flood control projects in the Merrimack River basin by $15,816,000 of which $3,830,000 would be reimbursed for water supply features. The construction of three reservoir projects at a future date would increase the necessary Federal appropriation by an additional $4,160,000 of which $1,396,000 would be reimbursed for water supply features. With approval of the project recommended in this report, the basin-wide flood control plan for the Merrimack River, together with the status of each element, is given below.

Project	Present Status
Dams and Reservoirs	
Blackwater	Completed
Edward MacDowell	Completed
Franklin Falls	Completed
Hopkinton-Everett	Completed
Mountain Brook	Inactive
Local Protection	
Fitchburg	Rehabilitation required
Haverhill	Completed
Lawrence	Inactive
Lincoln	Completed
Lowell	Completed
Nashua	Completed

Whitmanville	Recommended for immediate construction		
Nookagee	"	"	"
Phillips	"	"	"
Monoosnoc	"	"	"
North Nashua Channel Improvement	"	"	"
Baker Brook Channel Improvement	"	"	"
Monoosnoc Brook Channel Improvement	"	"	"
Saima	Recommended for future construction		
Shattuck	"	"	"
Pearl Hill	"	"	"

11. EFFECT OF PROJECT ON STATE AND LOCAL GOVERNMENTS

The proposed improvements will necessitate the acquisition of 1315 acres of land in fee. Loss of taxes on land areas to be inundated by reservoirs has not been included as it is expected that enhancement of lands along the periphery of the proposed reservoirs will offset any tax loss on inundated areas. The channel improvements on the North Nashua River and Baker and Monoosnoc Brook tributaries can be accomplished by the taking of permanent easements. Overall tax revenues will tend to increase due to construction of the recommended project, based on increase value of property through removal of the flood threat, and the stimulation of new construction in the flood-prone areas. No detailed estimate of this increase has been made as it will result from (a) the project; (b) increased economic activity in the area induced by population and industrial growth and (c) improved access by new highway construction.

12. ALTERNATIVE PROJECTS

Considered plans for flood protection for the Fitchburg-Leominster area include protection of major damage reaches to various degrees ranging from protection against the flood of 1936 to the Standard Project Flood, considering various alignments and structures for different levels of protection. An evaluation of all the alternate plans considered showed that they could not be economically justified and in many instances did not offer opportunities for full development of the available resources. The use of a major channel improvement in lieu of upstream reservoirs was found to be impractical due to the disruption of existing facilities in the

heavily built up flood plain areas. The use of diversion tunnels and closed conduits, although less disruptive to existing facilities, bridges, buildings, etc. was found to be excessive in cost. Further details on project formulation and evaluation of alternate plans of improvement are given in Appendix D.

TABLE NO. 1 - Attachment #1

COMPARISON OF PROJECT COSTS AND BENEFITS

	RESERVOIRS								CHANNELS					
	WHITMANVILLE		NOOKAGEE		PHILLIPS		MONOOSNOC		NO. NASHUA		BAKER BROOK		MONOOSNOC BROOK	
	50 Yrs.	100 Yrs.	50 Yrs.	100 Yrs.	50 Yrs.	100 Yrs.	50 Yrs.	100 Yrs.	50 Yrs.	100 Yrs.	50 Yrs.	100 Yrs.	50 Yrs.	100 Yrs.
Construction Expenditures	$ 3,840,000	$3,840,000	$5,430,000	$5,430,000	$2,320,000	$2,320,000	$2,610,000	$2,610,000	$700,000	$700,000	$900,000	$900,000	$290,000	$290,000
Annual Charges														
Interest & Amortization	153,000	126,000	216,100	178,000	92,300	76,000	103,900	85,200	27,900	23,000	35,800	29,600	11,600	9,500
Operation & Maintenance	5,600	5,600	15,500	15,500	4,000	4,000	12,400	12,400	7,000	7,000	4,500	4,500	1,300	1,300
Major Replacements	200	400	4,300	4,500	0	0	4,200	4,400	0	0	0	0	0	0
TOTAL ANNUAL CHARGES	$ 158,800	$ 132,000	$ 235,900	$ 198,000	$ 96,300	$ 80,000	$ 120,500	$ 102,000	$ 34,900	$ 30,000	$ 40,300	$ 34,100	$12,900	$10,800
Annual Benefits														
Flood Control	464,000	464,000	357,000	357,000	162,000	162,000	43,000	43,000	40,000	40,000	57,800	57,800	27,000	27,000
Water Supply	69,600	58,000	156,900	130,000	0	0	66,200	55,000	0	0	0	0	0	0
Recreation	0	0	90,000	90,000	0	0	71,000	71,000	0	0	0	0	0	0
TOTAL ANNUAL BENEFITS	$ 533,600	$ 522,000	$ 603,900	$ 577,000	$ 162,000	$ 162,000	$ 180,200	$ 169,000	$ 40,000	$ 40,000	$ 57,800	$ 57,800	$ 27,000	$ 27,000
Benefit-Cost Ratio	3.4	3.9	2.6	2.9	1.7	2.0	1.5	1.7	1.2	1.3	1.4	1.7	2.1	2.5

TABLE 2 - Attachment 1

ALLOCATIONS OF COST FOR WHITMANVILLE DAM

	Economic Life - 50 Years			Economic Life - 100 Years		
	Flood Control	Water Supply	Total	Flood Control	Water Supply	Total
	$	$	$	$	$	$
SEPARABLE COSTS - REMAINING BENEFITS METHOD						
1. Annual Benefits	464,000	69,600	533,600	464,000	58,000	522,000
2. Allocation of Costs						
a. Annual economic costs	107,900	45,100	153,000	88,800	37,200	126,000
b. Annual O&M and replacement costs	3,700	2,100	5,800	3,700	2,300	6,000
c. Construction expenditures in specific facilities	6,300	166,000	172,300	6,300	166,000	172,300
d. Construction expenditures in joint use facilities	2,703,700	964,000	3,667,700	2,703,700	964,000	3,667,700
e. Total construction expenditures (First Cost)	2,710,000	1,130,000	3,840,000	2,710,000	1,130,000	3,840,000
PRIORITY OF USE METHOD 1/						
1. Annual Benefits	464,000	69,600	533,600	464,000	58,000	522,000
2. Allocation of Costs						
a. Annual economic costs	135,300	17,700	153,000	111,500	14,500	126,000
b. Annual O&M and replacement costs	4,800	1,000	5,800	4,800	1,200	6,000
c. Construction expenditures in specific facilities	6,300	166,000	172,300	6,300	166,000	172,300
d. Construction expenditures in joint use facilities	3,383,700	284,000	3,667,700	3,383,700	284,000	3,667,700
e. Total construction expenditures (First Cost)	3,390,000	450,000	3,840,000	3,390,000	450,000	3,840,000
INCREMENTAL COST METHOD 2/						
1. Annual Benefits	464,000	69,600	533,600	464,000	58,000	522,000
2. Allocation of Costs						
a. Annual economic costs	129,500	23,500	153,000	106,600	19,400	126,000
b. Annual O&M and replacement costs	4,400	1,400	5,800	4,400	1,600	6,000
c. Construction expenditures in specific facilities	6,300	166,000	172,300	6,300	166,000	172,300
d. Construction expenditures in joint use facilities	3,243,700	424,000	3,667,700	3,243,700	424,000	3,667,700
e. Total construction expenditures (First Cost)	3,250,000	590,000	3,840,000	3,250,000	590,000	3,840,000

1/ Priority for assigning remaining costs (1) Flood Control; (2) Water Supply.

2/ Flood Control considered the basic function to which all remaining costs are assigned.

TABLE 3 - Attachment 1

ALLOCATIONS OF COSTS FOR NOOKAGEE RESERVOIR (1964 Dollars)

	Economic Life - 50 Years				Economic Life - 100 Years			
	Flood Control $	Water Supply $	Recreation $	Total $	Flood Control $	Water Supply $	Recreation $	Total $
SEPARABLE COSTS - REMAINING BENEFITS METHOD								
1. Annual Benefits	357,000	156,900	90,000	603,900	357,000	130,000	90,000	577,000
2. Allocation of Costs								
a. Annual economic costs	96,300	81,300	38,500	216,100	77,000	64,900	36,100	178,000
b. Annual O&M and replacement costs	2,900	2,000	14,900	19,800	3,000	2,100	14,900	20,000
c. Construction expenditures in specific facilities	90,000	134,000	244,000	468,000	90,000	134,000	244,000	468,000
d. Construction expenditures in joint use facilities	2,329,000	1,909,000	724,000	4,962,000	2,260,000	1,846,000	856,000	4,962,000
e. Total construction expenditures (First Cost)	2,419,000	2,043,000	968,000	5,430,000	2,350,000	1,980,000	1,100,000	5,430,000
PRIORITY OF USE METHOD 1/								
1. Annual Benefits	357,000	156,900	90,000	603,900	357,000	130,000	90,000	577,000
2. Allocation of Costs								
a. Annual economic costs	171,900	34,500	9,700	216,100	141,400	28,600	8,000	178,000
b. Annual O&M and replacement costs	4,600	1,200	14,000	19,800	4,600	1,200	14,200	20,000
c. Construction expenditures in specific facilities	90,000	134,000	244,000	468,000	90,000	134,000	244,000	468,000
d. Construction expenditures in joint use facilities	4,227,000	735,000	0	4,962,000	4,227,000	735,000	0	4,962,000
e. Total construction expenditures (First Cost)	4,317,000	869,000	244,000	5,430,000	4,317,000	869,000	244,000	5,430,000
INCREMENTAL COST METHOD 2/								
1. Annual Benefits	357,000	156,900	90,000	603,900	357,000	130,000	90,000	577,000
2. Allocation of Costs								
a. Annual economic costs	173,500	29,800	12,800	216,100	142,700	24,400	10,900	178,000
b. Annual O&M and replacement costs	3,900	1,400	14,500	19,800	4,300	1,600	14,100	20,000
c. Construction expenditures in specific facilities	90,000	134,000	244,000	468,000	90,000	134,000	244,000	468,000
d. Construction expenditures in joint use facilities	4,270,000	616,000	76,000	4,962,000	4,270,000	616,000	76,000	4,962,000
e. Total construction expenditures (First Cost)	4,360,000	750,000	320,000	5,430,000	4,360,000	750,000	320,000	5,430,000

1/ Priority for assigning remaining costs: (1) flood control; (2) water supply; (3) recreation.

2/ Flood control considered the basic function to which all remaining costs are assigned.

TABLE 4 - Attachment 1

ALLOCATIONS OF COSTS FOR MONOOSNOC RESERVOIR (1964 Dollars)

	Economic Life - 50 Years				Economic Life - 100 Years			
	Flood Control	Water Supply	Recreation	Total	Flood Control	Water Supply	Recreation	Total
SEPARABLE COSTS - REMAINING BENEFITS METHOD								
1. Annual Benefits	43,000	66,100	71,000	180,100	43,000	55,000	71,000	169,000
2. Allocation of Costs								
a. Annual economic costs	36,600	33,300	33,800	103,700	32,800	23,500	28,900	85,200
b. Annual O&M and replacement costs	2,500	1,600	12,500	16,600	2,500	1,600	12,700	16,800
c. Construction expenditures in specific facilities	25,000	85,000	305,000	415,000	25,000	85,000	305,000	415,000
d. Construction expenditures in joint use facilities	896,000	753,000	546,000	2,195,000	975,000	635,000	585,000	2,195,000
e. Total construction expenditures (First Cost)	921,000	838,000	851,000	2,610,000	1,000,000	720,000	890,000	2,610,000
PRIORITY OF USE METHOD 1/								
1. Annual Benefits	43,000	66,100	71,000	180,100	43,000	55,000	71,000	169,000
2. Allocation of Costs								
a. Annual economic costs	40,100	51,500	12,100	103,700	40,100	35,100	10,000	85,200
b. Annual O&M and replacement costs	2,900	2,600	11,100	16,600	2,900	2,600	11,300	16,800
c. Construction expenditures in specific facilities	25,000	85,000	305,000	415,000	25,000	85,000	305,000	415,000
d. Construction expenditures in joint use facilities	985,000	1,205,000	5,000	2,195,000	1,195,000	975,000	25,000	2,195,000
e. Total construction expenditures (First Cost)	1,010,000	1,290,000	310,000	2,610,000	1,220,000	1,060,000	330,000	2,610,000
INCREMENTAL COST METHOD 2/								
1. Annual Benefits	43,000	66,100	71,000	180,100	43,000	55,000	71,000	169,000
2. Allocation of Costs								
a. Annual economic costs	93,200	3,000	7,500	103,700	76,400	3,000	5,800	85,200
b. Annual O&M and replacement costs	3,500	1,000	12,100	16,600	3,600	1,000	12,200	16,800
c. Construction expenditures in specific facilities	25,000	85,000	305,000	415,000	25,000	85,000	305,000	415,000
d. Construction expenditures in joint use facilities	2,195,000	0	0	2,195,000	2,195,000	0	0	2,195,000
e. Total construction expenditures (First Cost)	2,220,000	85,000	305,000	2,610,000	2,220,000	85,000	305,000	2,610,000

1/ Priority for assigning remaining costs (1) Flood Control; (2) Water Supply; (3) Recreation.

2/ Flood Control considered the basic function to which all remaining costs are assigned.