

FLOOD-PLAIN AREAS

OF THE

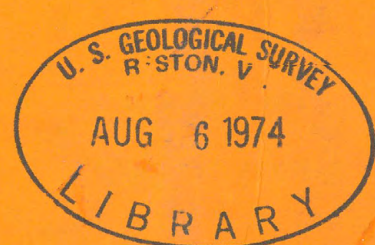
LOWER MINNESOTA RIVER



Flood of April, 1969 at Savage, Minn.

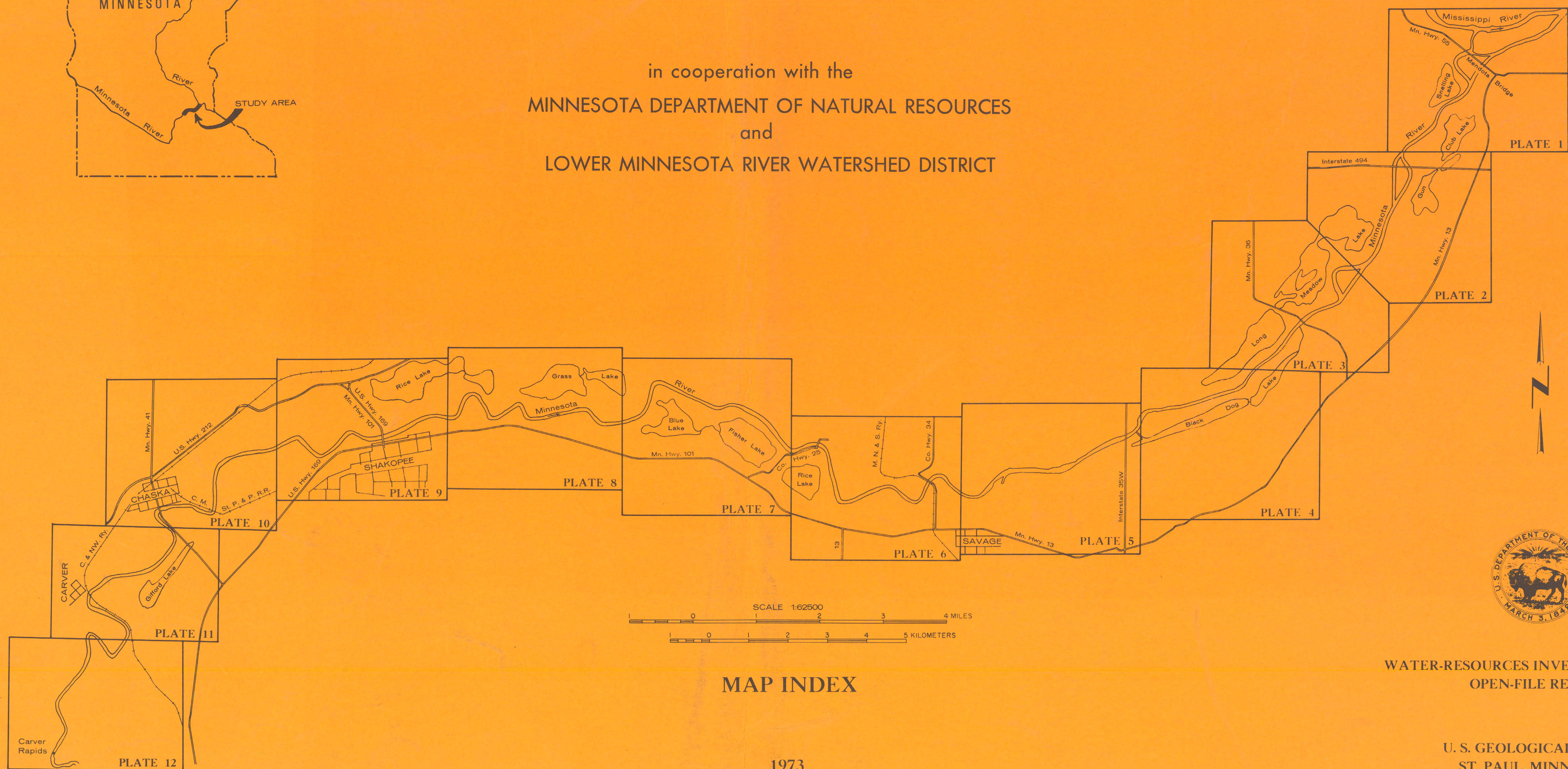


Flood of April, 1965 at Carver, Minn.



UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

in cooperation with the
MINNESOTA DEPARTMENT OF NATURAL RESOURCES
and
LOWER MINNESOTA RIVER WATERSHED DISTRICT



MAP INDEX

WATER-RESOURCES INVESTIGATIONS 15-74
OPEN-FILE REPORT

U. S. GEOLOGICAL SURVEY
ST. PAUL, MINNESOTA

FLOOD-PLAIN AREAS OF THE LOWER MINNESOTA RIVER

INTRODUCTION

Purpose and scope

This report presents the results of a flood-plain study along the lower Minnesota River from the mouth to Carver Rapids, 36 miles upstream. In this reach, there are flood-plain lands subject to recurrent flooding within the unincorporated areas of Scott and Carver Counties and 11 municipalities.

Floods have caused extensive damage to the agricultural and transportation industries as well as to private and industrial developments, the most recent notable flood being in 1969. Despite documented evidence of flood hazards, development of flood-prone areas has increased significantly in recent years. Maintenance of a navigation channel in the downstream part of the study reach and the fact that the lower Minnesota River valley is in the Twin City metropolitan area have attracted further industrial development. Unregulated development increases the potential for flood damage by the addition of structures and their associated municipal services. Also, structural constrictions of flood-plain areas decreases their capacity to carry flood flows, which causes higher flood elevations upstream.

Planning and implementation of a flood-plain management program requires reliable technical data to (1) define flood-plain limits, (2) determine flood protection elevations, and (3) evaluate the increases in the regional flood profile which will result from proposed development of flood-plain areas. Owing to the slight stream gradient in the study reach, the effect of changes within the flood plain can extend a considerable distance upstream. Therefore, a piecemeal approach involving studies of individual communities would not provide a realistic solution to their problems, which are highly interrelated. In recognition of this, the Lower Minnesota River Watershed District was formed to provide an integrated approach to the solution of problems related to the lower Minnesota River.

The Flood Plain Management Act, passed by the Minnesota Legislature in 1969 and amended in 1973, adds impetus to the regulation of flood-plain areas by requiring local units of government to adopt, enforce, and administer flood-plain management ordinances within their respective jurisdictions whenever sufficient data are available to formulate such regulations. Under the Act, the Minnesota Department of Natural Resources is given responsibility to collect and distribute information relating to flooding and flood-plain management, establish standards for local regulations, and assist local governmental units in flood-plain management activities.

The primary purpose of this study is to provide the information needed for adoption and administration of local flood-plain regulations. The hydrologic data contained herein can be used to evaluate the extent, depth, and frequency of flooding that will affect economic development of flood-plain areas in the lower Minnesota River valley. Designated floodways are shown for the entire study area. The effect of planned encroachment, by development to the limits of floodways, is evaluated and incorporated into the flood protection elevation profiles contained in this report.

This report was prepared by the U.S. Geological Survey in cooperation with the Lower Minnesota River Watershed District and the Minnesota Department of Natural Resources.

Acknowledgment

Acknowledgment is made to U.S. Army Corps of Engineers—St. Paul District, Minnesota Department of Highways, city of Bloomington, Itasca Engineering, Inc., and the many industrial firms and private individuals who provided historical flood information.

EXPLANATION OF TERMS 1/

Regional flood.—A flood which is representative of large floods known to have occurred generally in Minnesota and reasonably characteristic of what can be expected to occur on an average frequency in the magnitude of the 100-year recurrence interval. In terms of probability, the regional flood has a 1-percent chance of occurring in any given year.

Recurrence interval.—The average interval of time, based on statistical analysis of actual or representative streamflow records, which can be expected to elapse between floods equal to or greater than a specified stage or discharge. The recurrence interval is expressed in years.

Probability.—The inverse of recurrence interval. Thus a flood of specified magnitude having a 20-year recurrence interval has a 5-percent chance of being equaled or exceeded in any year, and a 100-year flood has a 1-percent chance in any year.

Flood plain.—Areas adjoining a watercourse which have been or hereafter may be covered by the regional flood. Delineation of the flood plain shall be based on the flood-protection elevation.

Flood-protection elevation.—The elevation corresponding to a point not less than 1 foot above the water-surface profile associated with the regional (100-year) flood plus any increases in flood stage attributable to encroachments on the flood plain.

Floodway.—The channel of a watercourse and those portions of the adjoining flood plains which are reasonably required to carry and discharge the regional flood.

1/ Explanation of terms is taken from or is in agreement with "Rules and Regulations of the Department of Natural Resources Relating to Statewide Standards and Criteria for Management of Flood Plain Areas of Minnesota, 1970."

Delineation of the floodway.—A part of the flood plain, outside of the immediate channel of a watercourse, shall be selected and designated as the floodway by a local governmental unit upon approval of the Commissioner, Department of Natural Resources. The selection must be based on an evaluation of the flood hazard for the area and must conform to the following standards:

The limits of the floodway shall be designated so that permissible encroachments on the flood plain will not cause an increase in stage of the regional flood of more than 0.5 foot in any one reach or for the cumulative effect of several reaches of a watercourse.

Conversion factors.—The following factors may be used to convert the English units published herein to the International System of Units (SI).

Multiply English units	By	To obtain SI units
feet (ft)	0.3048	meters (m)
miles (mi)	1.609	kilometers (km)
feet per second (ft/s)	.3048	meters per second (m/s)
cubic feet per second (ft ³ /s)	.02832	cubic meters per second (m ³ /s)

HISTORY OF FLOODING

Description of flood-plain areas

The lower Minnesota River valley from Carver Rapids to the Mississippi River is cut into Cambrian and Ordovician marine sedimentary rocks, consisting of Jordan Sandstone and the Prairie du Chien Group (mostly Jordan Sandstone). Jordan Sandstone is not exposed in the valley within the study area, but upper units of the Prairie du Chien Group are exposed at Shakopee and at places downstream as far as Savage. The valley is filled with glacial sediments and alluvium of relatively recent age.

The present-day Minnesota River is not large enough to have cut the valley it occupies and is thus classed as an underfit stream. The valley is more than 3 miles wide at Carver Rapids and even wider downstream. It was carved by Glacial River Warren, the southern outlet for Glacial Lake Agassiz to the west (Leverett, 1932, p. 123-126). Because of the slight gradient, about 0.3 foot per mile, and the erodibility of valley-fill sediments the river meandered considerably, giving rise to several oxbow lakes. Characteristically, the flood plain is poorly drained and contains many lakes and swamps.

Vast areas along the lower Minnesota River are subject to recurrent flooding because of extremely flat and wide flood plains. In some places, the outer edges of the flood plain are formed by high bluffs, whereas, in other places, the edges are formed by gently sloping terraces within the valley. At the terraced areas, the limits of areas subject to frequent flooding are less apparent. Most of the early settlements in the valley, such as Chaska and Carver, were developed on these terraced areas. These settlements occupied only a small part of the flood plain and did not materially reduce the capacity of the overbank areas to carry flood flows.

The pattern of development on flood-plain areas has changed in recent years. Diking to protect existing industries and new industrial expansion across large areas of the flood plain have increased the upstream flood potential. The most severe encroachments are in the flood extending several miles upstream from Interstate Highway 35W.

As part of this study, a detailed analysis was made of the peak discharge associated with the 1969 flood for flood-plain conditions existing in 1969 and also for flood-plain conditions existing in 1972. This analysis indicates that added encroachment on the flood plain since 1969 would increase the elevation for a flood of the same magnitude by almost half a foot in the Savage area. Although the increase in elevation would diminish upstream, some of the effect would continue to Carver Rapids.

Source of flooding

Flooding in the study area results not only from flows originating within the Minnesota River basin, but also from flows originating in the Mississippi River upstream from the mouth of the Minnesota River. Upstream from Carver, flooding is primarily associated with flows from the Minnesota River basin. Downstream from Carver, the backwater effect from combined flows of the Minnesota and Mississippi Rivers has an ever-increasing influence on flood elevations.

The crest elevation and the area inundated are greatly affected by the timing of flood crests at the mouth of the Minnesota River. If crests arrive simultaneously, as in 1969 (Anderson and Schwob, 1970, p. 57), the flood potential in the downstream reach of the study area is maximized. In 1965 the Mississippi River, above the Minnesota River, crested 6 days after the Minnesota River at its mouth (Anderson and Burmeister, 1970, p. A113). Under slightly different meteorological conditions, these crests might have been concurrent, which would have caused even higher stages along the lower Minnesota River.

Backwater in the Minnesota River caused by floods in the Mississippi River is a natural condition and depends on the flow capacity of the channel and adjoining flood plain in the reach downstream from the mouth of the Minnesota River. The gates at Lock and Dam 2 on the Mississippi River at Hastings, 29 miles below the mouth, are opened during floods to allow free passage of flow. Thus, the effect of the dam on flood elevations in the lower Minnesota River is negligible.

Historic floods

Flood peaks have been recorded on the Mississippi River at St. Paul since 1867. When flood elevations exceed 695 feet above mean sea level at St. Paul, significant flooding will occur in the lower Minnesota

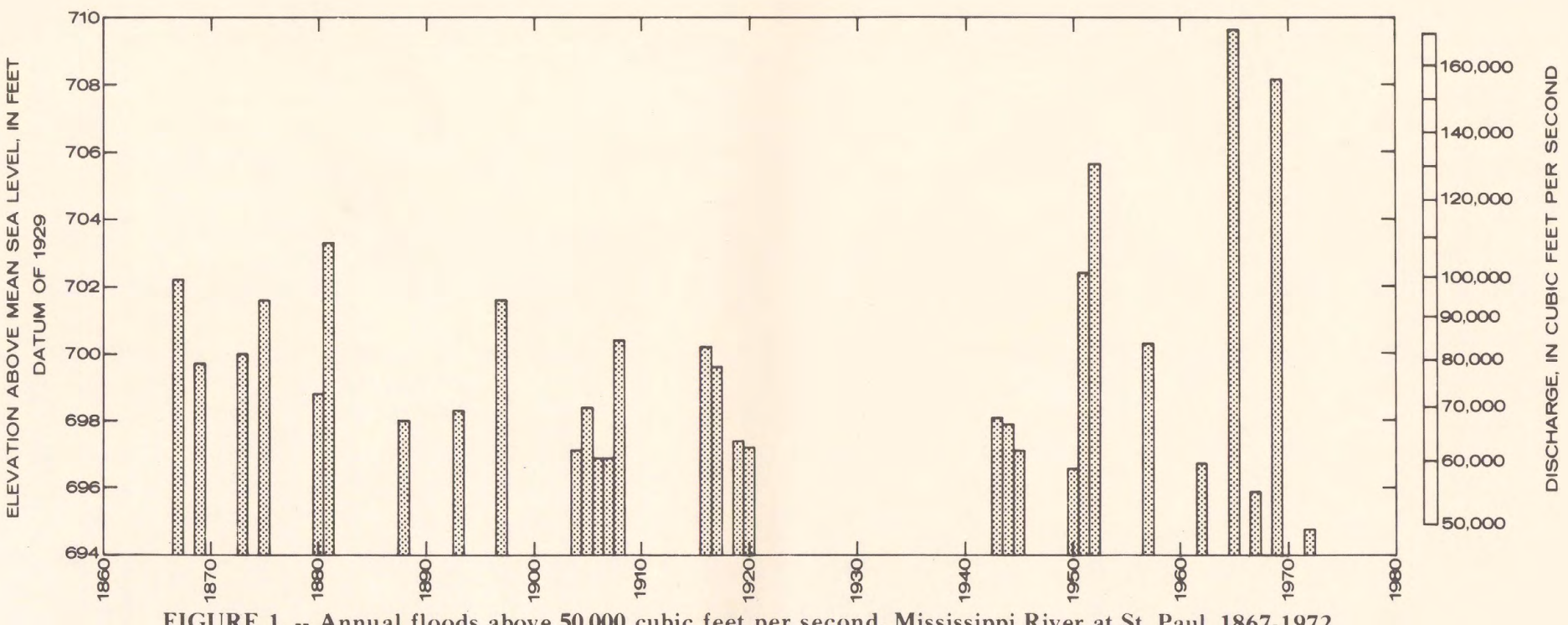


FIGURE 1. -- Annual floods above 50,000 cubic feet per second, Mississippi River at St. Paul, 1867-1972.

River valley. From figure 1, it is apparent that numerous floods affecting the study area have occurred during the 106-year period of record extending through 1972, the most outstanding being those of 1965 and 1969. The irregular occurrence of floods is evident.

Streamflow records on the Minnesota River have been collected by the U.S. Geological Survey since 1935 at Carver Rapids (mile 36.0) and at the county highway bridge 1.5 miles northwest of Jordan (mile 39.4). Because of slope, flood elevations at the Jordan site are about 1 foot higher, but flows are identical. For convenience, all flood elevations illustrated in figure 2 are adjusted to the Jordan site. During 1935-72, four severe floods (1951, 1952, 1965 and 1969) occurred in the lower Minnesota River valley. These all caused extensive damage, although emergency diking significantly reduced damages during the 1969 flood. The flood of 1981 was the highest flood recorded on the Minnesota River at Mankato, 67 miles upstream from Jordan. Although the elevation of this flood was not documented in the study area, it undoubtedly was a flood of major significance.

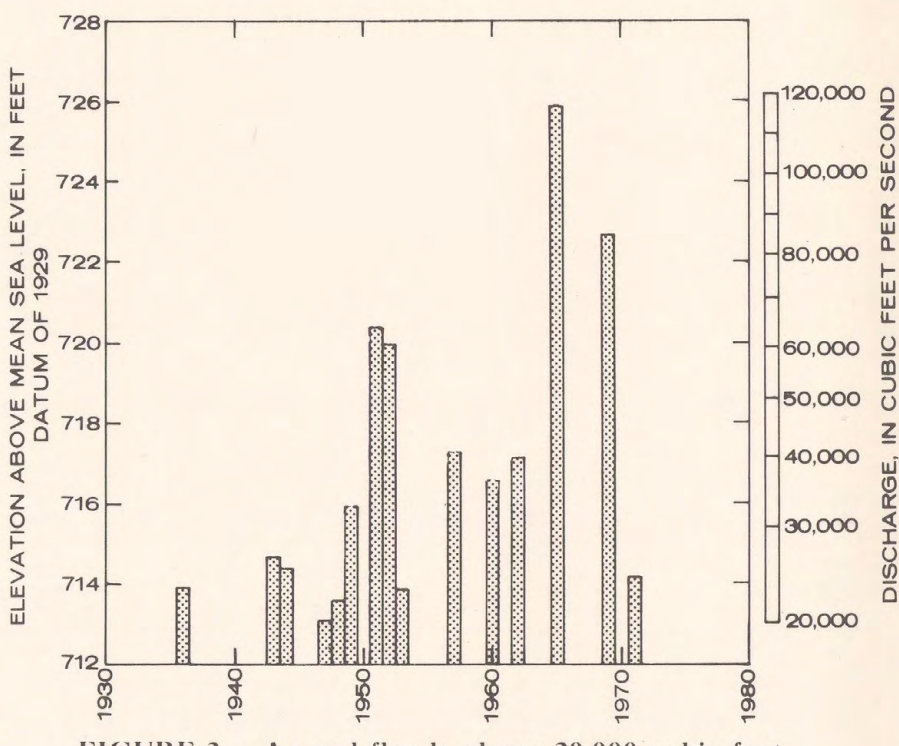


FIGURE 2. -- Annual floods above 20,000 cubic feet per second, Minnesota River near Jordan, 1935-72.

The contribution of flow from the Minnesota River to the total flow in the Mississippi River during major floods is shown in figure 3. Apparently flows originating from the Minnesota River account for a large percentage of the total flow in the Mississippi River during significant floods.

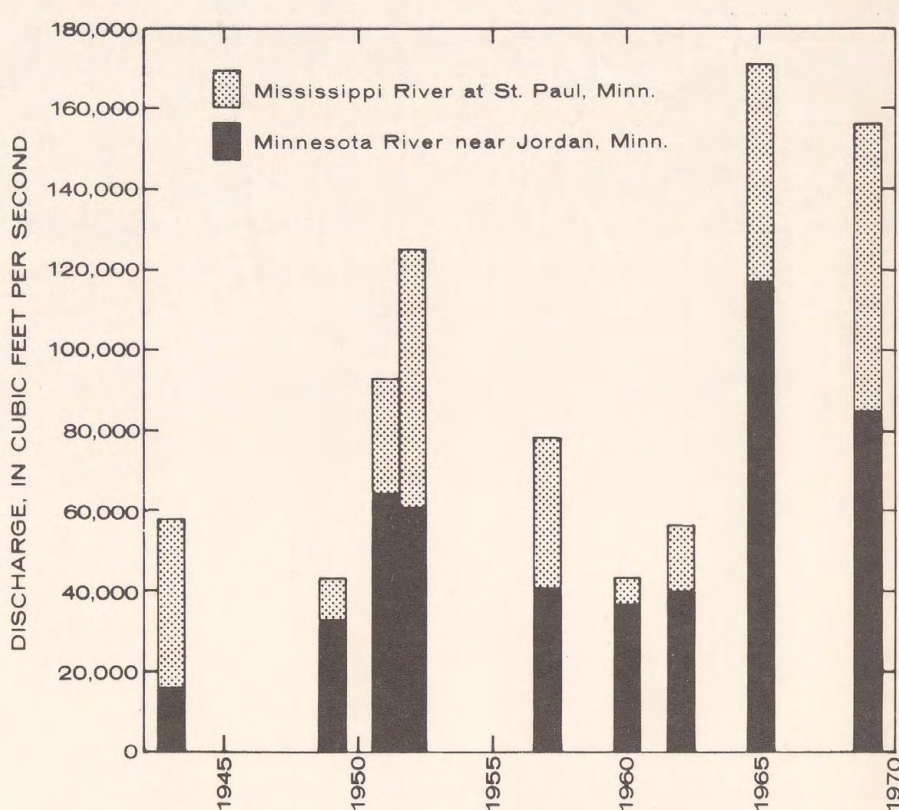


FIGURE 3. -- Contribution of Minnesota River flow to Mississippi River annual peak flows.

Flood plains of the lower Minnesota River are subject to frequent flooding. In many areas, banks are overtopped by floods having a 2- to 3-year recurrence interval. The probability of some degree of flooding in any given year is 33 to 50 percent. A flood having a 10-year recurrence interval, discharge of 48,400 cfs (cubic feet per second) at the Jordan gage, could cause significant damage to unprotected developments in many parts of the flood plain.

Peak discharges and estimated recurrence intervals for the five highest floods, as recorded on the Minnesota River near Jordan, are tabulated below.

Flood	Peak Discharge	Estimated Recurrence Interval
April 1965	117,000 cfs	101 years
April 1969	84,000 cfs	40 years
April 1951	64,100 cfs	19 years
April 1952	60,600 cfs	16 years
June 1957	40,800 cfs	7 years

REGIONAL FLOOD

Minnesota's Flood Plain Management Act (Minnesota Statutes, Chapter 104) provides that the regional (100-year) flood shall serve as a basis for delineation of the minimum limits of the flood plains for regulatory purposes. Thus, the regional flood becomes a prime controlling factor in defining the areas for which land-use controls are required.

Flow-frequency relations

Streamflow data collected at gaging stations on the Minnesota River near Jordan and the Mississippi River at St. Paul provide the basis for definition of 100-year floods on the two streams. Frequency of flooding is derived from a statistical analysis of annual flood peaks. The flow-frequency relationships are illustrated in figure 4. The estimate of the regional flood for the Minnesota River at Jordan is 115,000 cfs, and that for the Mississippi River at St. Paul is 160,000 cfs. Estimates of the 100-year flood were coordinated with the U.S. Army Corps of Engineers under an inter-agency agreement.

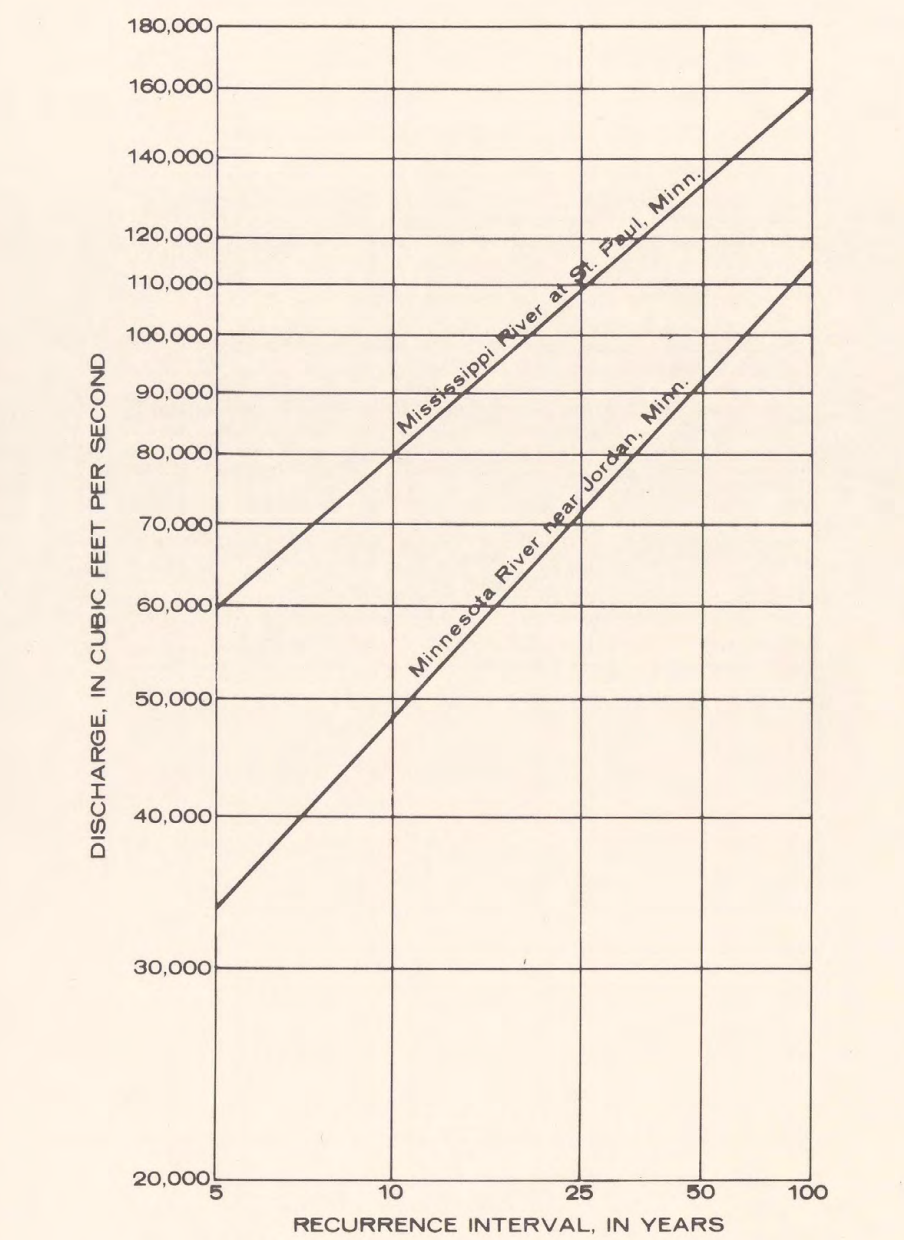


FIGURE 4. -- Frequency of flood discharges.

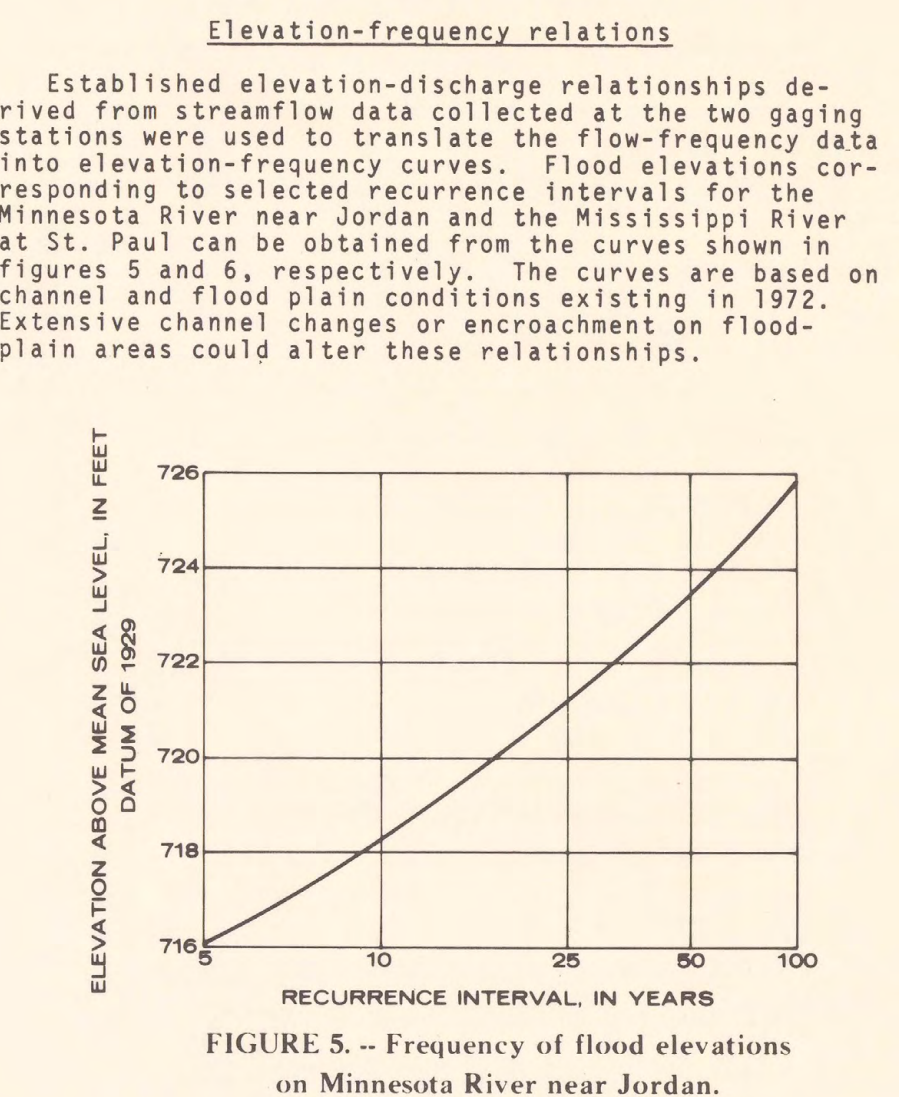


FIGURE 5. -- Frequency of flood elevations on Minnesota River near Jordan.

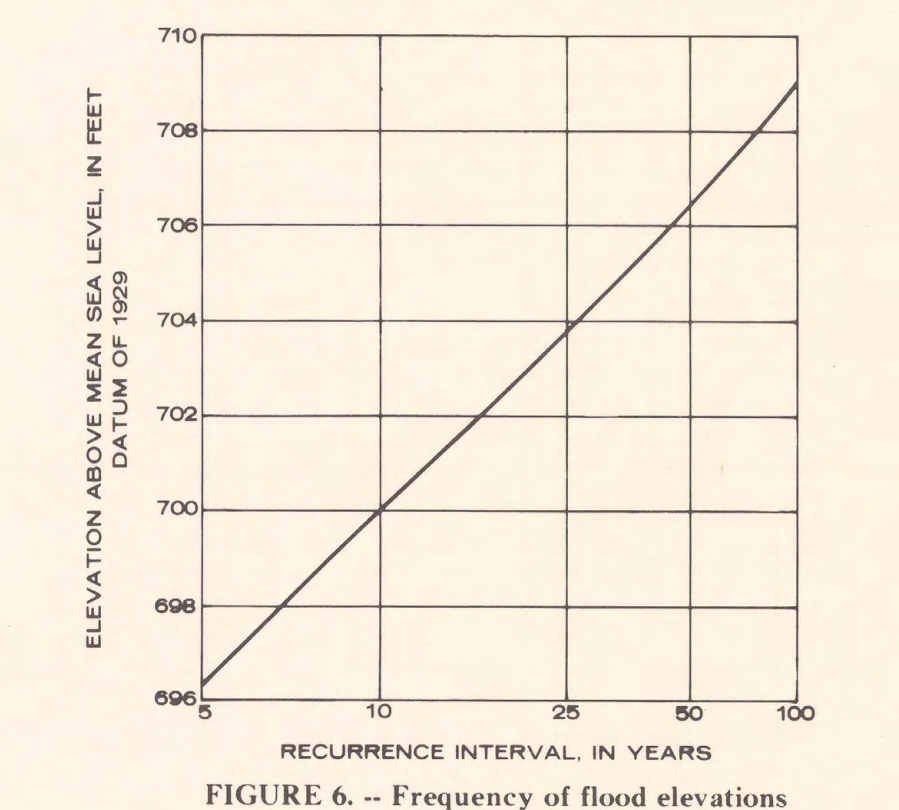


FIGURE 6. -- Frequency of flood elevations on Mississippi River at St. Paul.

Profile analysis

Derivation of the profile for the 100-year flood was done by standard step-backwater methods using a digital computer model. The model expresses in mathematical terms the geometry of the river valley and the roughness coefficients (retardance factors) that control the slope of the water-surface profile. The geometry of the valley is defined by cross-section data obtained at approximately 100 locations in the 36-mile study reach. These data describe natural valley sections, bridges, encroachments, and all significant hydraulic factors required to define the water-surface profile.

Cross-section data for overbank areas were acquired by photogrammetric methods from aerial photography taken in 1970 and 1971. Where changes had occurred since the date of photography, field surveys were made to define valley conditions existing in the spring of 1972. Underwater parts of the cross sections were obtained from soundings made by field survey crews.

High-water elevations for the 1965 and 1969 floods were collected from numerous sources. However, these elevations were based on different datums, so field surveys were run to adjust all elevations to a common datum. All elevations in this study are referenced to mean sea level, datum of 1929.

The digital computer model was calibrated on the basis of documented data from the 1969 flood. The 1969 flood was selected because of the availability of more reliable data and because changes in the river channel and flood-plain areas made it difficult to reconstruct conditions prevailing during the flood of 1965. The profile developed by the model closely matches known high-water elevations for the 1969 flood throughout the entire 36-mile reach.

The elevation for the 100-year flood at the mouth of the Minnesota River was obtained from a similar study of the Mississippi River conducted by the Minnesota Department of Natural Resources (1972). The elevation at this point is dependent upon the combined flows of the Mississippi and Minnesota Rivers. By substitution in the model of the 100-year peak discharge and the starting elevation at the mouth, the water-surface profile for the regional flood along the lower Minnesota River was calculated, as shown in figure 7. This profile, which reflects 1972 valley conditions, was used to delineate preliminary outlines of the flood-plain areas.

FLOODWAY DELINEATION

Purpose

Administration of flood-plain management ordinances is simplified by designation of a floodway. This designation assures retention of the channel and those parts of the flood plain adjacent to the stream that are needed to convey flood flows. Development within the floodway limits is restricted to open-space type uses having low flood-damage potential and offering minimum obstruction to flood flows. Developments adequately protected from flood damage, but which obstruct flood flows, can be permitted in those flood-plain areas outside the floodway limits. Using the floodway concept, the upstream increase in elevation for the 100-year flood resulting from proposed encroachment to the floodway limits can easily be evaluated by the digital computer model. If the increase exceeds State standards, the floodway limits can be redefined. Also, the cumulative effect of encroachment along the reach of stream is readily apparent.

Lack of a designated floodway requires a case by case analysis of individual development permits for flood-plain areas. This process is time consuming, generally less accurate, and may not reflect the true cumulative effect on flood stages.

Designation of floodways

Designated floodways for the 36-mile study reach are shown on plates 1-12. Selection of these floodways was made by local officials for their respective jurisdictional areas. Preliminary flood-plain area maps were provided to aid local officials in their selection and, in addition, several discussions were held under the auspices of the Lower Minnesota River Watershed District and the Minnesota Department of Natural Resources to provide technical background data.

An analysis of floodway conditions must also consider the effect of planned encroachment on the Mississippi River flood plain. A potential increase of 0.2 foot in the regional flood elevation at the mouth of the Minnesota River was estimated by the Minnesota Department of Natural Resources.

Data reflecting floodway conditions and the 1494 bridge geometry (from Minnesota Highway Department records) were incorporated into the digital model to predict the effects of planned encroachment. The model showed that initial floodway configurations for some areas did not meet State standards, and necessary adjustments to these configurations were made by the Lower Minnesota River Watershed District and the Minnesota Department of Natural Resources. After adjustment, the calculated maximum increase in elevation (surcharge) from the water-surface profile for the regional flood did not exceed 0.5 foot. Therefore, the selected floodway configurations meet minimum State standards.

The managers of the Lower Minnesota River Watershed District have revised the District's operating rules and regulations to adopt the floodway designations and flood plain limits to control development in the floodway of the lower Minnesota River. The District's regulatory actions, which are operative in the absence of local municipal ordinances, are in conformity with the requirements of the Minnesota Flood Plain Management Act and the regulations of the Minnesota Department of Natural Resources.

The water-surface profile reflecting the increase in elevation from permissible encroachments is designated as the floodway profile. It is used as the basis for determination of the flood-protection elevation.

FLOOD-PROTECTION ELEVATION

The flood-protection elevation is the level, designated by State standards, to which permitted developments on the flood plain are to be protected against flood damage. It is determined by adding 1 foot to the elevations of the floodway profile. Profiles showing the flood-protection elevation are shown in figure 7 and plates 1-12.

FLOOD-PLAIN AREAS

Outlines defining the flood plain along the lower Minnesota River, as shown on plates 1-12, are based on the flood-protection elevation according to State standards for flood-plain management. These areas are subject to regulation under the Minnesota Flood Plain Management Act. Outlines extending up tributary streams are intended to show only downstream areas along these tributaries where flooding from the Minnesota River is the dominant factor.

The information contained in this report will provide local governmental units with the technical data needed to minimize future flood losses by planning for wise use and orderly development of flood plains. It should also alert the public to the hazards of development on the flood plain and to the degree of protection required to reasonably safeguard their property against flood losses.

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- Leverett, Frank, 1932, Quaternary geology of Minnesota and adjacent States: U.S. Geol. Survey Prof. Paper 161, 149 p.
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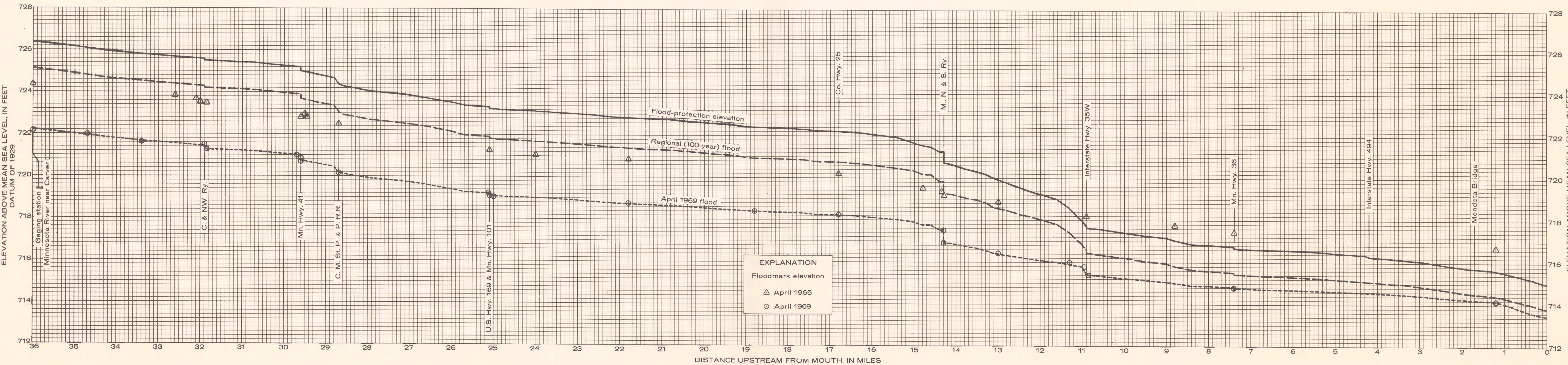
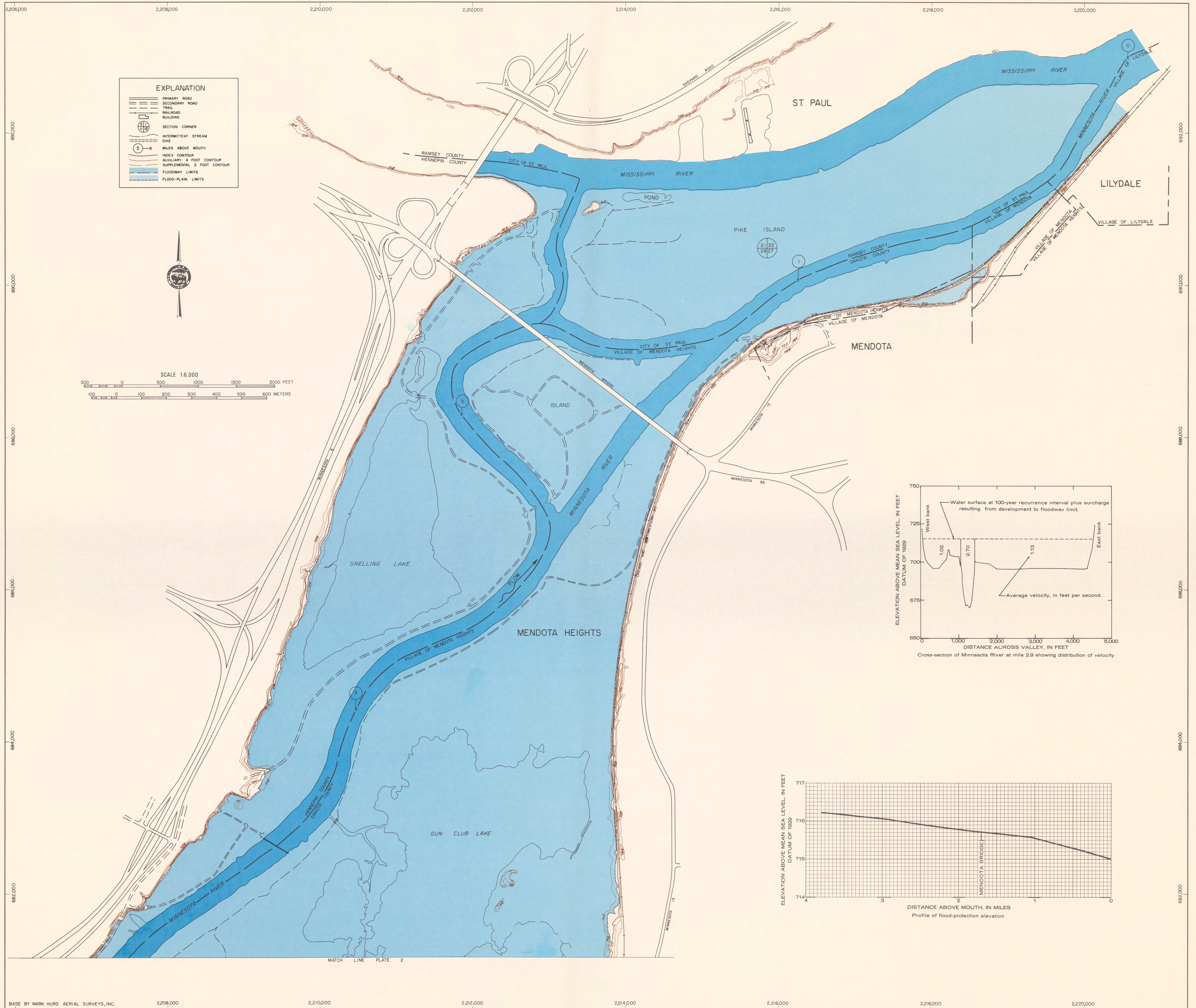


FIGURE 7. -- Profiles of Minnesota River.

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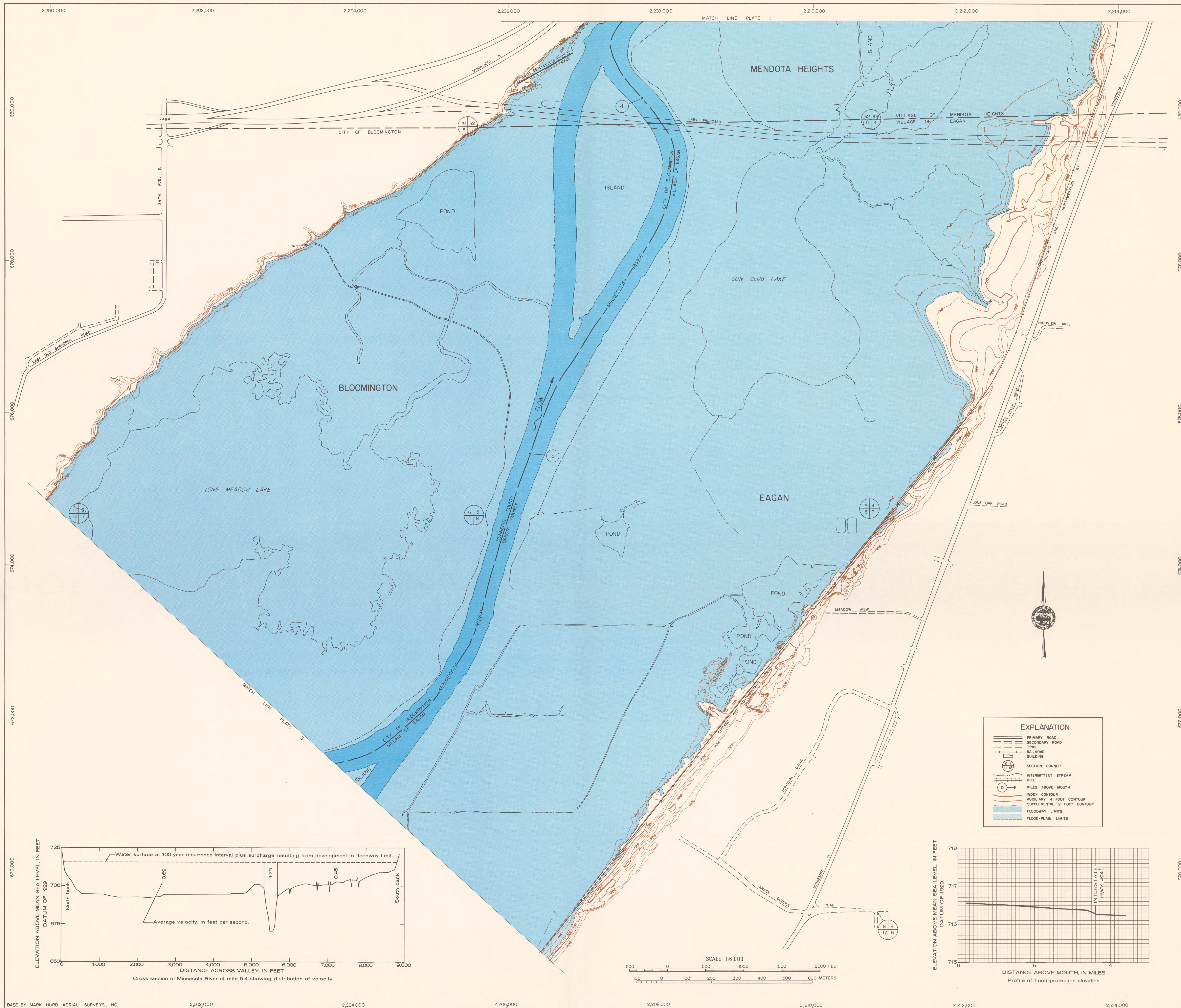
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PLATE 1



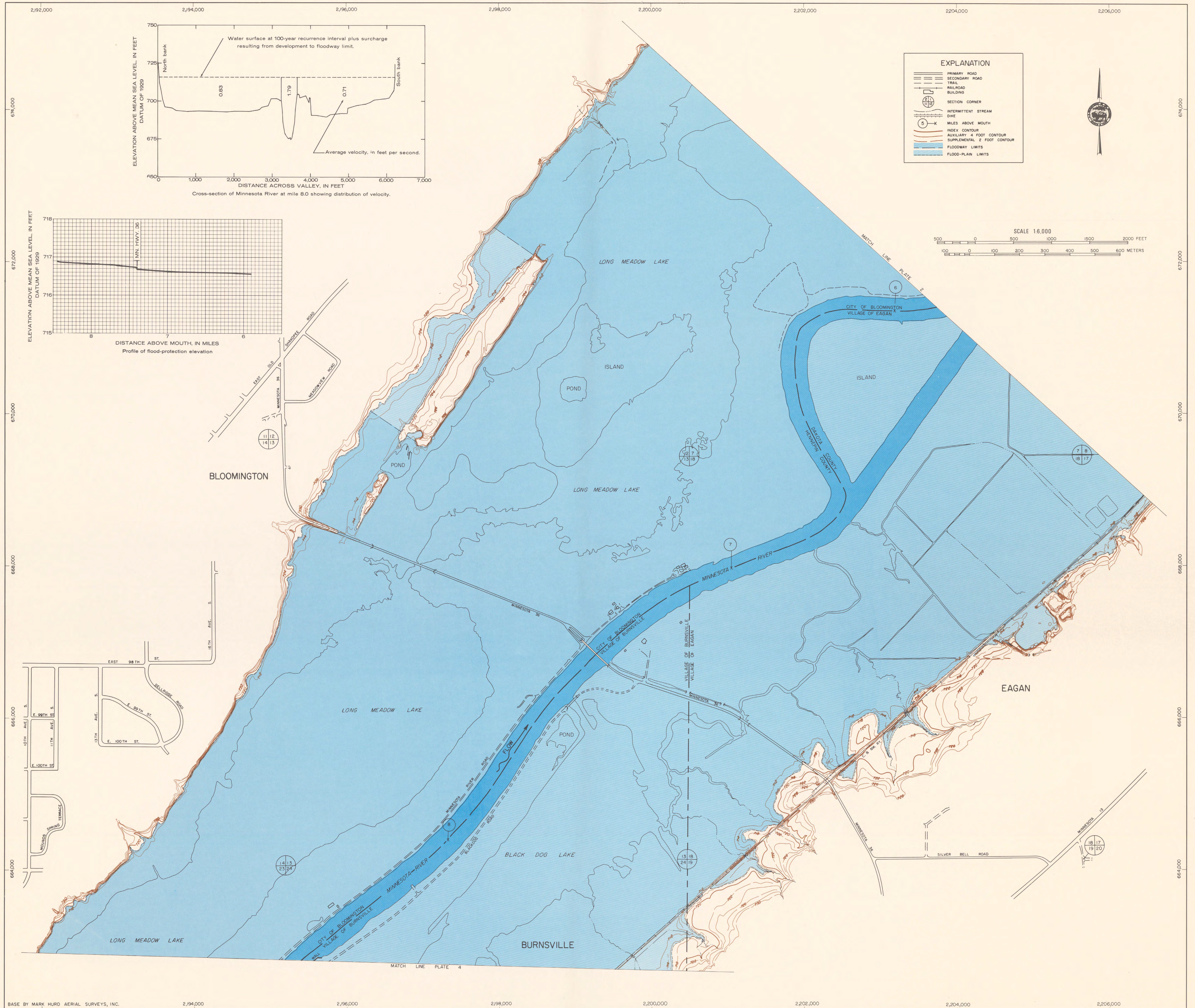
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PLATE 2

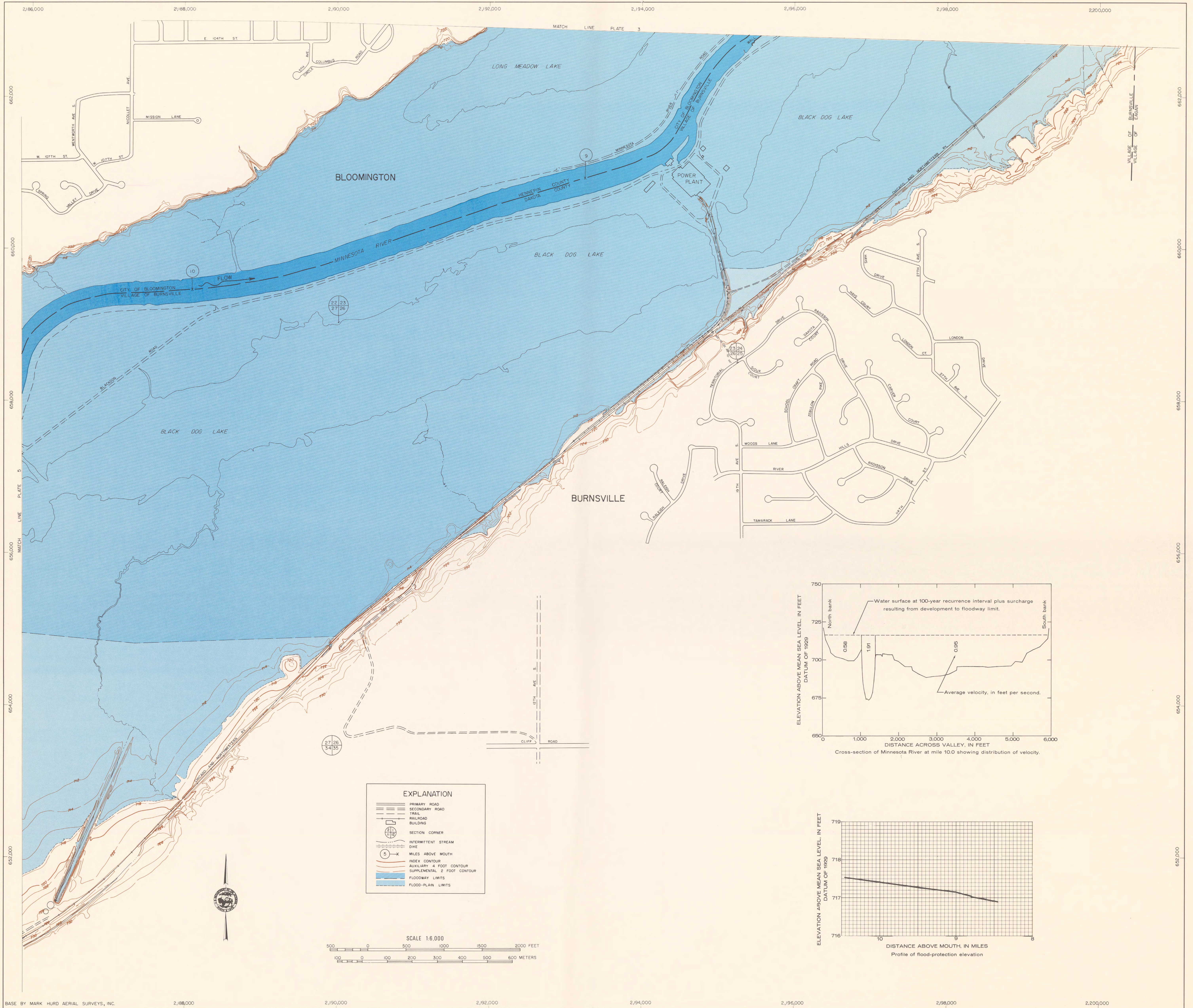


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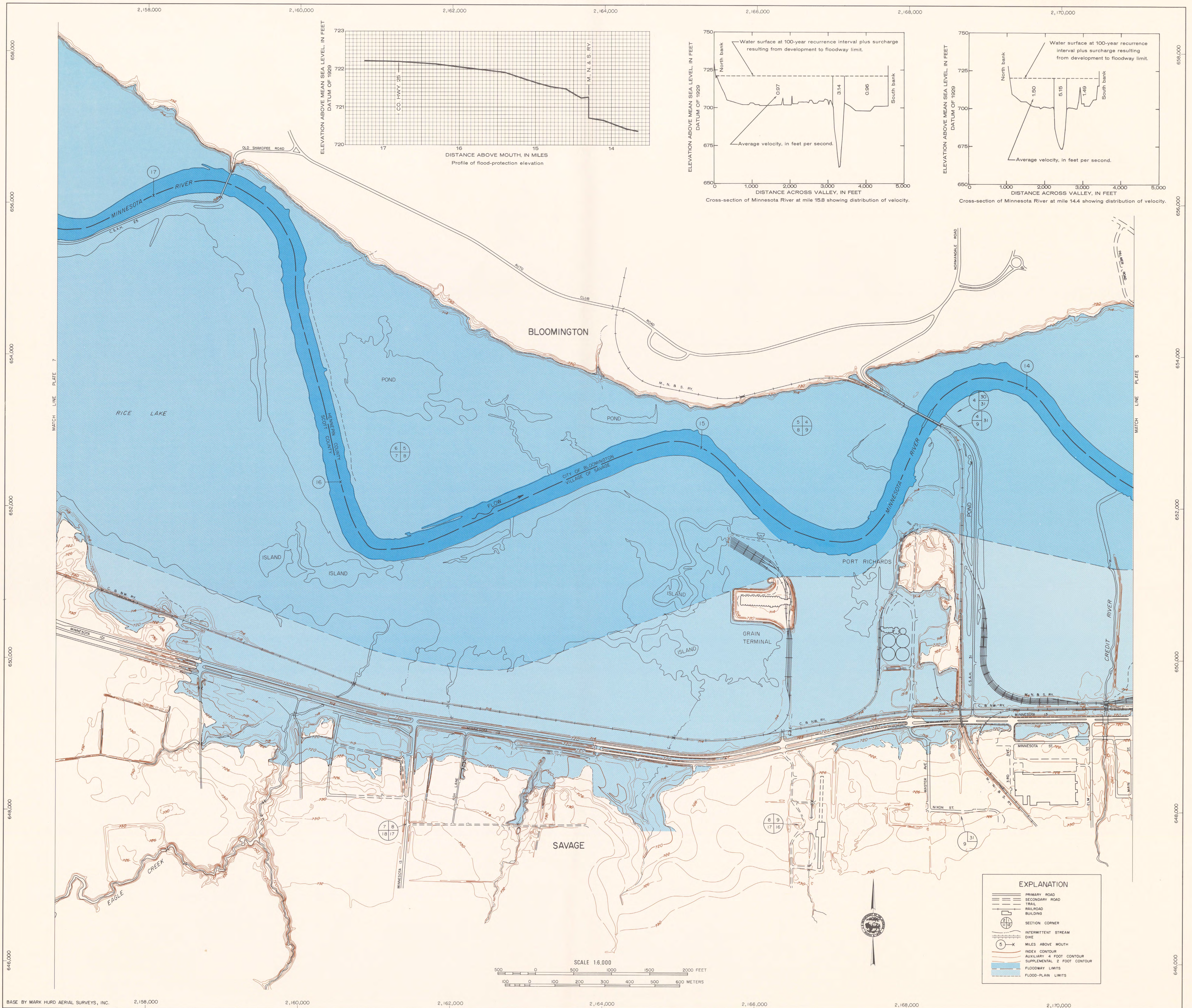
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PLATE 4

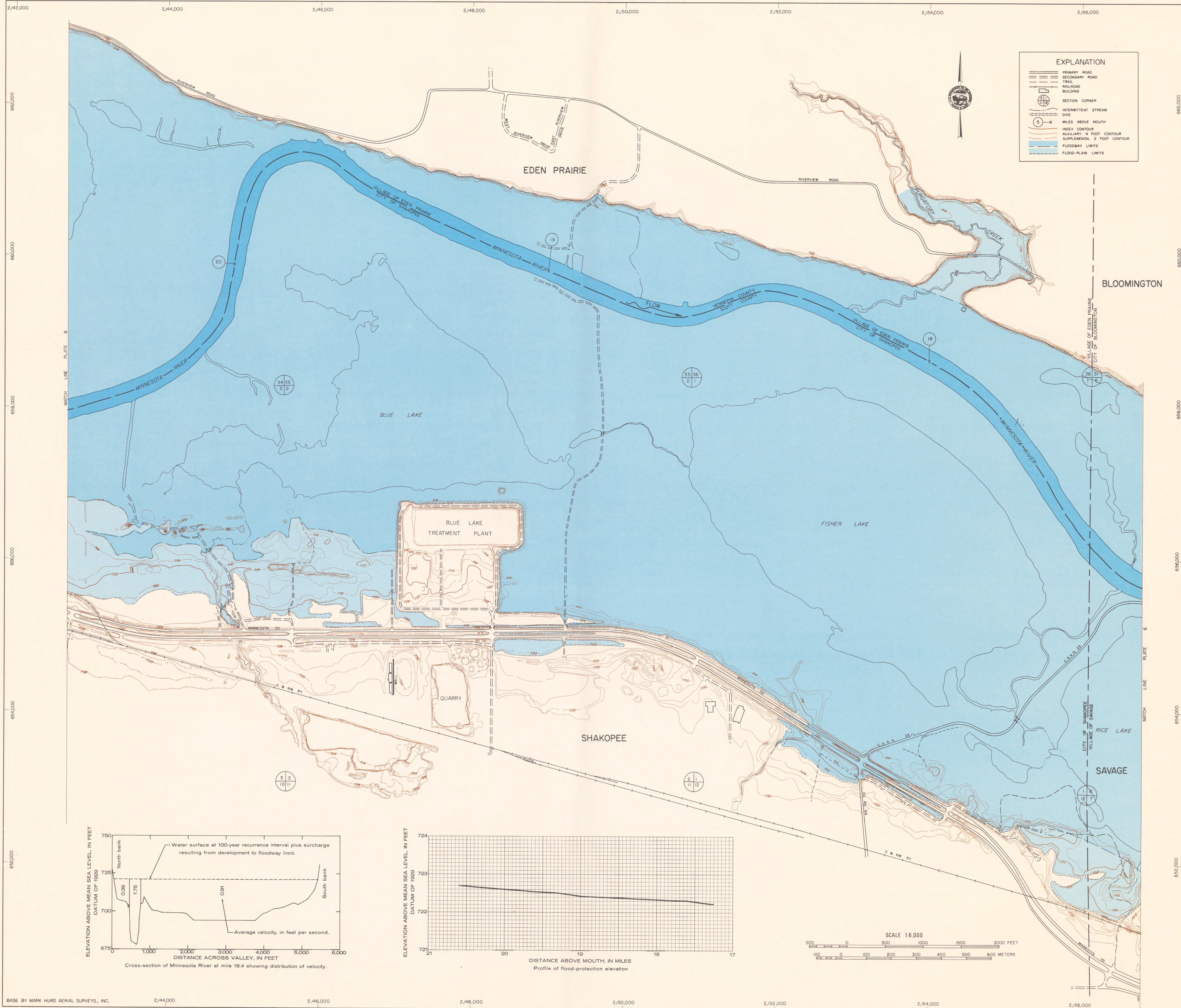


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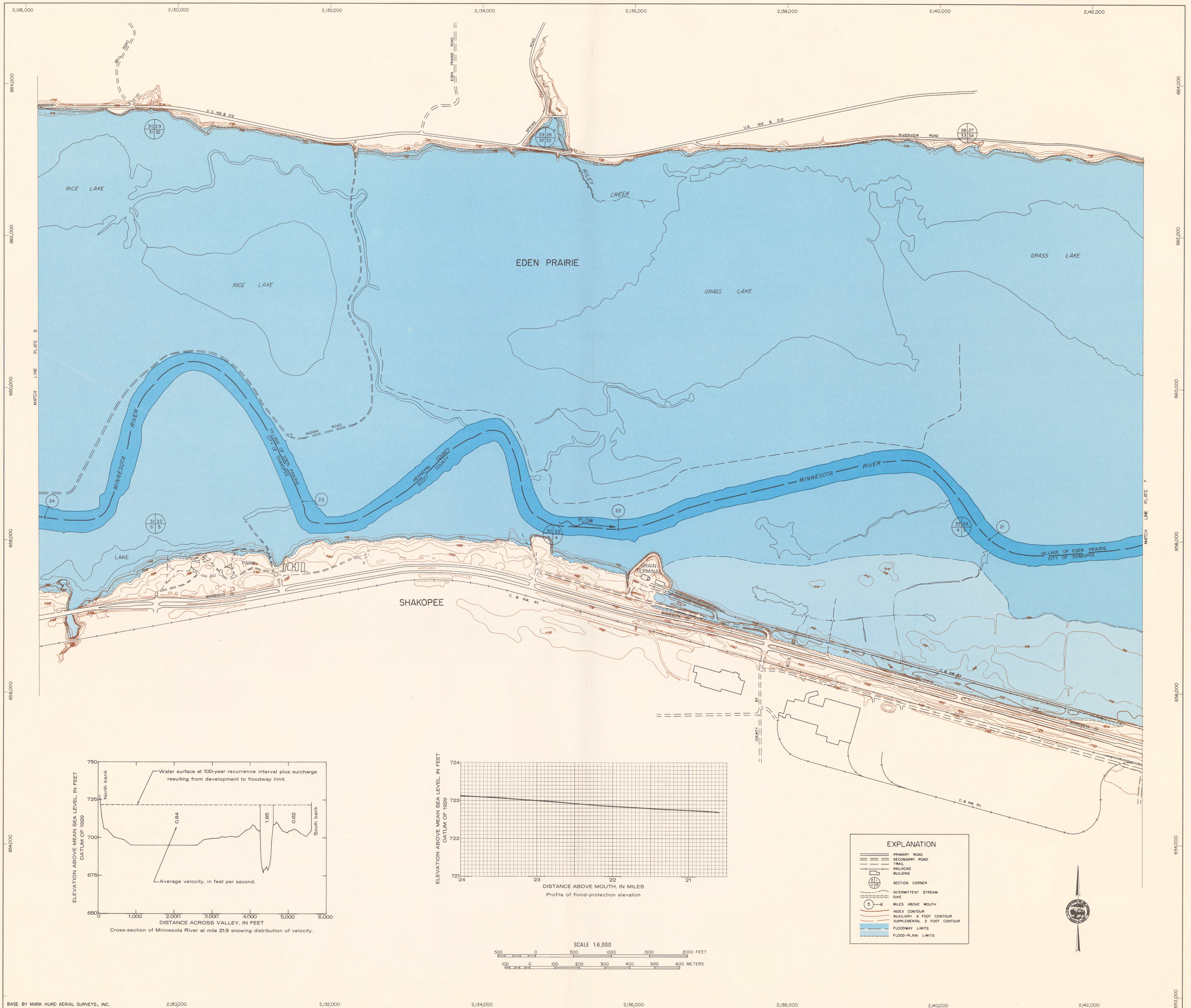
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PLATE 7



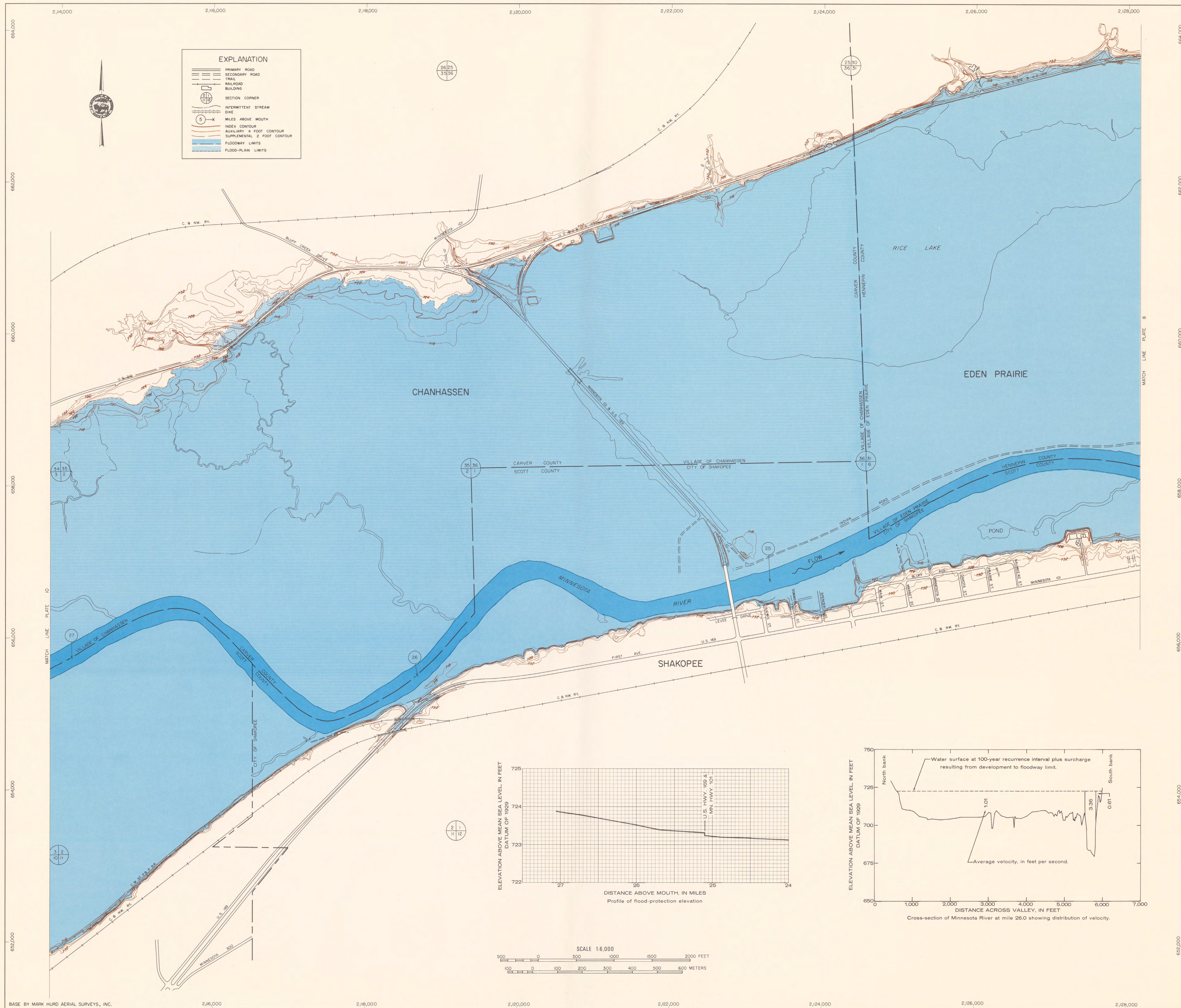
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PLATE 8



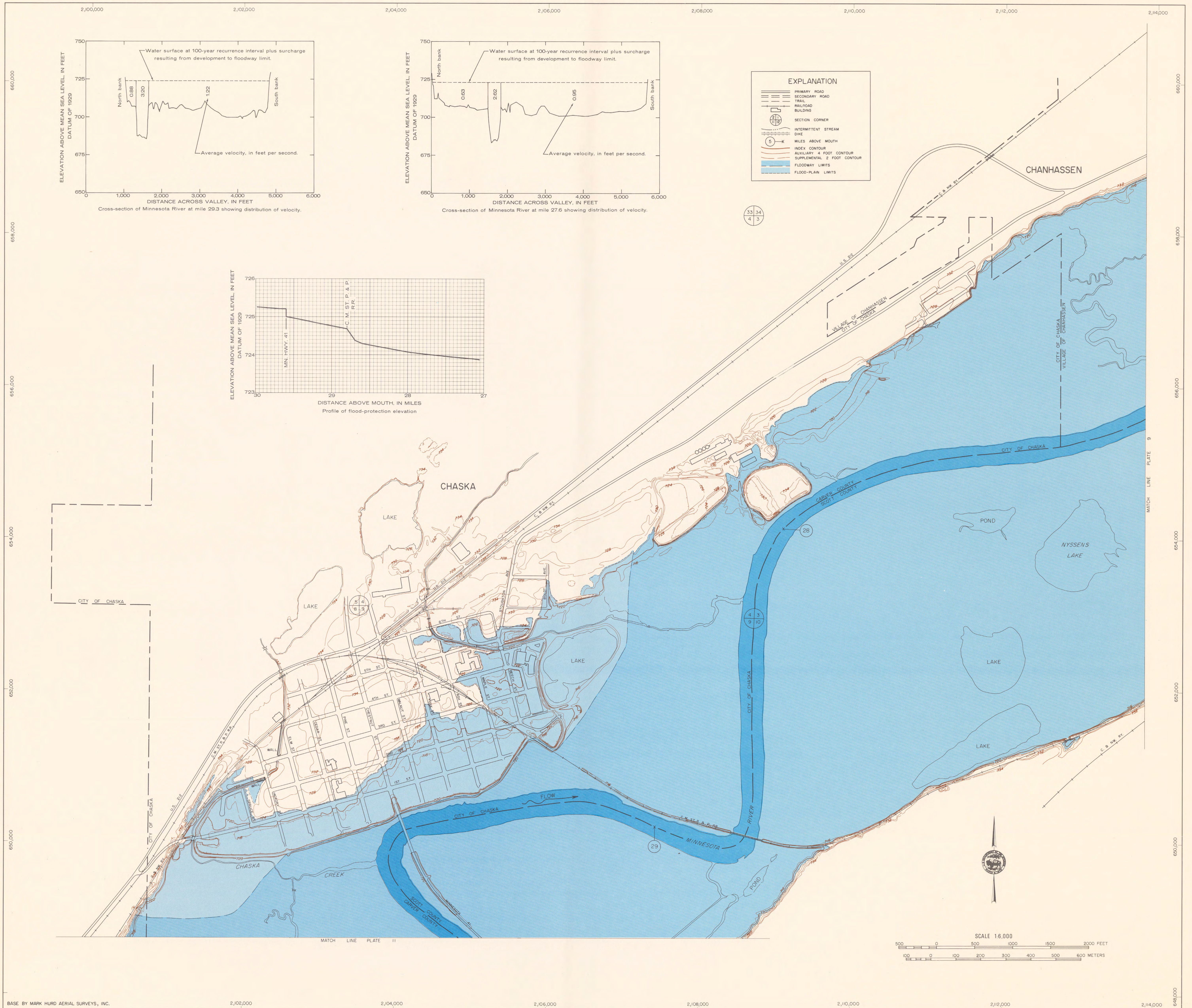
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PLATE 9

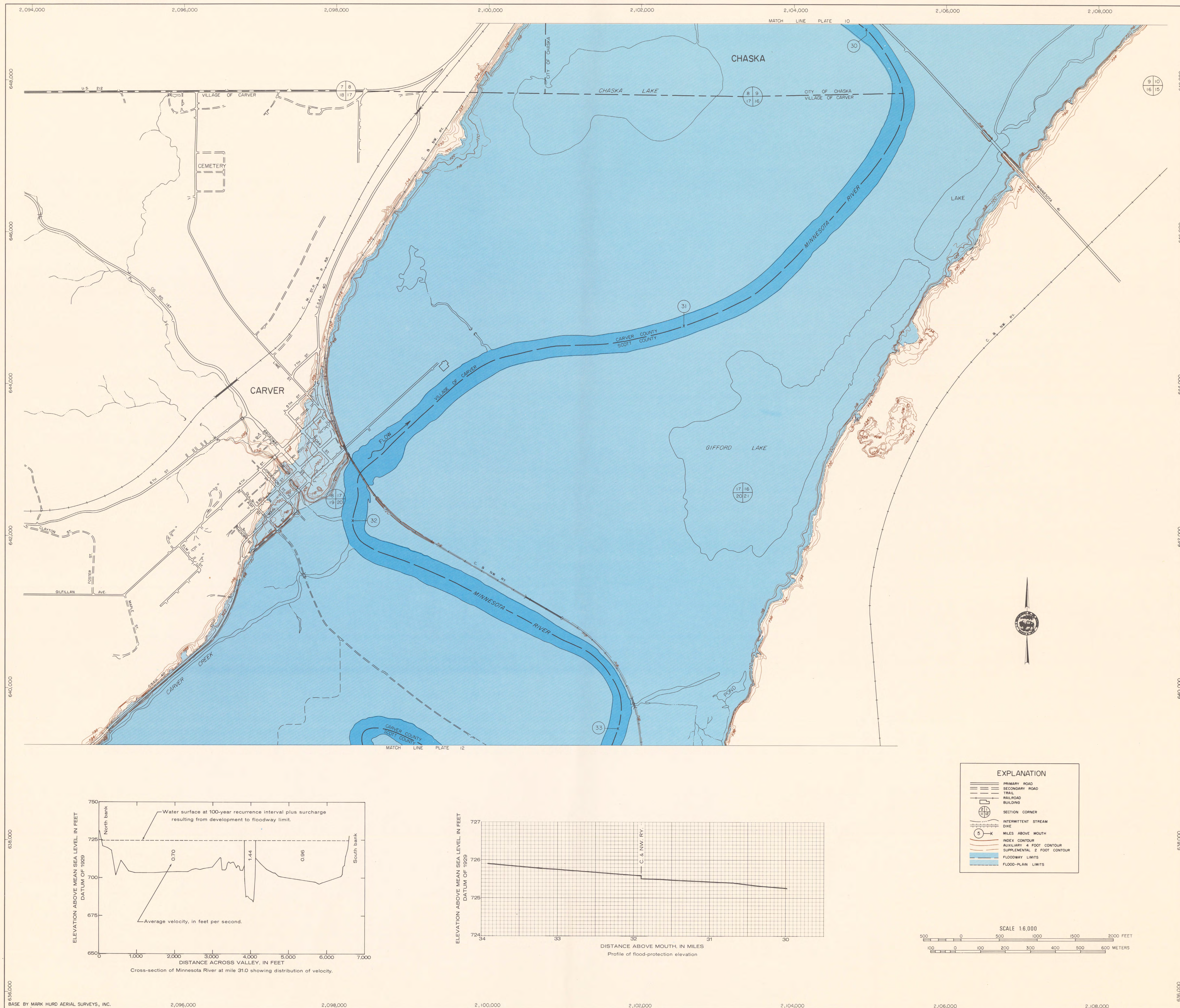


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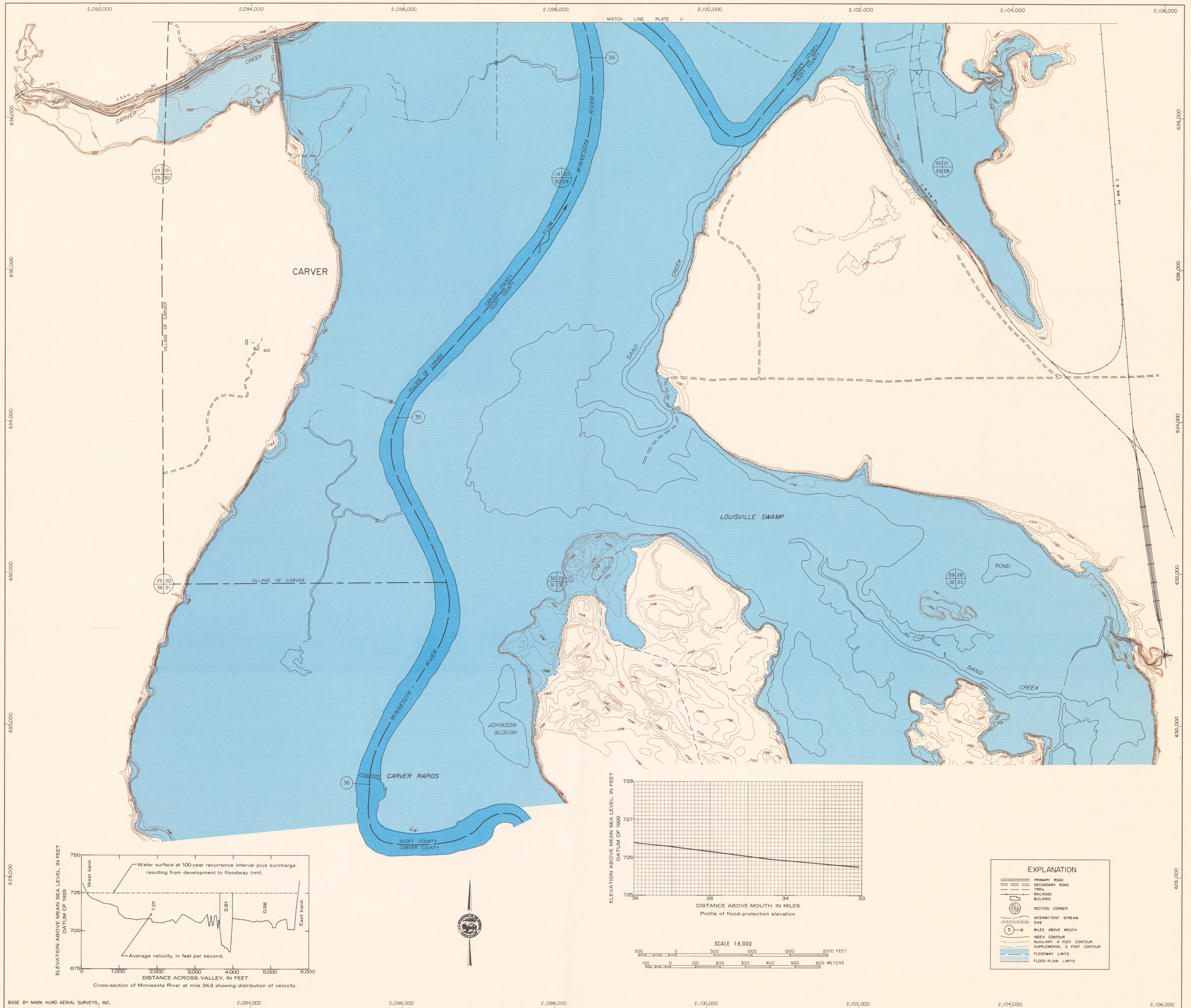
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PLATE 11



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PLATE 12

