# ANALYSIS OF ALTERNATIVE MODIFICATIONS FOR REDUCING BACKWATER FLOODING AT THE HONEY CREEK COAL STRIP MINE RECLAMATION SITE IN HENRY COUNTY, MISSOURI

By Terry W. Alexander

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1990

DEPARTMENT OF THE INTERIOR

MANUEL LUJAN, JR., Secretary

U.S. GEOLOGICAL SURVEY

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## CONVERSION FACTORS

For the convenience of readers who may want to use metric units (International System), the data given in this report may be converted by using the following factors:

| Multiply inch-pound unit | By | To obtain metric unit |
|---|---|---|
| inch (in.) | 0.0254 | meter (m) |
| foot (ft) | 0.3048 | meter (m) |
| foot per mile (ft/mi) | 0.1894 | meter per kilometer (m/km) |
| mile (mi) | 1.609 | kilometer(km) |
| square mile ($mi^2$) | 2.590 | square kilometer ($km^2$) |
| cubic feet per second ($ft^3/s$) | 0.02832 | cubic meter per second ($m^3/s$) |
| acre | $4.047 \times 10^{-3}$ | square kilometer ($km^2$) |

Sea level: In this report, "sea level" refers to the National Geodetic Vertical Datum of 1929 (NGVD of 1929)--a geodetic datum derived from a general adjustment of the first-order level nets of both the United States and Canada.

# ANALYSIS OF ALTERNATIVE MODIFICATIONS FOR REDUCING BACKWATER FLOODING AT THE HONEY CREEK COAL STRIP MINE RECLAMATION SITE IN HENRY COUNTY, MISSOURI

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## ABSTRACT

Studies to determine the hydrologic conditions in mined and reclaimed mine areas, as well as areas of proposed mining, have become necessary with the enactment of the Surface Mining Control and Reclamation Act of 1977. Honey Creek in Henry County, Missouri, has been re-routed to flow through a series of former strip mining pits which lie within the Honey Creek coal strip mine reclamation site. During intense or long duration rainfalls within the Honey Creek basin, surface runoff has caused flooding on agricultural land near the upstream boundary of the reclamation site. These flood waters are repeatedly damaging a nearby private roadway leading to several homes within the reclamation site. The U.S. Geological Survey, in cooperation with the Missouri Department of Natural Resources, has completed a hydrologic and hydraulic investigation for part of the Honey Creek basin and its adjacent area to evaluate the strip mining related causes of backwater flooding and possible means of alleviating future flooding.

The calculated existing design discharge (3,050 cubic feet per second) water-surface profile is compared to the expected water-surface profiles from three assumed alternative channel modifications within the Honey Creek study area. Emphasis is placed on evaluating the potential effects of each alternative to reduce water-surface elevations (backwater flooding) along the upstream boundary of the Honey Creek reclamation site near an agricultural field. The alternative channel modifications used in these analyses include 1) improvement of channel bottom slope, 2) relocation of spoil material, and 3) improved by-pass channel flow conditions. Study results indicate a 0.39, 0.43, and 0.30 foot backwater reduction at the agricultural field based on the assumed channel modifications of alternatives 1, 2, and 3, respectively. Several combinations of these alternatives were analyzed, and in each case the reduction in backwater flooding was numerically equal to the sum of their individual decreases. For example, a 1.12 feet lower water-surface elevation results when the channel modifications of alternatives 1, 2, and 3 are combined and analyzed. The concurrent water-surface elevation reduction (1.12 feet) of alternative 1 (design discharge increase of 400 cubic feet per second), alternative 2 (design discharge increase of 600 cubic feet per second), and alternative 3 (design discharge increase of 250 cubic feet per second) can be converted into a Honey Creek design discharge increase from 3,050 cubic feet per second to 4,300 cubic feet per second. Thus, the alternative 1, 2, and 3 design discharge increase will reduce the agricultural field current (1990) frequency of backwater flooding from a 3-year to a 6.5-year event. It was not within the scope of this study to conclude that these are the only viable individual alternatives or combinations thereof.

## INTRODUCTION

The Honey Creek drainage area is located in south-central Johnson and north-central Henry counties in Missouri. This drainage area includes approximately 2,035 acres of an abandoned coal strip mine site, parts of which are being reclaimed by the Missouri Department of Natural Resources, Land Reclamation Commission.

The U.S. Geological Survey, in cooperation with the Missouri Department of Natural Resources, has studied the backwater flooding conditions within the Honey Creek coal strip mine reclamation site (fig. 1) to determine if past surface strip mining practices may have contributed to the increased frequency of these overbank floods. The Surface Mining Control and Reclamation Act of 1977 (U.S. Congress, 1977) specifies that computer modeling estimations can be used to assist in evaluating existing flooding problems (or assumed solutions) associated with surface coal mining. Thus, hydrologic data for the Honey Creek drainage basin or adjacent drainage basins were needed for use with a computer model to assist in evaluating flooding problems within the study area (fig.1).

During intense or long duration rainfalls within the Honey Creek basin, the resulting surface runoff has caused Honey Creek to overflow its banks near the upstream boundary of the abandoned Honey Creek reclamation site. This overflow has resulted in flood damage to an adjacent agricultural field and severe damage to a private roadway that currently (1990) provides the only access to several homes. The severity of this damage has been compounded by the fact that the roadway runs along a 40 ft (feet) high strip pit highwall, and this fall causes increased floodwater velocities where the roadway overtopping occurs (fig. 2).

This report presents an analysis of the existing hydraulic conditions (factors causing backwater flooding) within the Honey Creek study area and estimates of reductions in the water-surface elevation that would be expected at the agricultural field from three assumed alternative channel modifications. The contents of this publication do not necessarily reflect the views and policies of the U.S. Department of the Interior, Office of Surface Mining Reclamation and Enforcement.

## HONEY CREEK BASIN

Honey Creek drains into Big Creek, a tributary to the Osage River in west-central Missouri. This part of Missouri is underlain mostly by shale, limestone, and sandstone of Pennsylvanian age, and has a nearly level to moderately sloping land surface (Allgood and Persinger, 1979, p. 26). Agriculture is the predominant land use, with a typical landscape consisting of large cultivated fields on the nearly level land slopes with smaller pasture lands on the steeper side slopes. Forest land constitutes a small part of the total area. Most wooded areas are along fencerows and streambanks that are not suitable for agricultural purposes. The average annual precipitation is approximately 39 in. (inches). About 70 percent of this annual total occurs during the growing season months of April through October. Rainfall during these months commonly occurs in the form of brief, intense thunderstorms. (Bevans and others, 1984, p. 16).

Upstream from the Honey Creek coal strip mine reclamation boundary, 33.75 $mi^2$ (square miles) of surface area are drained by Honey Creek and its principal tributary, East Fork Honey Creek (fig. 1). The average channel slope is 14.5 ft/mi (feet per mile). Generally, surface soils in the Honey Creek basin have low to moderate permeabilities (infiltration rates) ranging from 0.06 to 2.0 inches per hour (Allgood and Persinger, 1979, p. 58). These rates are controlled by the physical and mineral composition of the surface soils, which for the Honey Creek drainage basin are derived from shale and sandstone parent materials. Studies that describe the surface- and ground-water availability in the general vicinity, along with the physical, chemical, and biological characteristics of these waters, were conducted by Gann and others (1974), Vaill and Barks (1980), and Bevans and others (1984).

## MODEL ESTIMATIONS

The Honey Creek hydrologic investigation required the selection of a computer rainfall-runoff modeling technique that could be used to estimate instantaneous peak discharges resulting from known or hypothetical storms. The Honey Creek basin has no rainfall-runoff data base to support the computational requirements of a computer modeling technique, and no long-term hydrologic data are available for the drainage basin. However, by using rainfall-runoff data from a nearby U.S. Geological Survey streamflow-gaging station, a data base for modeling purposes was compiled.

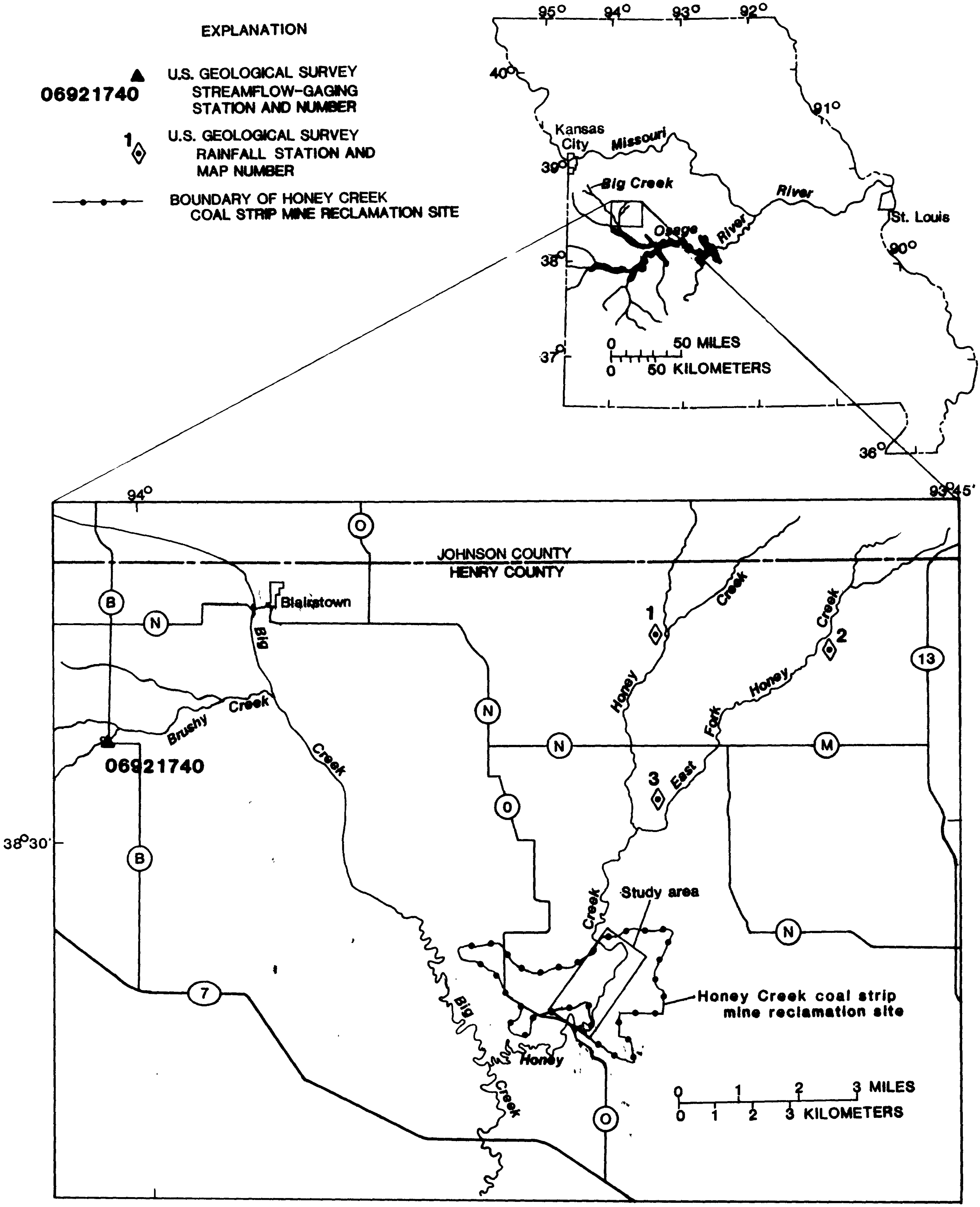



Figure 1.--Location of the Honey Creek study area, selected rainfall and streamflow-gaging stations, and Honey Creek coal strip mine reclamation site.

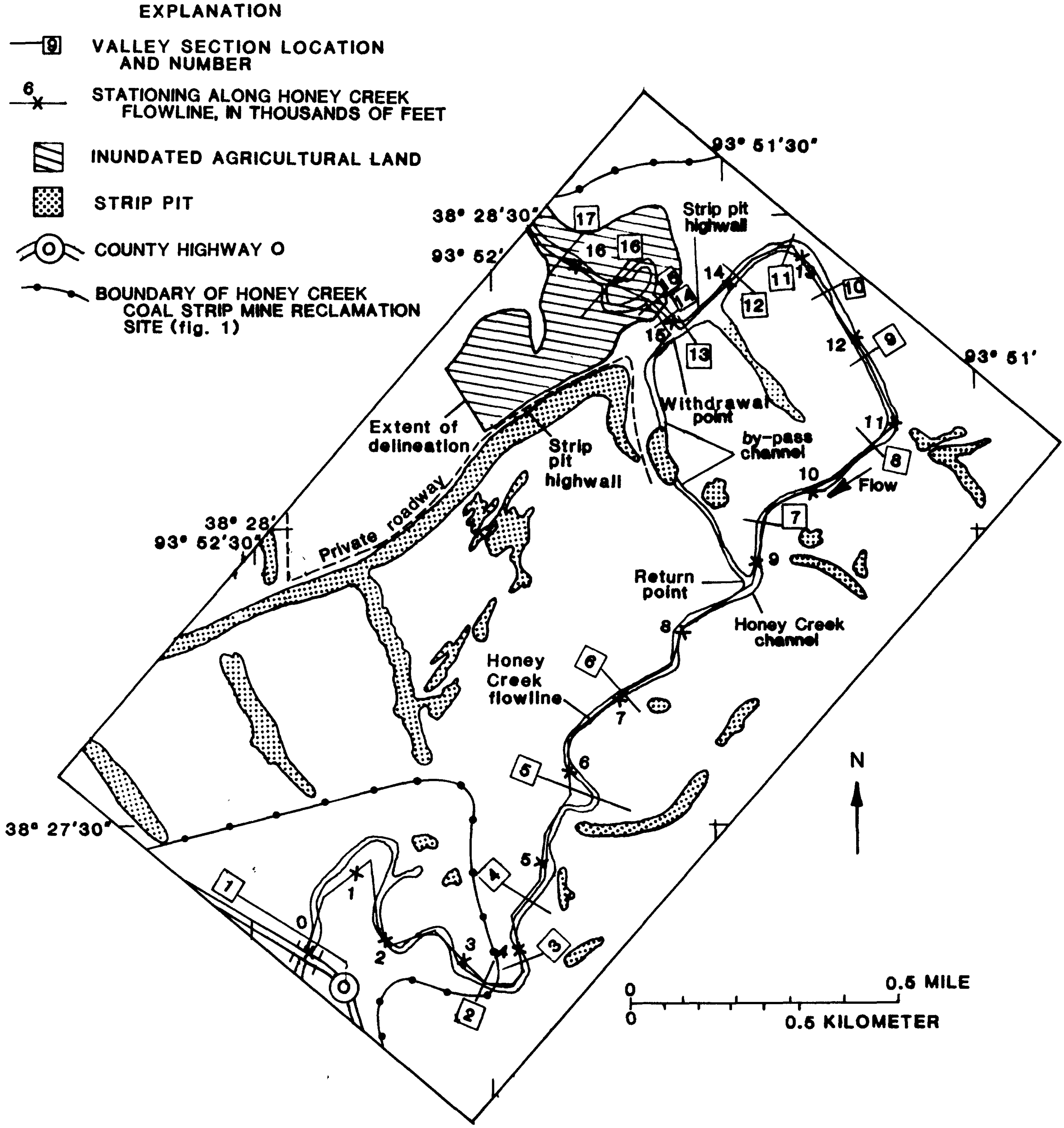



Figure 2.--Location of the Honey Creek valley sections, by-pass channel, and delineation of the inundated agricultural land. Study area location map is shown on figure 1.

A rainfall-runoff modeling technique designated HEC-1 was developed by the U.S. Army Corps of Engineers (1982) for stream hydrology computations and is widely used throughout the United States for flood and drainage analyses; thus, the general-purpose, multiparameter watershed-model, HEC-1 was selected for use in estimating Honey Creek peak discharges. This modeling technique is based on the analytical solution to optimized or calculated basin parameters using any rainfall-runoff data base compiled.

The Honey Creek hydraulic investigation required the selection of a computer surface-water modeling technique that could be used to accurately estimate water-surface profiles (subcritical flow) for a known or estimated instantaneous peak discharge. The one-dimensional U.S. Geological Survey step-backwater modeling technique (Shearman, 1976), which uses valley cross-section data (existing or assumed) and peak discharge to compute water-surface elevations, was used to estimate the Honey Creek water surface profiles. The step-backwater model mathematically balances energy losses and peak discharge between valley sections along the study reach (Davidian, 1984). Therefore, this model can be used to compute water-surface profiles for both existing stream conditions and for stream conditions that have been modified. This is a common method used in determining water-surface elevations and area inundated by specific flood discharges.

These modeling results could then be used to estimate the magnitude of backwater flooding at the agricultural field associated with specified peak discharges for Honey Creek. The minimum water-surface elevation that innundates the agricultural field and private roadway is 750 ft above sea level. This elevation was used as the optimum (design) criteria in determining the effectiveness of each alternative in reducing the frequency of backwater flooding within the study area. For this study, "backwater" denotes water backed up or retarded in its course to an existing condition water-surface elevation of 750 ft above sea level (at the agricultural field) as compared with the lower water-surface elevation of each alternative condition or combination thereof (Langbein and Iseri, 1960, p.4).

## Peak Discharge

The application of the HEC-1 modeling technique to the Honey Creek basin requires estimation of the basin soil-infiltration rate parameter. Because of insufficient rainfall-runoff data within the Honey Creek drainage basin to calibrate the soil-infiltration rate parameter, data from the nearby U.S. Geological Survey streamflow-gaging station, Brushy Creek near Blairstown, Missouri, was used for estimation (fig.1).

Brushy Creek near Blairstown, Missouri (06921740) drains 1.15 $mi^2$ and has a similar surface soil composition (soil-infiltration rate) to the Honey Creek basin (Allgood and Persinger, 1979, p. 26-28). A U.S. Geological Survey report for small drainage areas of Missouri (Hauth, 1973, p. 81-83) includes three recorded rainfall-runoff events for Brushy Creek near Blairstown. The Brushy Creek HEC-1 model parameter values for drainage-area and the dimensionless unit hydrograph time of concentration were measured from topographic maps (table 1). Because detailed valley section data for both Brushy Creek and Honey Creek were not available, the Muskingum streamflow routing method was used. The three rainfalls were modeled (fig. 3) using estimated soil-infiltration rates (Soil Conservation Service, SCS, curve numbers). These estimated Brushy Creek curve numbers, along with previous experience using the HEC-1 model (T.W. Alexander, written commun. to the U.S. Army Corps of Engineers concerning a second generation watershed model, St. Louis District, 1989), can provide an available means for estimating soil-infiltration rates usable within both the Honey Creek and Brushy Creek basins. From figure 3, the range in computed peak discharges and their hydrograph shapes using the estimated Brushy Creek soil-infiltration rates indicate that parameter adjustments were not necessary; henceforth, these SCS curve numbers are considered transferable to the Honey Creek basin. The HEC-1 Honey Creek model parameter values for subbasin drainage-area (fig. 4) and their dimensionless-unit-hydrograph time of concentrations were measured from topographic maps and field checked where possible (table 2).

To verify the transferred soil-infiltration rates (SCS curve numbers), three temporary U.S. Geological Survey continuous recording stations (fig. 1) were installed to collect rainfall data for use in the Honey Creek basin model. Data were collected from July l987 through September 1988 for this study.

Table 1.--*The HEC-1 Brushy Creek basin model parameters used to compute discharge hydrographs at Brushy Creek near Blairstown (06921740)*

[in., inches; $mi^2$, square miles; SCS, Soil Conservation Service; TC, time of concentration; h, hours]

| Storm dates | Total rainfall (in.) | Drainage area ($mi^2$) | SCS curve number | TC[1] (h) |
|---|---|---|---|---|
| August 1-2, 1961 | 5.88 | 1.15 | 92 | 0.76 |
| July 19, 1965 | 2.24 | 1.15 | 86 | .76 |
| July 17-18, 1968 | 4.36 | 1.15 | 79 | .76 |

[1] Chow (1964, p. 21-10)

Table 2.--*The HEC-1 model parameters used to compute discharge hydrographs for the Honey Creek basin*

[$mi^2$, square miles; TC, time of concentration; h, hours]

| Subbasin number (fig.4) | Drainage area ($mi^2$) | TC[1] (h) |
|---|---|---|
| 1 | 4.90 | 2.01 |
| 2 | 2.99 | 2.43 |
| 3 | 2.34 | 1.35 |
| 4 | 1.61 | .94 |
| 5 | 3.86 | 1.92 |
| 6 | .91 | .87 |
| 7 | 3.38 | 2.58 |
| 8 | 3.35 | 1.26 |
| 9 | 3.70 | 2.74 |
| 10 | 1.46 | .72 |
| 11 | 2.38 | 1.71 |
| 12 | 1.04 | .86 |
| 13 | 1.83 | 1.26 |

[1] Chow (1964, p. 21-10)

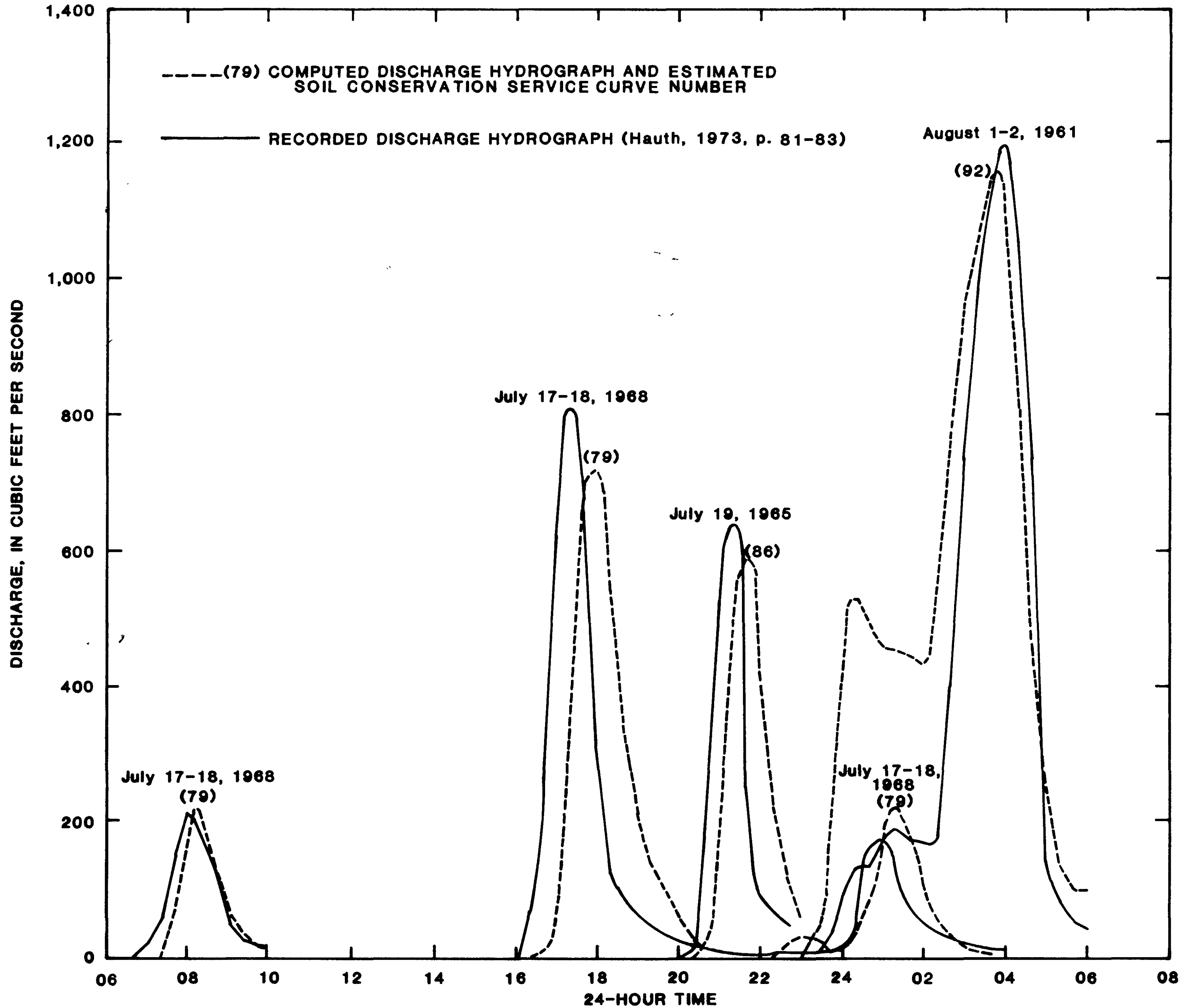



Figure 3.--Discharge hydrographs for selected storms at Brushy Creek near Blairstown (06921740).

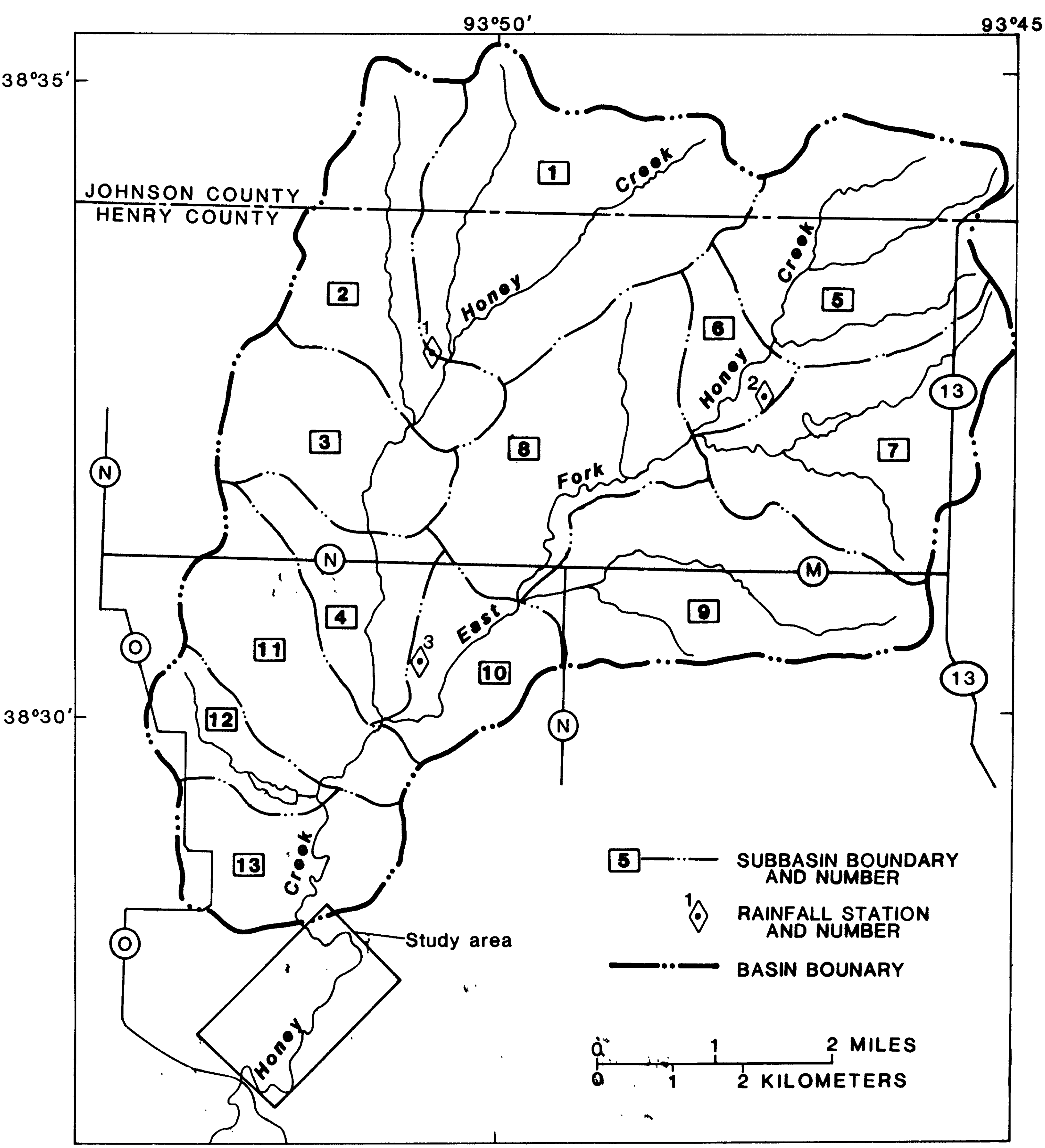



Figure 4.--Drainage area subbasins used in the Honey Creek basin model.

Because of drought conditions throughout Missouri, data for only one small (1.16 in.) rainfall-runoff event (March 28-29, 1988) were collected within the study area for use in verifying these rates. Using the March 1988 rainfall (SCS curve number 79), the Honey Creek HEC-1 model results upstream from the coal strip mine reclamation site (drainage area, 33.75 $mi^2$) show the two hydrograph characteristics of peak-time and peak-discharge comparing favorably to the field measured values (table 3). The statistical rainfall data developed by the National Weather Service for 2- to 100-year frequencies and 30-minute to 24-hour durations (Hershfield, 1961) were used to confirm the transferred rates that were applicable to the larger Honey Creek peak-discharge conditions. The 5-year frequency and 3-hour duration rainfall total of 2.90 in. (Hershfield, 1961, p. 55) was used to compute the Honey Creek peak discharge. Using an assumed triangular distribution of rainfall (SCS curve number 79), the Honey Creek HEC-1 model gave a 3,840 $ft^3/s$ (cubic feet per second) peak discharge at the upstream boundary of the Honey Creek reclamation site. From figure 5, the 5-year 3-hour rainfall peak discharge of 3,840 $ft^3/s$ compares within 1.5 percent of the Honey Creek 5-year regional peak discharge of 3,900 $ft^3/s$ (Hauth, 1974, p. 7). Based on these comparisons, the transferred Honey Creek soil- infiltration rates (SCS curve numbers) were considered to be verified for use in computing any instantaneous peak discharges within the Honey Creek coal strip mine reclamation site (study area).

Table 3.--*Select discharge hydrograph characteristics for the rainfall of March 28-29, 1988*

[h, hours; $ft^3/s$, cubic feet per second]

| | Peak of March 29, 1988 | |
|---|---|---|
| Results | Time (h) | Discharge ($ft^3/s$) |
| Honey Creek HEC-1 model | 15:00 | 254 |
| Field measured | 16:00 | 245 |

## Water-Surface Profile

The step-backwater modeling technique (Shearman, 1976) has versatility in estimating the effect of alternative valley section geometry on the resultant water-surface profile. This modeling technique includes the assumption that, at instantaneous peak discharge, the flood discharge (hydrograph) flattens out (broadens) and approximates a steady-state flow condition (subcritical). Therefore, a water-surface profile described by high-water marks is a reliable calibration tool. The Honey Creek step-backwater model parameter values for valley section roughness (Manning's N) were calibrated by matching a computed water-surface profile (peak discharge 3,500 $ft^3/s$) to field surveyed (measured) high-water mark elevations at or near the valley sections used in the study reach (fig. 6). These roughness values can then be used to compute water-surface elevations (profiles) for any instantaneous peak discharge condition within the Honey Creek study area.

# ALTERNATIVE MODIFICATIONS

The assumed channel modifications selected by Lindsey R. Henry, Missouri Department of Natural Resources (oral commun., May 1988) and used in the three alternative analyses are: (1) eliminate the steep channel bottom slope from valley sections 9 through 13; (2) remove spoil material to increase the channel cross-sectional area in the vicinity of valley sections 14 through 15; and (3) increase the cross-sectional area of the by-pass channel located between valley sections 13 and 14.

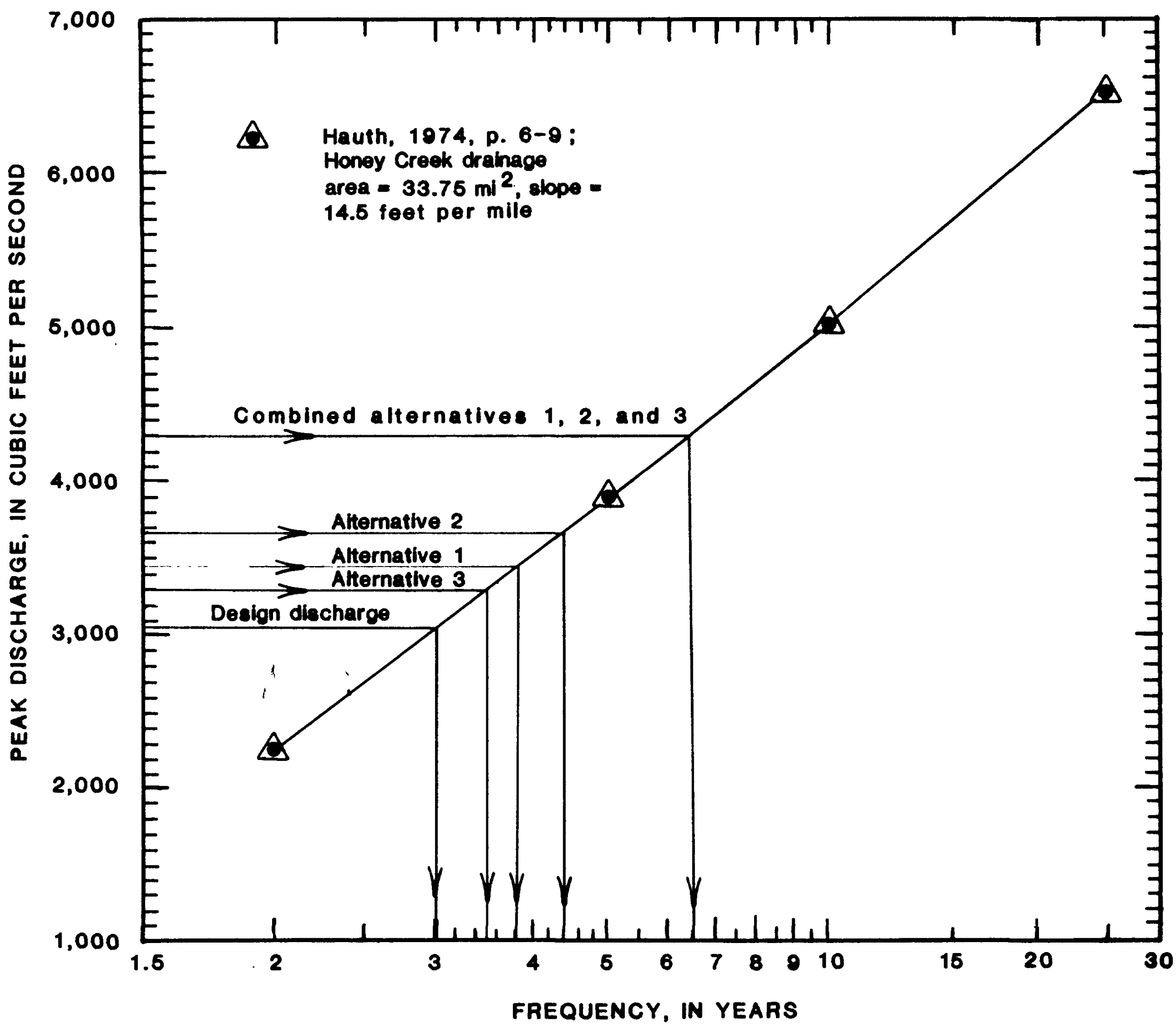



Figure 5.--Regional flood-frequency curve for Honey Creek at upstream boundary of Honey Creek coal strip mine reclamation site.

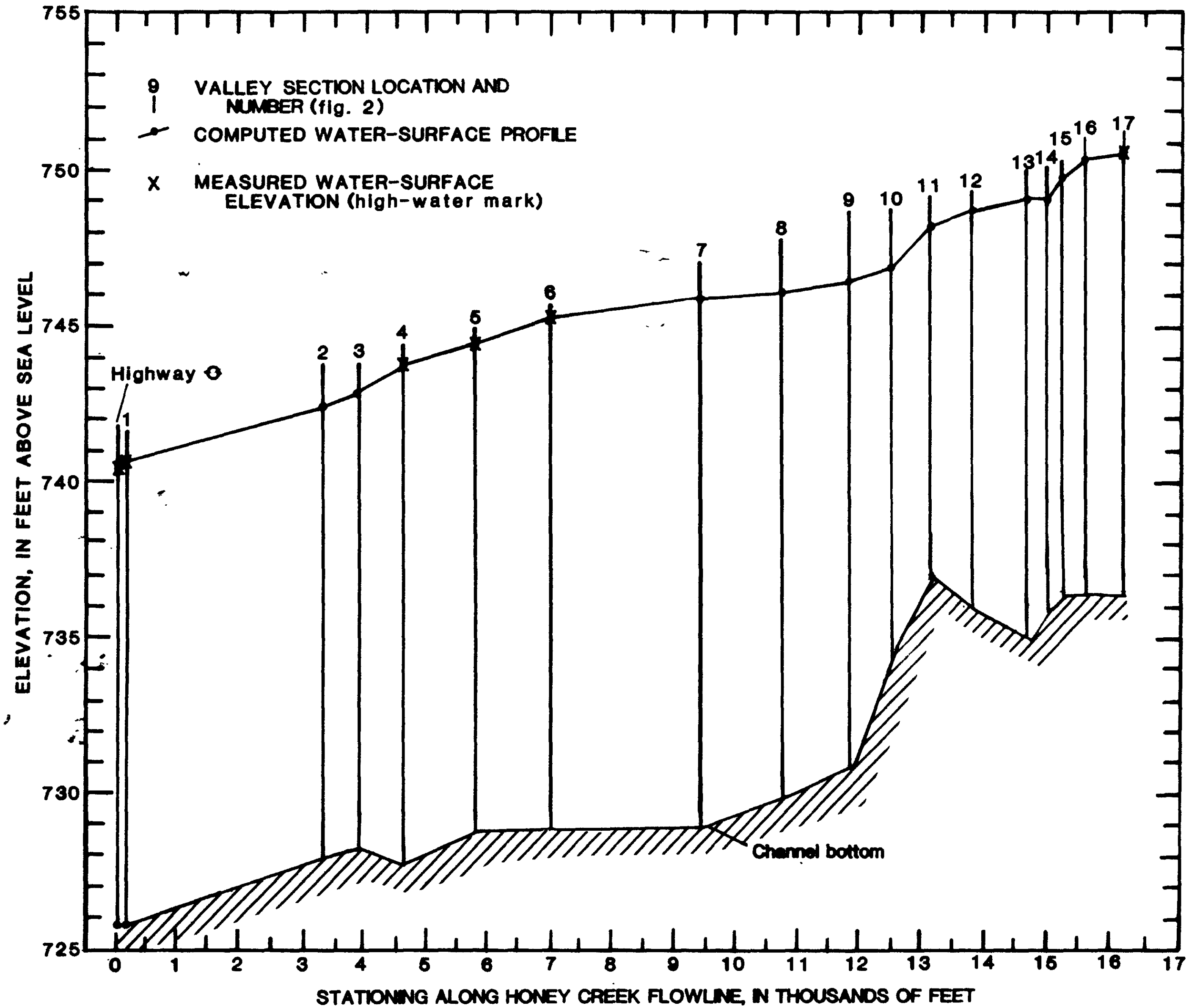



Figure 6.--Computed and measured water-surface elevations for a peak discharge of 3,500 cubic feet per second in the Honey Creek study area.

The Honey Creek flood-frequency relation is used to compare the results of the three alternative analyses. For this study, the 2- to 25-year peak-discharge-frequency relation for the Honey Creek study area was developed from the statewide frequency study for rural areas of Missouri (Hauth, 1974) and is plotted in figure 5. Computed water-surface profiles for each of three alternative channel modifications were evaluated against (subtracted from) the existing Honey Creek design discharge water-surface profile. A design discharge of 3,050 $ft^3/s$ (bank full) was determined by maximizing the water-surface elevation along the upstream boundary of the Honey Creek reclamation site to 750 ft above sea level. From figure 5, the existing Honey Creek design discharge represents a flood frequency of 3 years. The 3-year frequency is defined by this relation to be the instantaneous peak discharge that is equaled or exceeded once, on the average, during 3 years.

## Alternative 1

An examination of the computed water-surface profile for the existing Honey Creek design discharge of 3,050 $ft^3/s$ (fig. 7) shows a notable profile break occurs from valley sections 9 through 13. The assumed alternative 1 channel modifications are 1) to increase the channel width while 2) excavating the existing channel bottom (valley sections 9 through 13) to the lower bottom elevations shown in figure 8. By substituting these assumed channel modifications into the step-backwater model, the effects on the resulting water-surface profile (fig.7) were computed. Therefore, the alternative 1 channel modifications will reduce the existing backwater flooding elevation by 0.39 ft at valley section 17 (agricultural field) near the upstream boundary of the study area (table 4).

The recomputation of the step-backwater model using the alternative 1 channel modifications and maximizing the water-surface elevation at valley section 17 to 750 ft above sea level results in a 400 $ft^3/s$ design discharge increase for the Honey Creek study area. Thus, the alternative 1 maximized design discharge of 3,450 $ft^3/s$ (table 5) can lessen the existing backwater flooding near valley section 17 from a 3-year (design discharge) to an approximate 3.8-year (alternative 1) frequency (fig. 5).

Table 4.--*Computed water-surface elevations for the existing Honey Creek design discharge of 3,050 cubic feet per second*

| Valley section number (fig. 2) | Water-surface elevation, in feet above sea level<br>Existing condition | Alternative 1 | Alternative 2 | Alternative 3 |
|---|---|---|---|---|
| 1 | 740.05 | 740.05 | 740.05 | 740.05 |
| 9 | 745.81 | 745.94 | 745.78 | 745.68 |
| 10 | 746.28 | 746.23 | 746.25 | 746.08 |
| 11 | 747.69 | 746.88 | 747.68 | 747.38 |
| 12 | 748.34 | 747.47 | 748.33 | 748.00 |
| 13 | 748.62 | 747.86 | 748.62 | 748.25 |
| 14 | 748.66 | 747.98 | 748.74 | 748.27 |
| 15 | 749.24 | 748.69 | 748.88 | 748.92 |
| 16 | 749.80 | 749.39 | 749.20 | 749.56 |
| 17 | 750.00 | 749.61 | 749.57 | 749.70 |

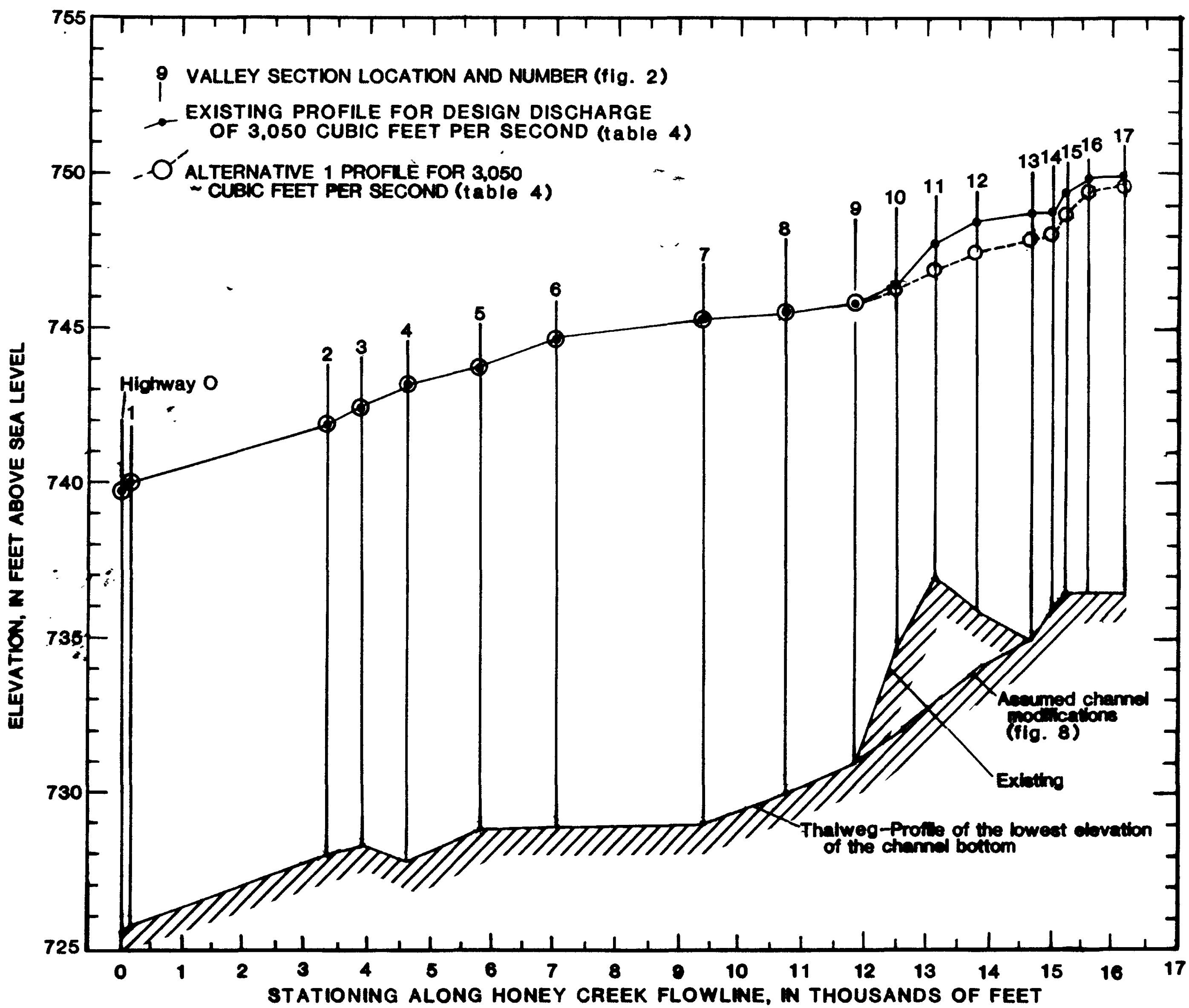



Figure 7.--Effects of alternative 1 channel modifications on the Honey Creek design discharge water-surface profile.

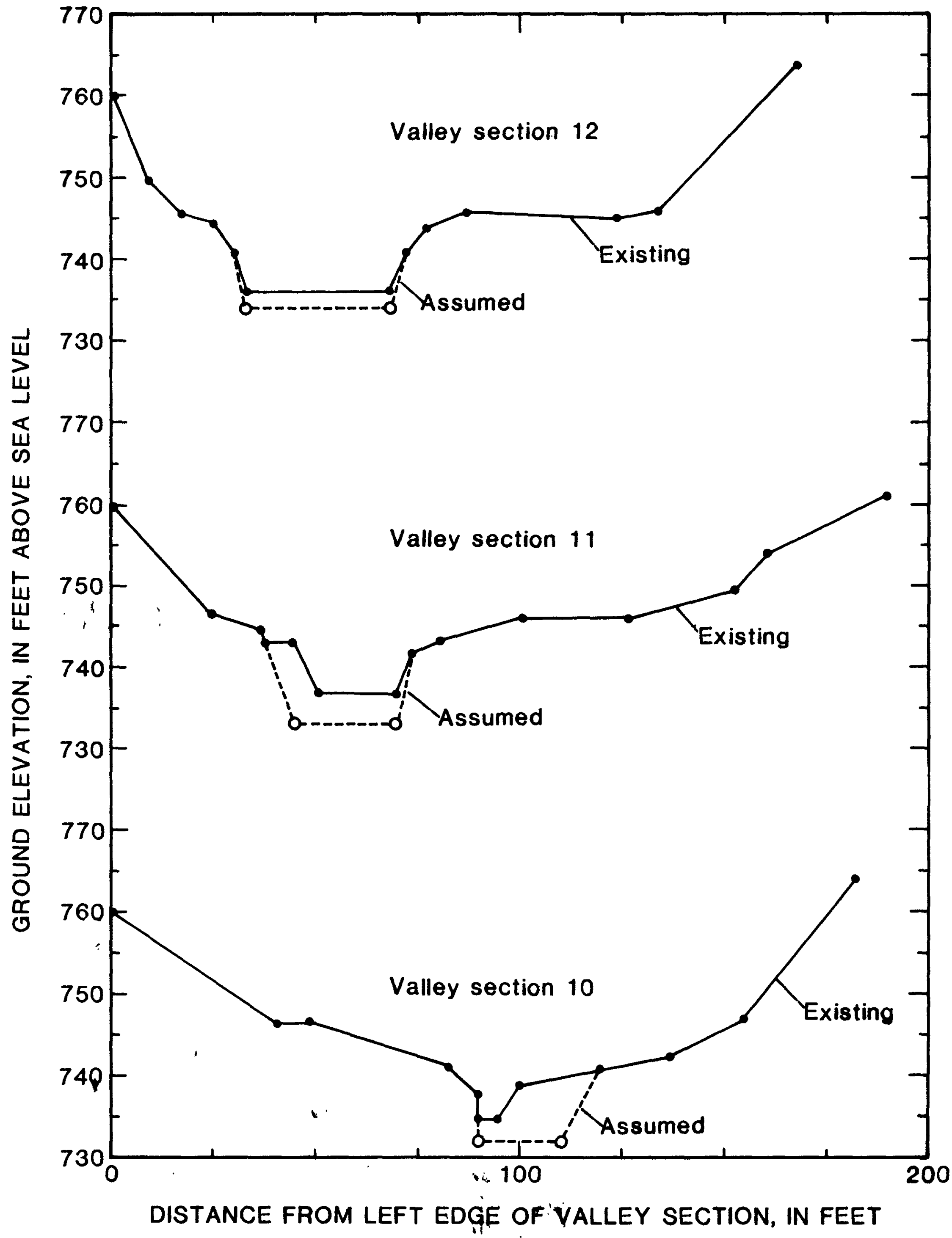



Figure 8.--Assumed channel modifications used in the alternative 1 water-surface profile computation.

Table 5.--*Maximized water-surface elevations for the three alternative design discharges*

[$ft^3/s$, cubic feet per second]

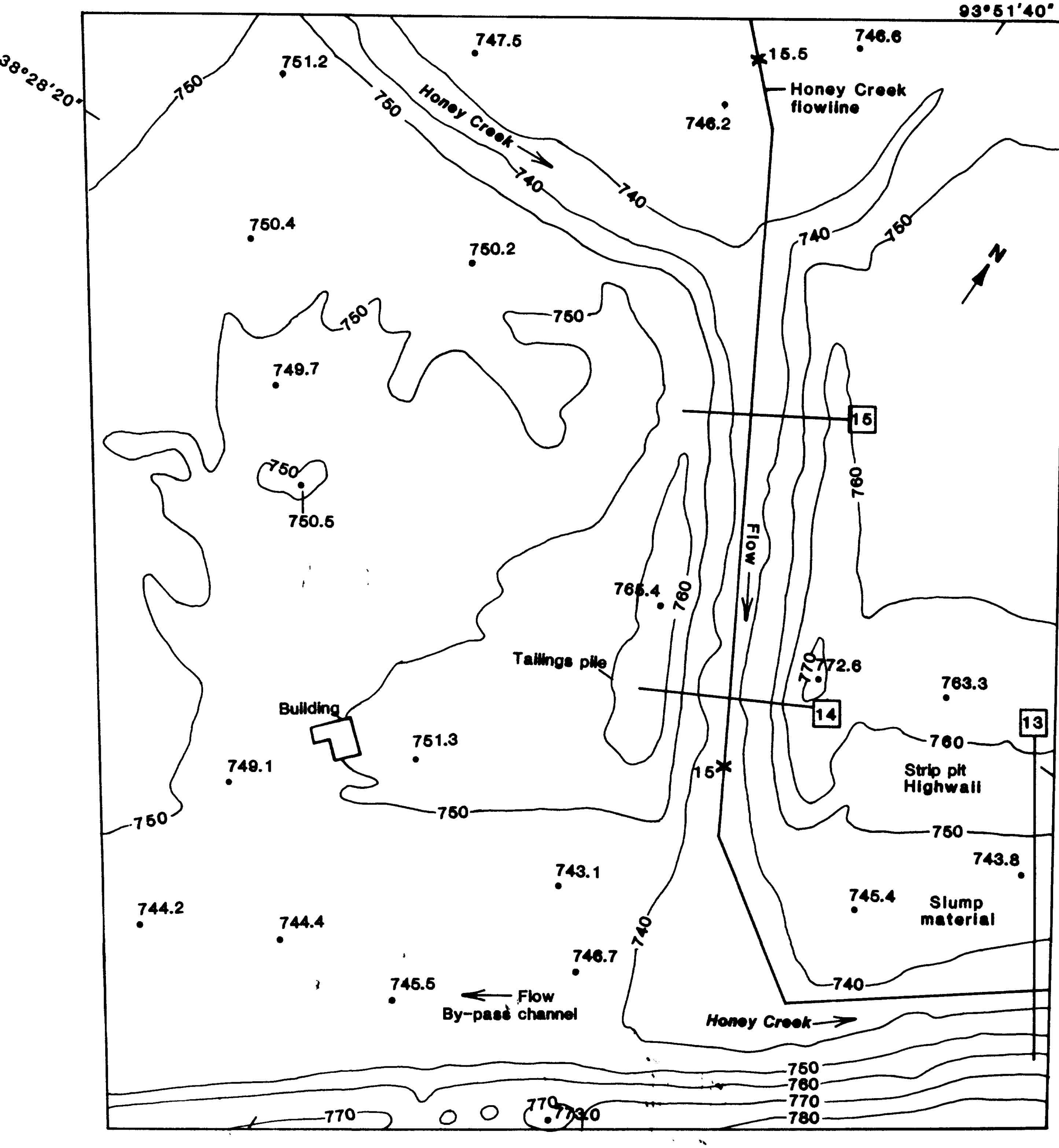
| Valley section number (fig. 2) | Water-surface elevation, in feet above sea level Alternative 1 3,450 $ft^3/s$ | Alternative 2 3,650 $ft^3/s$ | Alternative 3 3,300 $ft^3/s$ |
|---|---|---|---|
| 1 | 740.65 | 740.74 | 740.41 |
| 9 | 746.54 | 746.64 | 746.07 |
| 10 | 746.83 | 747.05 | 746.45 |
| 11 | 747.46 | 748.25 | 747.65 |
| 12 | 748.00 | 748.84 | 748.24 |
| 13 | 748.37 | 749.13 | 748.49 |
| 14 | 748.46 | 749.26 | 748.49 |
| 15 | 749.25 | 749.42 | 749.21 |
| 16 | 749.85 | 749.76 | 749.87 |
| 17 | 750.00 | 750.00 | 750.00 |

## Alternative 2

Further examination of the existing Honey Creek design discharge water-surface profile (fig. 7) shows a second prominent break occurs between valley sections 14 and 17. This profile break most likely results from a tailings pile (spoil material) constricting the overbank stream reach near valley sections 14 and 15, and the complicated flow condition (by-pass channel) downstream from valley section 14 (fig. 9). Only the effects of removing the valley constriction caused by the tailings pile are evaluated in the alternative 2 analysis.

The assumed channel modification of alternative 2 is to remove the tailings pile from the flood plain and, thereby, increase the right overbank (looking downstream) flood plain cross-sectional area. Thus, near valley section 14 the tailings pile was removed for approximately 150 ft with an overbank ground elevation at 744 ft above sea level, and near valley section 15 the tailings pile was removed for approximately 200 ft with an overbank ground elevation at 745 ft above sea level (fig. 10). By substituting the assumed channel modification into the step-backwater model, the resulting water-surface profile is shown in figure 11. The alternative 2 modification will reduce the existing backwater flooding elevation at valley section 17 (agricultural field) by 0.43 ft (table 4).

The recomputation of the step-backwater model using the alternative 2 channel modification and maximizing the water-surface elevation at valley section 17 to 750 ft above sea level results in a 600 $ft^3/s$ design discharge increase for the Honey Creek study area. Thus, the alternative 2 maximized design discharge of 3,650 $ft^3/s$ (table 5) can lessen the existing backwater flooding near valley section 17 from a 3-year (design discharge) to an approximate 4.4-year (alternative 2) frequency (fig. 5).




EXPLANATION

744.4 • GROUND ELEVATION, IN FEET ABOVE SEA LEVEL

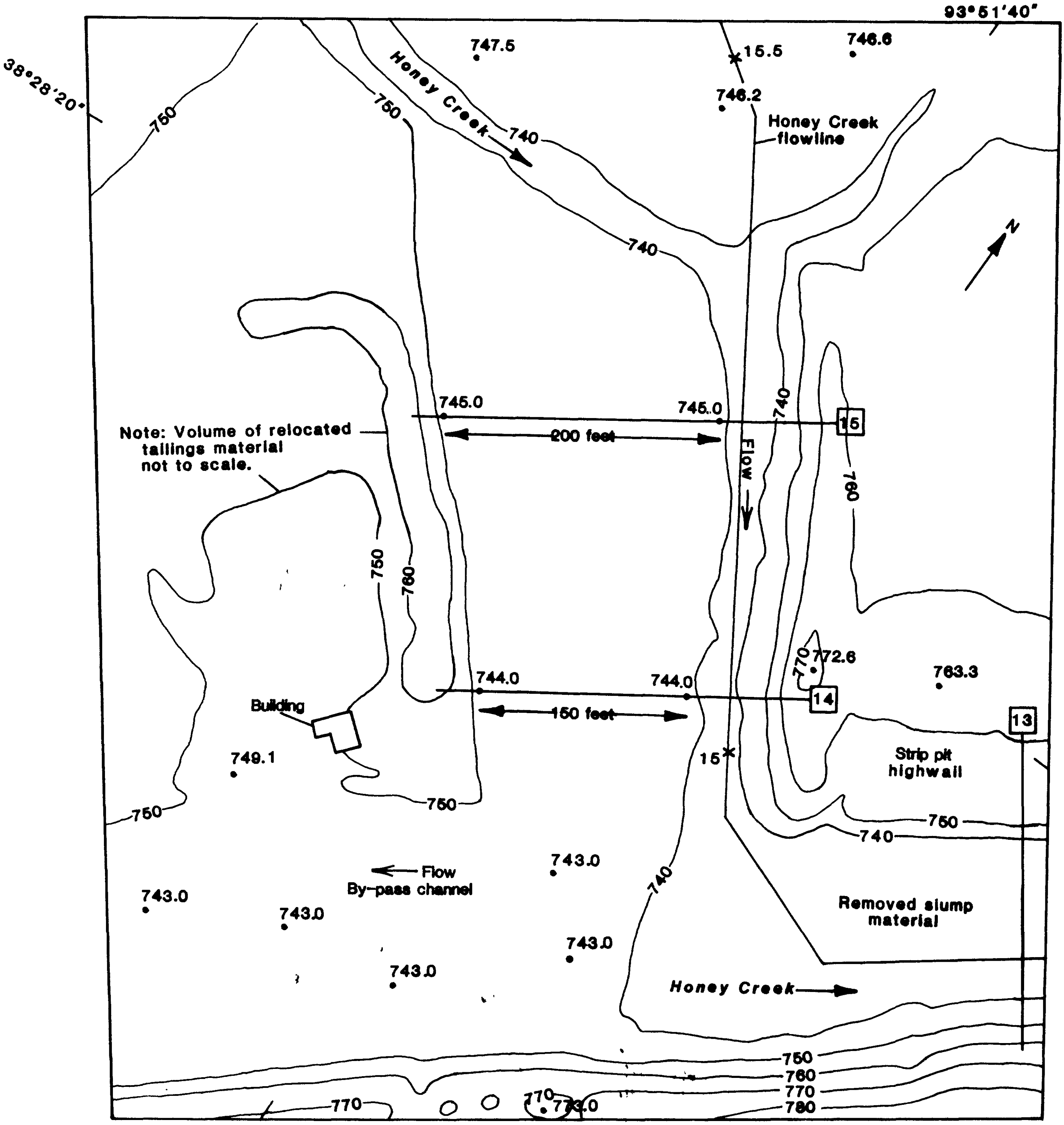
—[14] VALLEY SECTION LOCATION AND NUMBER (fig. 2)

15✱ STATIONING ALONG HONEY CREEK FLOWLINE, IN THOUSANDS OF FEET

0 50 100 FEET
0 25 METERS

CONTOUR INTERVAL 10 FEET
DATUM IS SEA LEVEL

Figure 9.--Topography in the vicinity of alternatives 2 and 3 channel modifications.



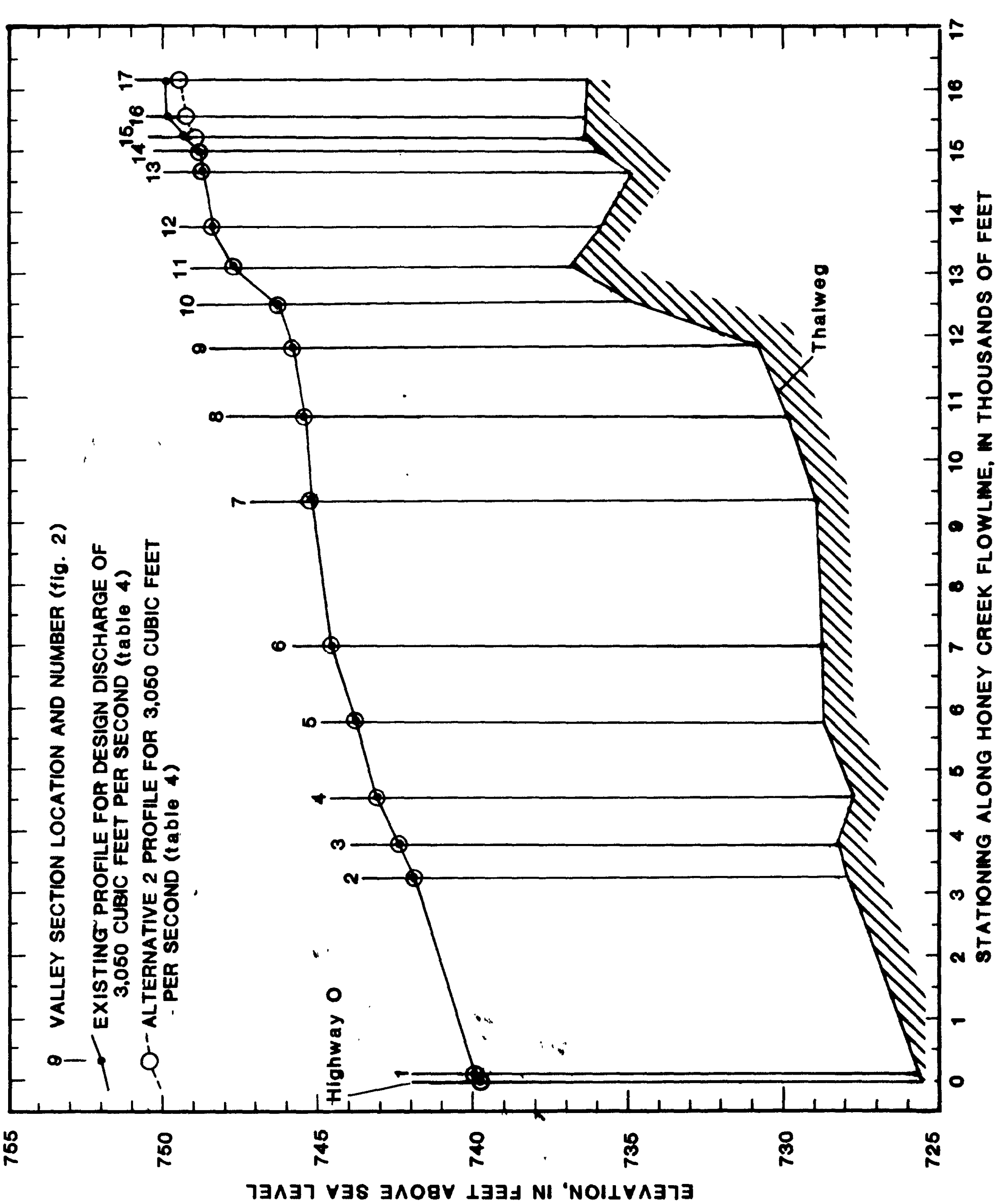

EXPLANATION

| | |
|---|---|
| 743.0 | GROUND ELEVATION, IN FEET ABOVE SEA LEVEL |
| 14 | VALLEY SECTION LOCATION AND NUMBER (fig. 2) |
| 15* | STATIONING ALONG HONEY CREEK FLOWLINE, IN THOUSANDS OF FEET |

0 50 100 FEET
0 25 METERS

CONTOUR INTERVAL 10 FEET
DATUM IS SEA LEVEL

Figure 10.--Assumed topography after channel modifications of alternatives 2 and 3, see figure 9.



9 VALLEY SECTION LOCATION AND NUMBER (fig. 2)
EXISTING PROFILE FOR DESIGN DISCHARGE OF 3,050 CUBIC FEET PER SECOND (table 4)
ALTERNATIVE 2 PROFILE FOR 3,050 CUBIC FEET PER SECOND (table 4)
Highway O
Thalweg
ELEVATION, IN FEET ABOVE SEA LEVEL
725
730
735
740
745
750
755
STATIONING ALONG HONEY CREEK FLOWLINE, IN THOUSANDS OF FEET
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17

## Alternative 3

As noted in the alternative 2 analysis, the by-pass channel flow conditions may contribute to the existing Honey Creek design discharge water-surface profile break between valley sections 14 and 17 (fig. 7). The effects of the channel improvements in and near the by-pass channel are evaluated in the alternative 3 analysis. The flow conditions are such that reliable computations for the by-pass channel discharge rating curve were determined by using the slope-conveyance method (Rantz and others, 1982, p. 334-337). This method assumes the energy-gradient, water-surface, and friction slopes are parallel and become constant at the higher discharges. The slope-conveyance method may have some degree of uncertainty associated with its results; therefore, this rating curve was verified by check step-backwater model analyses covering the entire range of applicable by-pass channel discharges.

Alternative 3 analysis includes the assumption of an increase in cross-sectional area of the by-pass channel by excavating and cleaning the channel bottom to an elevation of 743 ft above sea level. Also assumed in the analysis is the removal of strip pit highwall slump material near valley section 13. See figures 9 and 10. By balancing results from the alternative 3 step-backwater model computation (design discharge) and the by-pass channel discharge rating curve (Davidian, 1984, p. 30-32), the water-surface profile was computed and is shown in figure 12. Therefore, the alternative 3 modifications will reduce the existing backwater flooding elevation at valley section 17, along the agricultural field near the upstream boundary of the Honey Creek reclamation site, by 0.30 ft (table 4).

The recomputation of the step-backwater model using the alternative 3 channel modification and maximizing the water-surface elevation at valley section 17 to 750 ft above sea level will increase the Honey Creek design discharge by 250 $ft^3/s$. Thus, the alternative 3 maximized design discharge of 3,300 $ft^3/s$ (table 5) can lessen the existing backwater flooding near valley section 17 from a 3-year (design discharge) to a 3.5-year (alternative 3) frequency (fig. 5).

## Combined Alternatives

Throughout this study, emphasis has been directed toward evaluating each individual alternative. However, combining any two (or more) alternatives will further reduce backwater flooding along the upstream boundary of the Honey Creek study area (valley section 17). In all possible combinations, the floodwater elevation decreases and maximized design discharge increases at valley section 17 were approximately equal to the sum of their individual results. For simplicity of use, any combination of alternatives will be linearly additive with regard to their individual increases in the existing Honey Creek study area design discharge of 3,050 $ft^3/s$. For example, when alternative 1 (decreased backwater by 0.39 ft), alternative 2 (decreased backwater by 0.43 ft), and alternative 3 (decreased backwater by 0.30 ft) were combined and modeled, the decrease in water-surface elevation at valley section 17 was 1.12 feet. Also, the three channel modifications of alternative 1 (design discharge increase of 400 $ft^3/s$), alternative 2 (design discharge increase of 600 $ft^3/s$), and alternative 3 (design discharge increase of 250 $ft^3/s$) did increase the existing Honey Creek design discharge by 1,250 $ft^3/s$. By concurrently considering the three alternatives, the maximized Honey Creek flooding discharge is increased to 4,300 $ft^3/s$ (existing design discharge of 3,050 $ft^3/s$ plus the increase of 1,250 $ft^3/s$). Thus, the current (1990) frequency of overbank flooding at the upstream boundary of the reclamation site is reduced from a 3-year (design discharge) flood event to a 6.5-year (alternative 1, 2 and 3) frequency (fig. 5).

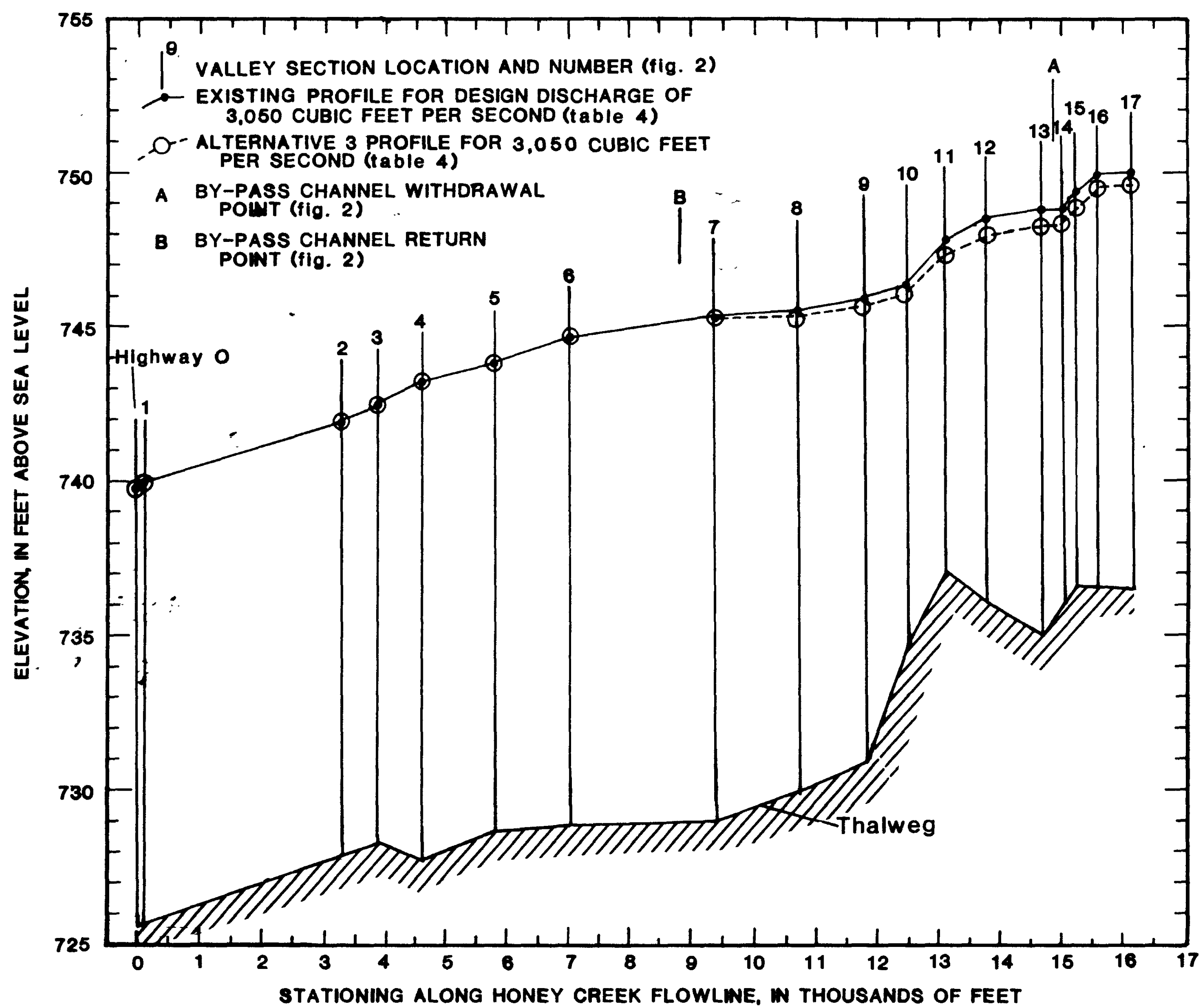



Figure 12.--Effects of alternative 3 channel modifications on the Honey Creek design discharge water-surface profile.

# SUMMARY

This report documents the results from computer model analyses of three assumed alternative channel modifications, and combinations thereof, to evaluate each as a possible solution to the flood-related problems occurring in an agricultural field near the upstream boundary of the Honey Creek coal strip mine reclamation site. The computed water-surface profile for each alternative analysis was compared to the water-surface profile for the existing Honey Creek design discharge of 3,050 $ft^3/s$. Therefore, the potential of each alternative (or combinations thereof) for reducing the frequency of backwater flooding is discussed.

Study results show that alternative 1 (improvement of channel bottom slope) would decrease backwater elevations near the agricultural field by 0.39 ft; alternative 2 (relocation of spoil material) by 0.43 ft; and the assumed by-pass channel improvements discussed in alternative 3 by 0.30 ft. The backwater reductions of alternative 1 (design discharge increase of 400 $ft^3/s$), alternative 2 (design discharge increase of 600 $ft^3/s$), and alternative 3 (design discharge increase of 250 $ft^3/s$) can be converted into a Honey Creek design discharge increase of 1,250 $ft^3/s$. Therefore, the alternative 1, 2, and 3 maximized design discharge of 4,300 $ft^3/s$ would reduce the current (1990) frequency of backwater flooding from a 3-year to a 6.5-year flood event.

It is not the intent of this study to conclude that these are the only solutions for mitigating backwater flooding problems within the Honey Creek coal strip mine reclamation site. Possible alternatives such as levee construction along Honey Creek or culvert construction on the private roadway to alleviate the effects of backwater were not considered in this study.

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