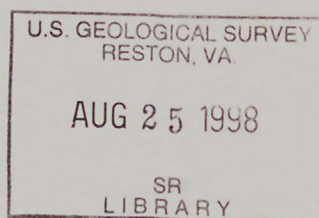


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PRELIMINARY WATER-SURFACE ELEVATIONS AND BOUNDARY OF THE 100-YEAR PEAK FLOW IN THE BIG LOST RIVER AT THE IDAHO NATIONAL ENGINEERING AND ENVIRONMENTAL LABORATORY, IDAHO

U.S. GEOLOGICAL SURVEY
Water-Resources Investigations Report 98-4065



Prepared in cooperation with the
U.S. DEPARTMENT OF ENERGY

DEPOSITORY

Preliminary Water-Surface Elevations and Boundary of the 100-Year Peak Flow in the Big Lost River at the Idaho National Engineering and Environmental Laboratory, Idaho

By Charles Berenbrock and L.C. Kjelstrom

U.S. GEOLOGICAL SURVEY

Water-Resources Investigations Report 98-4065

Prepared in cooperation with
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1998

U.S. DEPARTMENT OF THE INTERIOR

BRUCE BABBITT, Secretary

U.S. GEOLOGICAL SURVEY

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PLATE

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1. Map showing preliminary water-surface elevations at selected cross sections and preliminary boundary of the 100-year peak flow in the Big Lost River at the Idaho National Engineering and Environmental Laboratory, Idaho

FIGURES

1. Map showing location of study area, Big Lost River Basin, the Idaho National Engineering and Environmental Laboratory, and nearby streams. 3
2. Map showing location of study area and facilities and features at the Idaho National Engineering and Environmental Laboratory 4

CONVERSION FACTORS AND VERTICAL DATUM

Multiply	By	To obtain
acre	0.004047	square kilometer
acre-foot (acre-ft)	1,233	cubic meter
cubic foot per second (ft ³ /s)	0.02832	cubic meter per second
cubic foot per second per mile [(ft ³ /s)/mi]	0.0176	cubic meter per second per kilometer
foot (ft)	0.3048	meter
foot per mile (ft/mi)	0.1894	meter per kilometer
mile (mi)	1.609	kilometer
square mile (mi ²)	2.590	square kilometer

Sea level: In this report, “sea level” refers to the National Geodetic Vertical Datum of 1929—a geodetic datum derived from a general adjustment of the first-order level nets of the United States and Canada, formerly called Sea Level Datum of 1929.

Preliminary Water-Surface Elevations and Boundary of the 100-Year Peak Flow in the Big Lost River at the Idaho National Engineering and Environmental Laboratory, Idaho

By Charles Berenbrock and L.C. Kjelstrom

Abstract

Delineation of areas at the Idaho National Engineering and Environmental Laboratory that would be inundated by a 100-year peak flow in the Big Lost River is needed by the U.S. Department of Energy to fulfill flood-plain regulatory requirements. The Big Lost River flows southeastward about 50 miles through an alluvium-filled valley onto the eastern Snake River Plain. The 35-mile downstream reach of the Big Lost River that flows across the Idaho National Engineering and Environmental Laboratory and ends in a series of playas is of particular concern. Many anthropogenic features in the study area affect flood hydraulics and flow.

Thirty-seven channel cross sections were surveyed to develop and apply a one-dimensional hydraulic model to calculate water-surface elevations and estimate the areas of inundation for the 100-year peak flow in the Big Lost River. From the western boundary of the Idaho National Engineering and Environmental Laboratory to the diversion dam, a peak flow of 7,260 cubic feet per second was simulated. On the basis of a structural analysis, the diversion dam was assumed incapable of retaining high flows and, thus, was not included in model simulations. However, the diversion channel does affect flows downstream from the dam. Model results indicated that 6,220 cubic feet per second would flow downstream from the dam in the Big Lost River if the dam did not exist, and the remainder would flow in the diversion channel. Where State Highway 26 crosses the Big Lost River, about 47 percent of the flow would pass under the bridge and the remainder would flow over the highway about 1,200 feet southeast of the bridge. The calculated water-surface elevation was about 1 foot higher than the highway. Where Lincoln Boulevard crosses the Big Lost River near the Idaho Chemical Processing Plant, the calculated water surface was about 0.4 foot higher than the road. About 24 percent of the flow would pass through the culverts, and the remainder would flow over the road. At the railroad bridge near the Idaho Chemical Processing Plant, the calculated water surface averaged 0.5 foot higher than the railroad. About 40 percent of the flow would pass under the bridge, and the remainder would flow over the railroad. Model results also indicated that

30 percent of the total flow would pass under the bridge at Lincoln Boulevard near the Naval Reactors Facility, and the remainder would flow over the road.

The 100-year peak flow boundary at the Idaho National Engineering and Environmental Laboratory was defined. The flood plain was as narrow as 120 feet near the western boundary of the study area and as wide as 1.2 miles near the Idaho Chemical Processing Plant. The northern part of the Idaho Chemical Processing Plant and its entrance road would be the only facility that would be flooded. The experimental dairy farm about 2.5 miles downstream from the plant also would be flooded.

Discretion must be exercised in the use of these model results. The simplifying assumptions used in this and other one-dimensional models and the limited number of cross sections used prevent precise simulation of the flood hazard. The model gives a reasonable determination of the water-surface elevations and the inundated areas for the 100-year peak flow. However, these one-dimensional model results are preliminary and primarily intended to provide guidance in the construction of a more stringent flow model. Application of more stringent models (two dimensional) is needed to refine and better delineate the extent of possible flooding of the Big Lost River at the Idaho National Engineering and Environmental Laboratory.

INTRODUCTION

The Big Lost River in southeastern Idaho flows southeastward about 50 mi through an alluvium-filled valley to the eastern Snake River Plain (fig. 1). Peaks in the Pioneer Mountains and Lost River Range that border the valley are 9,000 to 12,700 ft above sea level. Precipitation on the mountains supplies most water in the valley. Mackay Reservoir, 30 mi upstream from Arco and 45 mi upstream from the boundary of the Idaho National Engineering and Environmental Laboratory (INEEL), stores Big Lost River water for irrigation. Before reaching the plain, most water stored

in the reservoir and most tributary inflow between the reservoir and Arco are diverted for irrigation or lost by infiltration through the streambed. Throughout most of the year, little or no streamflow is recorded at streamflow-gaging station 13132500, Big Lost River near Arco. Streamflow that reaches the Arco gaging station is depleted further by infiltration through the streambed downstream from the station. When the water supply is adequate, the Big Lost River flows onto the INEEL and terminates in a series of playas, connected by branching channels, in the northern part of the INEEL (fig. 2). On the INEEL, a diversion dam (fig. 2 and pl. 1) routes water to spreading areas to prevent flooding of facilities along the river. Because of upstream irrigation, streamflow in many years does not reach the playas. Nevertheless, the extent of possible flooding at the INEEL needs to be determined to fulfill flood-plain requirements for emergency planning, environmental studies, construction of proposed facilities, and controlling flood damage. In 1994, the U.S. Department of Energy at the INEEL entered into a cooperative agreement with the U.S. Geological Survey (USGS) to develop and implement 100-year flood-plain studies.

Purpose and Scope

The Big Lost River flood-plain study was divided into four steps: (1) Determine the 100-year peak flow, (2) survey flood-plain cross sections, (3) calculate water-surface elevations by using a one-dimensional model and delineate the 100-year peak flow boundary, and (4) calculate water-surface elevations by using a two-dimensional model and delineate the 100-year peak flow boundary. In step one, Kjelstrom and Berenbrock (1996) estimated 100-year peak flows and flow volumes for several recurrence intervals. They used flood-frequency analyses at two gaging stations and regional regression equations to estimate peak flows and flow volumes at the Arco gaging station. They estimated that the 100-year peak flow in the Big Lost River near the Arco gaging station was 7,260 ft³/s. In step two, 37 flood-plain cross sections were surveyed within the boundary of the INEEL. The cross sections provided data needed in step three to develop a one-dimensional flood-plain model of the Big Lost River and to determine flow in the diversion channel. Using the 100-year peak flow, the model calculated water-surface eleva-

tions along the surveyed cross sections, which then were used to delineate the areal extent of flooding. The areal extent of flooding will be used in step four to develop a preliminary grid for a two-dimensional model. A two-dimensional model can simulate the natural flooding process of the Big Lost River more precisely than a one-dimensional model can.

This report describes the results of study steps two and three. It presents results of a study to calculate water-surface elevations and delineate the areal extent of possible flooding at the INEEL that would result from peak flow in the Big Lost River having a recurrence interval of 100 years.

Description of Study Area

The study area is the lower 35-mi reach of the Big Lost River that begins where the river crosses the western boundary of the INEEL and ends in a series of playas in the northern part of the INEEL (fig. 2). In the study area, the Big Lost River is an ephemeral stream. Near the western boundary of the INEEL, the river exits Box Canyon, a narrow gorge with nearly vertical walls cut into basaltic rocks. On the INEEL, the river typically is incised less than 20 ft into surficial sediment and basalt. Water-surface slope averages about 8 ft/mi from the western boundary of the INEEL to the diversion dam, and about 14 ft/mi from the dam to Highway 26. Downstream from Highway 26, the flood plain broadens and is characterized by braided channels and remnants of old meander channels. Water-surface slope averages about 13 ft/mi from Highway 26 to Lincoln Boulevard near the Idaho Chemical Processing Plant (ICPP), 16 ft/mi from Lincoln Boulevard near the ICPP to the railroad, 10 ft/mi from the railroad to Lincoln Boulevard near the Naval Reactors Facility (NRF), and 6 ft/mi from Lincoln Boulevard near the NRF to the Big Lost River Sinks. In the Big Lost River Sinks, the river is highly braided and flow spreads across the area with no discernible main channel. Water-surface slope in the sinks averages about 2.7 ft/mi. Downstream from the Big Lost River Sinks are four playas underlain by silt and clay, the last being Birch Creek Playa. The water surface in channels connecting the playas typically slopes less than 1 ft/mi. Several INEEL facilities, including the Test Support Facility (TSF) and the Contained Test Facility (CTF), are located in and around Birch Creek Playa.

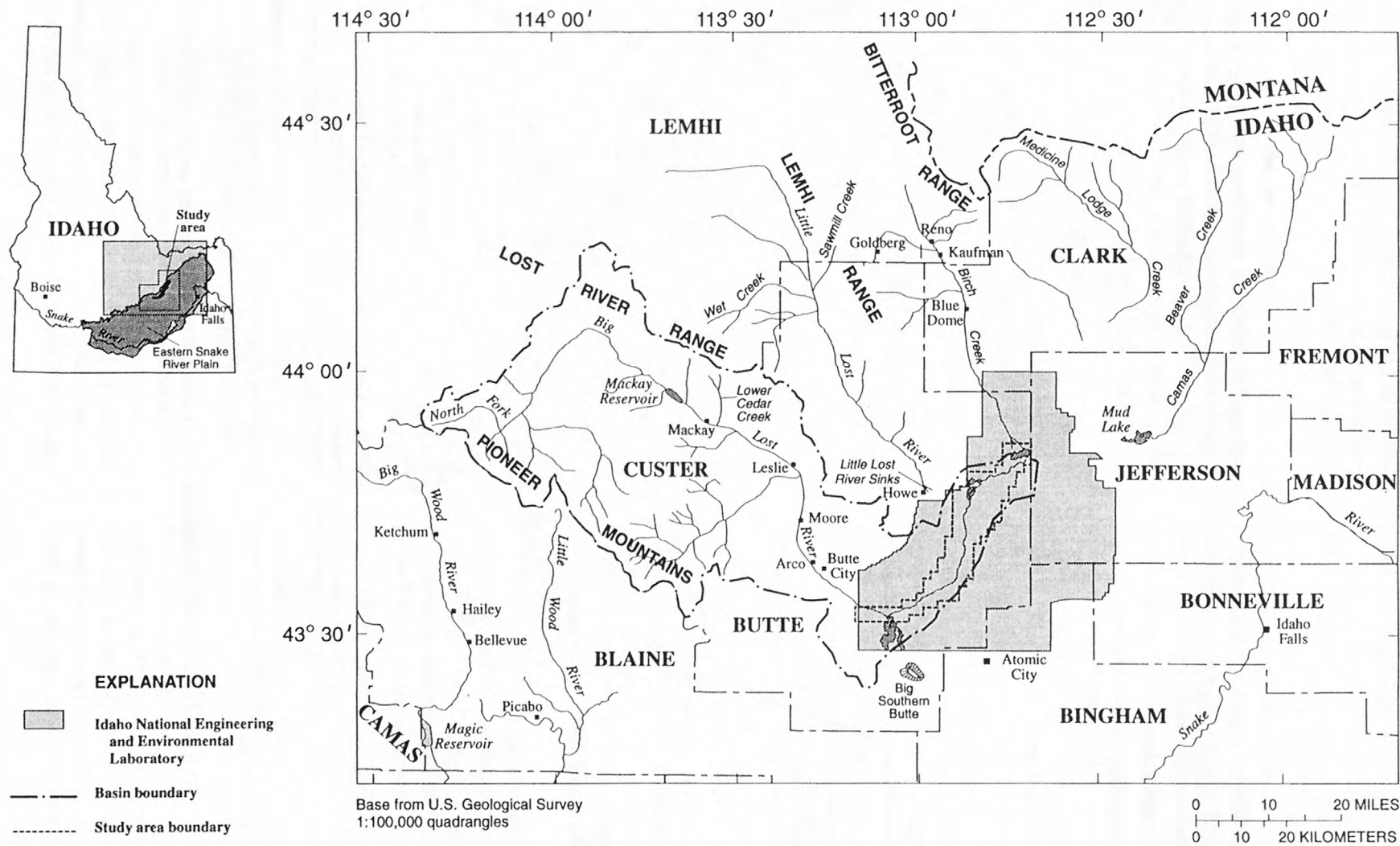


Figure 1. Location of study area, Big Lost River Basin, the Idaho National Engineering and Environmental Laboratory, and nearby streams.

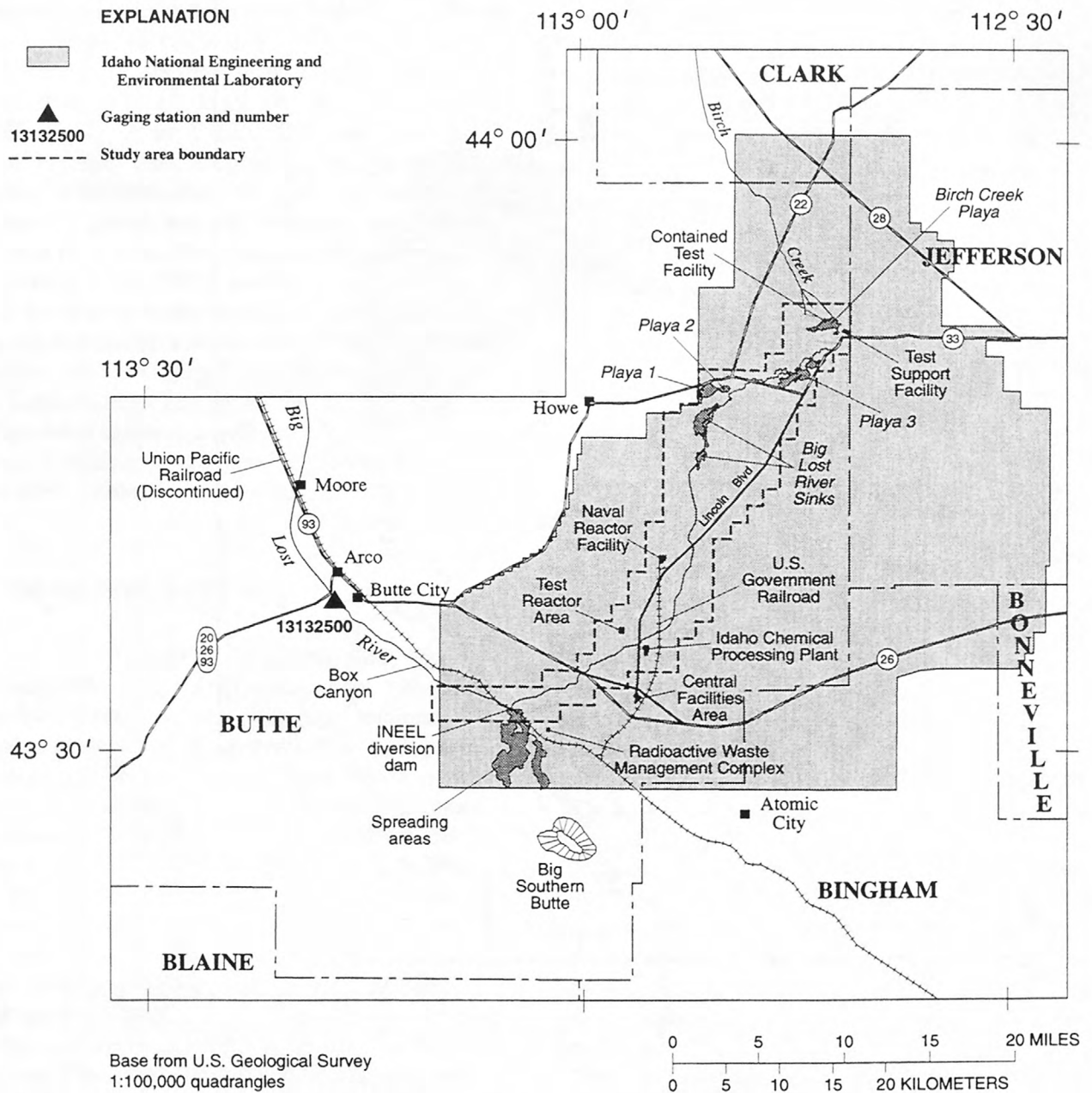


Figure 2. Location of study area and facilities and features at the Idaho National Engineering and Environmental Laboratory.

Bed material in the Big Lost River consists largely of coarse sand with some gravel and cobbles. Alluvial fill overlies basalt, which crops out in several places. Bennett (1990, p. 6) indicated that streamflow decreases downstream from Arco because of infiltration through the streambed.

Riparian vegetation in the study area is mainly sagebrush and grass; vegetation increases near the river. Sparse stands of cottonwood trees grow along the river upstream from the Big Lost River Sinks. Most of these trees are now dead because streamflow in that area has been very infrequent. Sparse grasses grow on the playas.

Many anthropogenic features in the Big Lost River and flood plain affect flood hydraulics and flow. About 6 mi downstream from the western INEEL boundary is the INEEL diversion dam (fig. 2 and pl. 1), a low, earthen dam constructed in 1958 and enlarged in 1984 to reduce the threat of floods from the Big Lost River. Water is diverted southeastward at the dam through a diversion channel and is stored in a connected series of spreading areas (fig. 2). Two culverts with control valves regulate flow through the dam. The culverts are corrugated circular steel, 5.7 ft high and about 150 ft long. Immediately downstream is another pair of culverts under a discontinued railroad. These culverts are also corrugated circular steel, about 6 ft high and 75 ft long, with no control devices.

About 3 mi downstream from the diversion dam is a concrete weir (pl. 1) constructed to divert water to canals on both sides of the river. The weir and canals were constructed for agricultural interests before the inception of the INEEL in 1949 and, since then, have been abandoned. The canals have been filled in at their heads and in many other places and have been breached to prevent water from flowing in them. The canal west of the river is about 20 mi long, intersects the Test Reactor Area (TRA) facility, goes around the NRF, and ends at Playa 1. The canal east of the river is about 5 mi long, intersects the Firing Range area, and ends at the river near the ICPP. These canals generally parallel the river and have banks raised as much as 10 ft above the flood plain. Canal banks are high enough to act as levees and probably would confine flooding between them.

About 6 mi downstream from the diversion dam, Highway 26 crosses the river and its flood plain. A 55-ft-long, 40-ft-wide bridge, supported by concrete abutments, spans the river at an angle of about 45 degrees to the river. The streambed is about 8 ft below

the bottom of the bridge girders. The lowest elevation of Highway 26, about 1,200 ft to the southeast, is 5 ft lower than the bridge elevation.

Near the ICPP, Lincoln Boulevard crosses the Big Lost River and its flood plain. Three corrugated circular steel culverts, 7.5 ft high and about 150 ft long, pass water under Lincoln Boulevard. The upstream and downstream ends of the culverts are embedded in concrete headwalls. Culvert tops are 3.75 ft below the road surface. The channel from Lincoln Boulevard to the railroad bridge (about 1 mi downstream) has been straightened and deepened, and the river banks have been raised with excavated materials.

About 1 mi east of Lincoln Boulevard near the ICPP, a U.S. Government Railroad bridge (fig. 2 and pl. 1) crosses the Big Lost River at nearly a right angle. The bridge, 37 ft long and 10 ft wide, is supported by concrete abutments and a concrete pier in the middle of the channel. At the bridge, the streambed is about 7 ft below the bottom of the bridge girders. The highest elevation of the railroad in the flood plain is at the bridge. The railroad is raised several feet above the flood plain and probably would confine flooding to the right-hand (facing downstream) flood plain.

About 5 mi downstream from the railroad bridge where Lincoln Boulevard again crosses the Big Lost River near the NRF is the head of another canal that generally parallels the river to the east for about 10 mi. Canal banks are several feet higher than the flood plain and probably would confine flooding to the right-hand flood plain.

Where Lincoln Boulevard crosses the Big Lost River near the NRF, a bridge spans the river at nearly a right angle. The bridge, 45 ft long and 33 ft wide, is supported by concrete abutments. The streambed is about 5 ft below the bottom of the bridge girders.

Farther downstream, water flows freely between Playa 1 and Playa 2 through a natural opening. Three culverts that have control valves regulate flow through a dike from Playa 2 to Playa 3. The culverts are corrugated circular steel, 2.5 ft high and 43 ft long (Lamke, 1969, p. 24); culvert tops are about 4.5 ft below the top of the dike. About 1.5 mi downstream from Playa 2, Highway 33 (fig. 2) crosses the river. At this crossing, three culverts with control valves regulate flow under the highway. The culverts are corrugated circular steel, 2.5 ft high and 91 ft long (Lamke, 1969, p. 26); tops of the culverts are about 6 ft below

the highway. Water from Playa 3 flows freely over a dirt road embankment to Birch Creek Playa.

Previous Investigations

The first reported occurrence of streamflow reaching the playas was in 1894 (Nace and others, U.S. Geological Survey, written commun., 1959, p. 12). Streamflow has reached the playas several times since the 1890's because of flooding of the Big Lost River (Nace and others, U.S. Geological Survey, written commun., 1959, p. 12; Barraclough and others, 1967, p. 31). Barraclough and others (1967, p. 31) noted that streamflow in the Big Lost River reached Playa 1 twelve times since Mackay Dam was built in 1917 and reached Playas 2 and 3 three times. Lamke (1969) developed stage-discharge relations for the Big Lost River at the diversion channel. He estimated that the maximum capacity of the diversion channel was about 3,500 ft³/s and the maximum capacity of the culverts at the diversion dam was about 900 ft³/s. Bennett (1986) updated the stage-discharge relations at the diversion channel after the diversion was enlarged and the dam and dikes were raised in 1984 to provide additional flood control. He estimated that the maximum capacities of the diversion channel and swales were about 7,200 and 2,100 ft³/s, respectively; flows greater than these capacities would overtop the dam and fill the spreading areas.

Channel infiltration tests on the Big Lost River have been conducted by the USGS since 1951. Early seepage tests indicated that infiltration losses from the Big Lost River Sinks to Playa 2 were about 11 (ft³/s)/mi. Later tests (Bennett, 1990, p. 25, fig. 12) indicated that infiltration losses averaged about 1.5 (ft³/s)/mi from the western INEEL boundary to the diversion dam; 2.5 (ft³/s)/mi from the diversion dam to Highway 26; 5 (ft³/s)/mi from Highway 26 to Lincoln Boulevard near the ICPP; 1 (ft³/s)/mi from Lincoln Boulevard near the ICPP to Lincoln Boulevard near the NRF; 4 (ft³/s)/mi from Lincoln Boulevard near the NRF to the Big Lost River Sinks; and 18 (ft³/s)/mi in the Big Lost River Sinks.

Several analyses of flood magnitude and frequency on or near the INEEL have been done. Estimates of the 100-year peak flow at the Big Lost River near Arco gaging station (13132500, fig. 2) by flood-frequency analysis of gaged flow were 4,480 ft³/s

(U.S. Army Corps of Engineers, 1991, p. A-8), 3,700 ft³/s (Stone and others, 1993, p. 30), and 5,480 ft³/s (Kjelstrom and Berenbrock, 1996, p. 9). Differences in these estimates resulted from the use of data from different periods of record, omission of the 1965 peak flow by the U.S. Army Corps of Engineers (1991) and Stone and others (1993), and use of different skew coefficients. Kjelstrom and Berenbrock (1996, p. 9-12) used regional regression equations and flood-frequency analysis, and adjusted for channel infiltration losses to estimate the 100-year peak flow of 7,260 ft³/s at the Arco gaging station because flood-frequency analysis alone produced an unacceptably high level of uncertainty. Estimates made by flood-frequency analysis alone also are less reliable because of storage and diversion effects on peak flows upstream from the Arco gaging station.

Niccum (Aerojet Nuclear Company, written commun., 1973), Druffel and others (1979), Noble (1980), and Koslow and Van Haaften (1986) examined the hypothetical failure of Mackay Dam and the behavior of flood waves downstream. If Mackay Dam failed, Niccum estimated that peak flow at the ICPP would be about 30,000 ft³/s. He indicated that the present channel and old flood channels of the Big Lost River would convey about 20,000 ft³/s. Druffel and others (1979) estimated that peak flow resulting from dam failure would be about 54,000 ft³/s at the western INEEL boundary (about 45 mi downstream from Mackay Dam). Noble (1980) used a two-dimensional model, with cells 530 ft on a side, to simulate a peak flow in the area from the western INEEL boundary to the Radioactive Waste Management Complex (RWMC). He estimated that the depth of water at the RWMC resulting from the failure of Mackay Dam would be about 6 ft. Koslow and Van Haaften (1986) estimated that peak flow would be about 45,000 ft³/s at the southern INEEL boundary and 4,440 ft³/s at Birch Creek Playa near the TSF and CTF. Rathburn (1989, 1991) estimated that the depth of water at the RWMC, resulting from a paleoflood of 2 to 4 million ft³/s in the Big Lost River in Box Canyon and overflow areas, was 50 to 60 ft.

Acknowledgments

Appreciation is extended to Ken Beard, Lockheed Martin Idaho Technologies Company at the INEEL, who obtained horizontal and vertical control

data by use of a Global Positioning System (GPS) and converted the data for our use. Appreciation also is extended to Sabrina A. Nicholls, Susan E. Moore, and Douglas C. Werner, USGS, for their assistance in surveying cross sections.

DATA COLLECTION

The computer model used to compute water-surface elevations for the 100-year peak flow, described later in this report, required definition of channel and flood-plain cross-section geometry and roughness coefficients. Cross-section geometry was defined by a series of land-surface elevation data measured at variably spaced distances from a reference point along section lines perpendicular to the direction of flow. In October 1994 and April through August 1995, USGS personnel surveyed the Big Lost River from the western boundary of the INEEL to about the Big Lost River Sinks (pl. 1). The diversion channel at the INEEL diversion dam also was surveyed. Thirty-seven cross sections were surveyed: thirty-five of these sections were on the river and two were on the diversion channel (D1 and D2). Three bridges and three sets of culverts also were surveyed. Cross sections that were not surveyed across the entire flood plain were extended by adding data from the 2-ft topographic contours generated by Aerial Mapping, Inc. (Wayne Eskridge, Aerial Mapping, Inc., written commun., 1996). Each cross section was located to best represent the hydraulic characteristics of that part of the river. The diversion channel was surveyed to define its general shape. Surveying began with cross-section 4 (pl. 1) at the western boundary of the INEEL. Project constraints prevented surveys of cross-sections 1 through 3, upstream from the INEEL boundary in Box Canyon.

All cross-section data were based on a common datum. Horizontal control was based on North American Datum of 1927 (NAD 27), State Plane Coordinates, Idaho East Zone, in feet; vertical control was based on the National Geodetic Vertical Datum of 1929 (sea level), in feet. Horizontal and vertical controls for the surveys were obtained using differential GPS. A GPS receiver (base station) was located within several miles of a cross section on known, geographically referenced points. Horizontal and vertical controls were surveyed at a minimum of three sites, where the electronic total-station instrument was set up, at

each cross section using a second GPS receiver. Also, other known geographic reference points in the vicinity of each cross section were surveyed to ensure accuracy to one-hundredth of a foot in horizontal and vertical directions. Each cross section was surveyed in a local coordinate system using conventional surveying techniques. Cross-section data were transformed from the local coordinate system to a common, geographically referenced map unit using the GPS control data and a geographic information system.

Channel roughness coefficients (Manning's n) were assigned for each cross section at the time of survey and were based on best engineering judgment. The roughness coefficient represents the resistance to open-channel flow. Factors that affect the roughness coefficient include (1) the type and size of materials that compose the streambed and banks, (2) shape of the channel, (3) variation in dimensions of adjacent cross sections, (4) riparian and aquatic vegetation, (5) structures, and (6) degree of meandering. Roughness values used in the hydraulic analysis ranged from 0.035 to 0.051 for the main channel, 0.040 to 0.058 for braided channels, and 0.048 to 0.068 for the flood plain.

METHODS OF ANALYSIS

Flood-frequency analysis in 1994 resulted in a computed 100-year peak flow of 5,480 ft³/s at the Arco gaging station (Kjelstrom and Berenbrock, 1996, p. 9). Results from the flood-frequency analysis for this gaging station were considered to show an unacceptably high level of uncertainty because of a wide range in confidence limits. This estimate also was considered unreliable because natural peak flows have been altered significantly as a result of upstream storage and diversions. Therefore, Kjelstrom and Berenbrock (1996) used regional regression equations and flood-frequency analysis, and adjusted for channel infiltration losses to estimate the 100-year peak flow at the Arco gaging station. The 100-year peak flow has a 1-percent chance of being equaled or exceeded in any given year. Although the recurrence interval represents the long-term average period between flows of a specific magnitude, rare high flows could occur at shorter intervals or even within the same year.

A computer model was used to compute water-surface elevations for the hypothetical 100-year peak flow in the Big Lost River and the diversion channel.

The model incorporated horizontal and vertical data collected along channel cross sections perpendicular to the direction of flow.

Hydrologic Analysis

Kjelstrom and Berenbrock (1996, p. 9) estimated that the 100-year peak flow of Big Lost River at the western boundary of the INEEL was about 7,260 ft³/s. They indicated that channel infiltration losses between Arco and the INEEL boundary were balanced by local runoff from precipitation; thus, peak flow at the INEEL boundary can be considered the same as that at Arco. Niccum (Aerojet Nuclear Company, written commun., 1973) reported no loss of flow resulting from infiltration during the early part of the 1965 flood of the Big Lost River. At that time, infiltration was blocked by frozen ground and (or) ice. Niccum also indicated that similar conditions greatly reduced channel infiltration along the Big Lost River during the floods of 1962 and 1969. Therefore, infiltration losses at peak flow were assumed negligible.

Hydraulic Analysis

Water-surface elevations of the Big Lost River and the diversion channel were computed for the 100-year peak flow using the step-backwater computation model Water-Surface PROfile (WSPRO), developed by the USGS for the Federal Highway Administration (Shearman and others, 1986; Shearman, 1990). WSPRO is a computer program used to analyze one-dimensional, gradually varied, steady flow in open channels with fixed boundaries. The model uses the standard step method (Chow, 1959, p. 265) to determine changes in water-surface elevation from a downstream cross section to an upstream cross section by balancing the total energy at the sections.

One-dimensional models assume that energy is uniform in a cross section. This assumption is not accurate in locations where flow is not parallel to the main channel or where vertical velocities are significant. Additional inaccuracies in model results also can occur because of the number and locations of the cross sections used to depict the channel geometry. The number of cross sections used limits the variation in water-surface elevation that can be computed and affects the influence of variations in channel shape on

the flow. Model results will not include all the effects of variations in channel shape on the flow if significant changes in channel geometry along the reach are not appropriately depicted.

The surveyed cross sections and assigned roughness coefficients (Manning's n) defined channel and flood-plain hydraulic characteristics used in the model. To calculate water-surface elevations, starting water-surface elevations at the downstream end of the modeled reach and at locations of large changes in channel slope were determined from a slope-conveyance computation of normal depth. Engineering judgment was used to adjust the starting water-surface elevations and roughness coefficients from field estimates because no high-flow data were available to calibrate the model. At selected cross sections, however, the model was calibrated against flows in the main channel measured in the spring and summer of 1995. Immediately upstream from the INEEL diversion dam, flows were about 400 ft³/s; immediately downstream, flows were about 200 ft³/s. The water-surface elevations at these cross sections were surveyed and flow was estimated from the nearest streamflow-gaging station. The diversion channel also was calibrated against flows measured in the spring and summer of 1995 and against the stage-discharge rating at the INEEL diversion channel gaging station (13132513).

A culvert analysis program (Fulford, 1995) was used to compute flow through culverts at the INEEL diversion dam, under the railroad, and under Lincoln Boulevard near the ICPP. The program computes flow from upstream and downstream water-surface elevations, culvert geometry, and roughness coefficients. The culverts were assumed to be free of debris.

COMPUTATION OF PRELIMINARY WATER-SURFACE ELEVATIONS

Preliminary water-surface elevations for the 100-year peak flow were computed with WSPRO. A peak flow of 7,260 ft³/s was simulated at the western boundary of the INEEL and routed downstream. This peak flow was routed downstream as if the INEEL diversion dam did not exist. On the basis of a structural analysis of the INEEL diversion dam (U.S. Army Corps of Engineers, written commun., 1997), the dam was assumed incapable of retaining high flows. The Corps indicated that the diversion dam could fail if

flows were to exceed 6,000 ft³/s. Possible failure mechanisms are: (1) erosion of the upstream face of the dam that results from high-flow velocities and loss of slope protections (rip-rap), (2) overtopping of the diversion dam by flows exceeding the capacity of the diversion channel and culverts, (3) piping and breaching of the diversion dam because of seepage around the culverts, and (4) instability of the dam and its foundation because of seepage (U.S. Army Corps of Engineers, written commun., 1997). Thus, for the purpose of this report, the 100-year peak flow was routed downstream as if the diversion dam did not exist and was used to calculate the water-surface elevations at respective cross sections. However, the diversion channel does affect flow downstream from the dam. Channel and flood-plain infiltration losses in the study area were assumed to be balanced by precipitation and runoff from nearby drainages or blocked by frozen ground. Therefore, infiltration losses were considered zero. River channel and canal banks were assumed to remain stable during the peak flow.

Cross-Sections 4 Through 10a

A peak flow of 7,260 ft³/s was simulated at cross-sections 4 through 10a (pl. 1) from the western boundary of the INEEL to the diversion dam. Resulting water-surface elevations for cross-sections 4 and 8 are shown on plate 1. The computed water surface was narrowest (about 120 ft) near cross-section 4, where the river is entrenched in a single channel. The water surface was widest (about 1,600 ft) at cross-section 8, where the entrenched channel is narrow and water would overflow onto the flood plain. The graph at lower right on plate 1 shows a profile of the water-surface elevations for all cross sections along the river. The water surface sloped about 8 ft/mi between the western boundary of the INEEL and the diversion dam.

Diversion Dam Area

Peak flow in the model is not affected by the INEEL diversion dam. However, flow is affected by the diversion channel. Model results indicated that about 6,220 ft³/s of the peak flow was contained in the Big Lost River downstream from the dam, and the remaining 1,040 ft³/s flowed in the diversion channel.

Water-surface elevations upstream from the diversion dam would be significantly different if the dam were capable of retaining high flows during flooding. Without the dam, water-surface elevations at cross-sections 9 and 10a resulting from the 100-year peak flow were 5,065.0 and 5,058.9 ft, respectively. With the dam in place, the calculated water-surface elevation was about 2 ft higher at section 9 and 6 ft higher at section 10a. Water-surface elevation at cross-section 8 was 0.2 ft higher with the dam than without it. The calculated water-surface elevation at cross-section 7 was the same with or without the dam. At a flow of 1,040 ft³/s in the diversion channel, the calculated water-surface elevation at cross-section D2 (pl. 1) was 5,053.7 ft. Simulation with the dam in place indicated that the maximum flow capacity of the culverts in the dam and railroad totaled 825 ft³/s, about 75 ft³/s less than Carrigan's (1972) estimate. Downstream from the diversion dam, flow was less than 900 ft³/s and no flooding occurred.

Cross-Sections 10b Through 37

A flow of 6,220 ft³/s was simulated from cross-sections 10b through 37, the volume that would flow downstream if the diversion dam did not exist. Water-surface elevations for selected cross sections along this reach are shown on plate 1. Where Highway 26 crosses the river, no water flowed over the bridge, though the simulated water-surface elevation of 4,975.4 ft was higher than the bottom of the bridge girders. Simulations indicated that about 2,920 ft³/s (47 percent) flowed under the bridge; the remaining 3,300 ft³/s (53 percent), flowed onto the right-hand (facing downstream) flood plain and over the highway about 1,200 ft to the southeast. In that area, the highway is 5 ft lower than at the bridge. The water surface sloped about 13 ft/mi between the diversion dam and Highway 26 (pl. 1). The greatest change in water-surface elevation was between cross-sections 12 and 13, where there was a 13-ft decrease and a large change in channel slope.

Three culverts allow water to pass under Lincoln Boulevard near the ICPP. Calculated water-surface elevation at the culverts was 4,923.0 ft, about 0.4 ft higher than the road. However, the lowest road elevation is at the intersection of Monroe Boulevard (pl. 1) and Lincoln Boulevard, where the road is 2.3 ft lower than the simulated water-surface elevation.

Therefore, the greatest quantity of water flowed over-land to this area located on the left-hand flood plain. Simulation indicated that about 1,500 ft³/s flowed through the combined culverts under Lincoln Boulevard (24 percent of the total). The remaining 4,720 ft³/s (76 percent) flowed over the road. If the culverts and road were removed, water-surface elevation at cross-section 20 and Lincoln Boulevard would be about 2 ft lower. The simulated water surface was about 1 mi wide at cross-section 19 (pl. 1). The water surface sloped about 12 ft/mi between Highway 26 and Lincoln Boulevard, near the ICPP (pl. 1).

About 1 mi east of Lincoln Boulevard, a U.S. Government Railroad crosses the river. A bridge allows water to move under the railroad. No water flowed over the bridge, though the simulated water-surface elevation of 4,905.6 ft was higher than the bottom of the bridge girders. The railroad slopes downward from the bridge in the flood plain; the water surface averaged 0.5 ft higher than the railroad bed. Simulation indicated that about 2,500 ft³/s (40 percent) flowed under the bridge and the remaining 3,720 ft³/s (60 percent) flowed over the railroad bed. If the bridge and railroad were removed, water-surface elevation at the railroad and cross-section 23 would be about 2 ft lower; removal did not affect the simulated water-surface elevation at cross-section 22. Flood-plain width at cross-section 21 was about 3,500 ft and, at cross-section 23, about 1.2 mi (pl. 1). The simulated water surface at cross-section 21 was 4,918.1 ft. Water surface sloped about 16 ft/mi between Lincoln Boulevard and the railroad.

Lincoln Boulevard again crosses the Big Lost River near the NRF. A bridge at this site allows water to pass under the road. Simulation indicated that the bridge was overtopped by about 1 ft of water at a water-surface elevation of 4,839.0 ft. If the bridge and road were removed, the water-surface elevation at the road and cross-section 30 would be about 2 ft lower. Water-surface elevation at cross-section 29b (about 0.5 mi upstream) was not affected by the road or bridge. Simulation indicated that about 1,850 ft³/s (30 percent) flowed under the bridge, and the remaining 4,370 ft³/s (70 percent) flowed over the bridge and road. The simulated water surface at cross-sections 21 through 27 and 30 exceeded 0.5 mi in width. The water surface sloped about 10 ft/mi between the railroad and Lincoln Boulevard near the NRF.

The segment of river modeled ended upstream from the Big Lost River Sinks because the river in that

area is highly braided and no main channel is discernible. Therefore, WSPRO modeling is inappropriate in that area. The calculated water-surface elevation at cross-section 37 (pl. 1) was 4,806.6 ft. At cross-sections 32 and 33, simulated flow on the left-hand flood plain was about 3,400 ft³/s (55 percent) and, on the right-hand flood plain, was 2,820 ft³/s (45 percent). The water surface sloped about 6 ft/mi between Lincoln Boulevard near the NRF and cross-section 37 (pl. 1). Between cross-sections 36 and 37, the water surface sloped 2.7 ft/mi.

Because the river could not be modeled downstream from cross-section 37 to the playas, water-surface elevations were estimated at the playas by using the slope from the previous reach. If the water-surface slope between cross-sections 36 and 37 was representative of water-surface slope in the Big Lost River Sinks and playas, the water-surface elevation in Playas 1 and 2 would be about 4,790 ft. The water-surface elevation in Playa 3 would be about 4,786 ft and, in Birch Creek Playa, would be about 4,780 ft. At an elevation of 4,780 ft, water in Birch Creek Playa would have a surface area of about 1,030 acres and a volume of about 1,160 acre-ft (Berenbrock and Kjelstrom, 1997, fig. 3). The TSF and CTF facilities in and around Birch Creek Playa would not be flooded by the 100-year peak flow because dikes surrounding these facilities are at an elevation of about 4,786.4 ft (Berenbrock and Kjelstrom, 1997, p. 22), about 6.5 ft higher than the estimated water surface.

PRELIMINARY BOUNDARY OF THE 100-YEAR PEAK FLOW

Water-surface elevations computed at each cross section were used to delineate the preliminary boundary of the 100-year peak flow of 7,260 ft³/s along the Big Lost River. Between cross sections, where survey data were unavailable, the peak flow boundary was interpolated from topographic maps with a 2-ft contour interval, provided by Aerial Mapping, Inc. (Wayne Eskridge, Aerial Mapping, Inc., written commun., 1996). The 100-year peak flow boundary is shown on plate 1. Small areas within the flood plain that would be above the simulated water surface also are shown on plate 1.

The total area of flooding from cross-sections 4 through 37 that might be expected from the 100-year

peak flow is about 12 mi². Although part of Highway 26, Lincoln Boulevard, and the U.S. Government Railroad would be flooded, the only INEEL facility that would be flooded is the northern part of the ICPP and its entrance road (pl. 1). The experimental dairy farm, near cross-section 25, also would be flooded. The flooded area is as narrow as 120 ft at cross-section 4 and as wide as 1.2 mi at cross-section 23 (pl. 1).

LIMITATIONS OF THE MODEL

Discretion is needed in the use of these model results. The computer model, WSPRO, incorporates many simplifying assumptions about the riverine system. Most important are the assumptions of one-dimensional flow, gradually varied flow, steady flow, and fixed boundaries. These simplifications might allow the model to calculate water-surface elevations with a peak flow greater than or less than would be experienced under actual conditions in the study area. WSPRO has been somewhat successful in calculating water-surface elevations in the Big Lost River and flood plain, even though it fails to account for (1) flows in more than one direction, (2) uneven water-surface elevation in a cross section, (3) infiltration losses in the channels and flood plain, (4) back-water conditions, and (5) other aspects of actual flooding processes in the Big Lost River.

The number of cross sections used to depict the channel geometry also simplified the riverine system. The use of a much larger number of cross sections could have improved model results but would have required considerable additional effort to include in the model. Considerable uncertainty is associated with how flow-paths are distributed laterally during a flood. This uncertainty cannot be addressed by a one-dimensional model like WSPRO. Because of these uncertainties, the number of cross sections was considered sufficient to provide reasonable results that can be used to guide the application of more stringent flow models. Application of more stringent models (two dimensional) that would simulate the flood hazard more precisely is needed to refine and delineate the extent of possible flooding of the Big Lost River at the INEEL.

SUMMARY

The Big Lost River flows southward about 50 mi through an alluvium-filled valley to the eastern Snake River Plain. The study area is a 35-mi reach that starts at the western boundary of the INEEL and ends in a series of playas. The river on the INEEL is an ephemeral stream and is typically incised less than 20 ft on the INEEL. Downstream from Highway 26, the flood plain broadens and is characterized by braided channels and remnants of old meander channels. Streambed materials are largely coarse sand with some gravel and cobbles. Alluvial fill overlies basalt over most of the streambed, but in several places, the basalt crops out. The playas are underlain by silt and clay.

Anthropogenic features in the study area affect flood hydraulics of the Big Lost River. A low, earthen dam (INEEL diversion dam), about 6 mi downstream from the western boundary of the INEEL, is part of a flood-control diversion system to reduce the threat of flooding of INEEL facilities from the Big Lost River. Water passes through culverts in the dam. State Highway 26, Lincoln Boulevard, and a railroad cross the Big Lost River and its flood plain and affect natural river flow. At these sites, water flows under bridges or through culverts and, during high flow, over the roads and railroad.

Thirty-five river and two diversion channel sections were surveyed, as were three bridges and three sets of culverts. These cross sections were surveyed to provide data for a hydraulic model (WSPRO), which was used to compute preliminary water-surface elevations resulting from a 100-year peak flow in the Big Lost River. The modeled reach ended at the start of the Big Lost River Sinks. The river and flood plain were not modeled downstream from cross-section 37 because the river channel becomes highly braided and a main channel was not discernible.

A 100-year peak flow of 7,260 ft³/s was simulated at cross-sections 4 through 10a, upstream from the INEEL diversion dam. On the basis of a structural analysis by the U.S. Army Corps of Engineers, the diversion dam was assumed incapable of retaining flows in excess of 6,000 ft³/s, so the dam was not included in model simulation. Simulation indicated that about 6,220 ft³/s would flow in the river channel downstream from the dam if the dam did not exist, and the remaining 1,040 ft³/s would flow in the diversion channel. Computed water-surface elevations without

the diversion dam at cross-sections 9 and 10a were 5,065.0 ft and 5,058.9 ft; with the dam, the water-surface elevations increased 2 and 6 ft, respectively.

A flow of 6,220 ft³/s without the dam was simulated at cross-sections 10b through 37. The Highway 26 bridge was not overtopped; however, flow was higher than the bottom of the bridge girders. About 2,920 ft³/s (47 percent) flowed under the bridge, and the remaining 3,300 ft³/s (53 percent) flowed over the highway about 1,200 ft to the southeast.

Where Lincoln Boulevard crosses the Big Lost River near the ICPP, three culverts allow water to pass under the road. Total flow through the culverts was 1,500 ft³/s (24 percent); the remaining 4,720 ft³/s (76 percent) flowed over the road. Depth of water over Lincoln Boulevard was 0.4 to 2.3 ft near its intersection with Monroe Boulevard. If the culverts and road were removed, the water-surface elevation at Lincoln Boulevard would be about 2 ft lower.

A railroad crosses the river about 1 mi east of Lincoln Boulevard near the ICPP. The simulated water-surface elevation at this crossing was 4,905.6 ft, averaging 0.5 ft higher than the railroad. Simulation indicated that 2,500 ft³/s (40 percent) flowed under the bridge and 3,720 ft³/s (60 percent) flowed over the railroad. If the bridge and railroad were removed, the water-surface elevation at the crossing would be about 2 ft lower. Removal had no effect on the simulated water-surface elevation at cross-section 22, 1 mi upstream and near the ICPP.

Lincoln Boulevard again crosses the river near the NRF. The simulated water-surface elevation at the bridge was 4,839.0 ft, and the bridge and road were overtopped by about 1 ft of water. Simulation indicated that 1,850 ft³/s (30 percent) flowed under the bridge, and the remaining 4,370 ft³/s (70 percent) flowed over the bridge and road. If the bridge and road were removed, the water-surface elevation would be about 2 ft lower at this site.

The preliminary 100-year peak flow boundary was delineated using calculated water-surface elevations at each cross section and interpolating between cross sections by using a topographic map with 2-ft contour intervals. The flooded areas were as narrow as 120 ft, at cross-section 4, and as wide as 1.2 mi, at cross-section 23. Highway 26, Lincoln Boulevard, and the railroad crossing the river and flood plain would be flooded. The ICPP, adjacent to the river, would be the only major facility flooded; only the northern part of the ICPP and its entrance would be flooded. The

experimental dairy farm near cross-section 25 also would be flooded.

The model has been somewhat successful in calculating water-surface elevations in the Big Lost River and flood plain. However, discretion is needed in the use of these model results. The results are primarily intended to provide guidance in the construction of a more stringent flow model. Model results are limited by the number of cross sections used and, most significantly, by the type of model used. The number of cross sections used was considered sufficient to provide a reasonable result because of the limitations of one-dimensional models. The simplification in one-dimensional models does not incorporate many of the aspects of the actual flooding process. More stringent models (two dimensional) would better refine and delineate the extent of possible flooding of the Big Lost River at the INEEL.

REFERENCES CITED

- Barracough, J.T., Teasdale, W.E., and Jensen, R.G., 1967, Hydrology of the National Reactor Testing Station, Idaho, 1965: U.S. Geological Survey Open-File Report, 107 p.
- Bennett, C.M., 1986, Capacity of the diversion channel below the flood-control dam on the Big Lost River at the Idaho National Engineering Laboratory, Idaho: U.S. Geological Survey Water-Resources Investigations Report 86-4204, 25 p.
- , 1990, Streamflow losses and ground-water level changes along the Big Lost River at the Idaho National Engineering Laboratory, Idaho: U.S. Geological Survey Water-Resources Investigations Report 90-4067, 49 p.
- Berenbrock, Charles, and Kjelstrom, L.C., 1997, Simulation of water-surface elevations for a hypothetical 100-year peak flow in Birch Creek at the Idaho National Engineering and Environmental Laboratory, Idaho: U.S. Geological Survey Water-Resources Investigations Report 97-4083, 20 p.
- Carrigan, P.H., Jr., 1972, Probability of exceeding capacity of the flood-control system at the National Reactor Testing Station, Idaho: U.S. Geological Survey Open-File Report IDO-22052, 102 p.
- Chow, V.T., 1959, Open-channel hydraulics: New York, McGraw-Hill, 680 p.
- Druffel, Leroy, Stiltner, G.J., and Keefer, T.N., 1979, Probable hydrologic effects of a hypothetical failure of Mackay Dam on the Big Lost River Valley from Mackay, Idaho, to the Idaho National Engineering Laboratory: U.S. Geological Survey Water-Resources Investigations Report 79-99, 47 p.

- Fulford, J.M., 1995, User's guide to the culvert analysis program: U.S. Geological Survey Open-File Report 95-137, 69 p.
- Kjelstrom, L.C., and Berenbrock, Charles, 1996, Estimated 100-year peak flows and flow volumes in the Big Lost River and Birch Creek at the Idaho National Engineering Laboratory, Idaho: U.S. Geological Survey Water-Resources Investigations Report 96-4163, 23 p.
- Koslow, K.N., and Van Haaften, D.H., 1986, Flood routing analysis for a failure of Mackay Dam: Idaho Falls, Idaho, EG&G Idaho, Inc., EGG-EP-7184, 33 p.
- Lamke, R.D., 1969, Stage-discharge relations on Big Lost River within National Reactor Testing Station, Idaho: U.S. Geological Survey Open-File Report IDO-22050, 29 p.
- Noble, C., 1980, A two-dimensional analysis of flooding of the Big Lost River below Box Canyon outlet: Idaho Falls, Idaho, EG&G Idaho, Inc., EGG-EI-80-2, [26 p.]
- Rathburn, S.L., 1989, Pleistocene glacial outburst flooding along the Big Lost River, east-central Idaho: Tucson, Ariz., University of Arizona, M.S. thesis, 41 p.
- , 1991, Quaternary channel changes and paleoflooding along the Big Lost River, Idaho National Engineering Laboratory: Laramie, Wyo., TriHydro Corporation, prepared for EG&G Idaho, Inc., EGG-WM-9909, 33 p.
- Shearman, J.O., 1990, User's manual for WSPRO—a computer model for water surface profile computations: U.S. Department of Transportation, 177 p. [available from the National Technical Information Service, U.S. Department of Commerce, Springfield, Va., 22161 as Report No. FHWA-IP-89-027].
- Shearman, J.O., Kirby, W.H., Schneider, V.R., and Flippo, H.N., 1986, Bridge waterways analysis model—research report: U.S. Department of Transportation, 112 p. [available from the National Technical Information Service, U.S. Department of Commerce, Springfield, Va., 22161 as Report No. FHWA/RD-86/108].
- Stone, M.A.J., Mann, L.J., and Kjelstrom, L.C., 1993, Statistical summaries of streamflow data for selected gaging stations on and near the Idaho National Engineering Laboratory, Idaho, through September 1990: U.S. Geological Survey Water-Resources Investigations Report 92-4196, 35 p.
- U.S. Army Corps of Engineers, 1991, Feasibility report, Big Lost River Basin, Idaho: Walla Walla, Wash., U.S. Army Corps of Engineers, 250 p.

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