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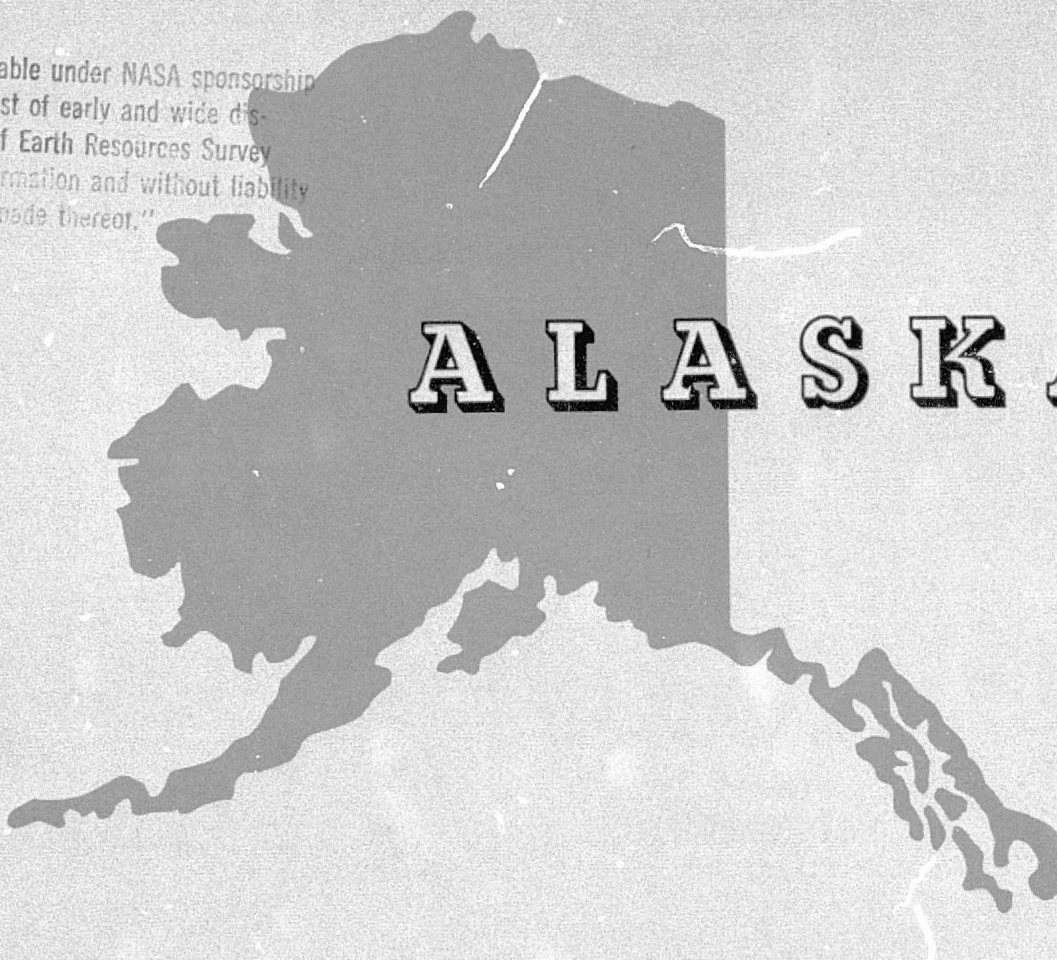
IDENTIFICATION OF FLOOD HAZARD RESULTING FROM AUFEIS FORMATION IN AN INTERIOR ALASKAN STREAM



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U.S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

IDENTIFICATION OF FLOOD HAZARD RESULTING FROM AUFEIS FORMATION IN AN INTERIOR ALASKAN STREAM

An Information and Evaluation Report prepared for the Soil Conservation Service as part of a feasibility study to evaluate the utility of LANDSAT imagery for flood hazard analysis and consequent land-use decisions.

Original photography may be purchased from:
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ORIGINAL CONTAINS
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ABSTRACT

LANDSAT band 5 and 7 data have been combined to produce a multi-spectral product which allows identification and mapping of areas flooded during April 1974 as a result of aufeis formation in Jarvis Creek near Delta Junction, Alaska. The resulting map has been produced at a scale of one inch to the mile to serve as flood documentation for a multi-agency cooperative effort to develop a land use plan for the Big Delta area. The planning requirements imposed by aufeis formation and subsequent flooding are discussed briefly.

I. Introduction

During the Spring of 1974 the Geophysical Institute and the Soil Conservation Service entered into a joint program to investigate the utility of LANDSAT data for identification of potential flood-hazard areas in Alaska. The location chosen for this study was the Big Delta Planning Area, a region approximately 120 by 40 miles centered at Delta Junction, Alaska, one hundred miles southeast of Fairbanks (see Figure 1). LANDSAT imagery and digital tapes have been used to provide landform and vegetational information related to flood hazard analysis as well as historical flood data for the study area. In Alaska, flooding occurs as a result of all causes known to be responsible for floods in temperate regions and, in addition, as a result of conditions unique to arctic and subarctic regions. One of these conditions is the creation of "aufeis" (stream glaciering) during winter months which often results in channel blockage and subsequent diversion of stream waters. This report details the use of LANDSAT data to document one such event of flooding and its implications to land use planning.

II. LANDSAT Data

Detailed descriptions of LANDSAT data can be found in many places. Here we will briefly describe only those aspects and characteristics of the satellite data which have a direct bearing on this paper.

The chief function of LANDSAT is to acquire photograph-like imagery of the earth which can be used for earth-resource or land-use analysis. The imagery is acquired by means of photo-electronic sensors, each of which measures the light reflected by the earth in a narrow wavelength band. Each sensor scans the earth in a systematic manner to generate an image. Light areas on the image represent earth surface features reflecting large quantities of energy in the wavelength being measured. The wavelength bands measured by LANDSAT include green, red and two near-infrared wavelength bands. Although the term "infrared" is often associated with heat, the infrared region actually spans the electromagnetic spectrum all the way from red light to microwave wavelengths. The two infrared bands monitored by LANDSAT lie just beyond the visible red wavelengths in the electromagnetic spectrum and are not in any way used as an indication of heat. However, chlorophyll strongly reflects these two wavelengths, with the result that healthy plants reflect these wavelengths well. Water, on the other hand, strongly absorbs radiation in the infrared bands.

The most common data products available from LANDSAT are the now-familiar black-and-white photograph-like images produced by the individual LANDSAT sensors. Each product is commonly referred to by the wavelength band monitored; thus, a "band 5 image" refers to the image produced by the sensor monitoring red light reflected from the earth, while a "band 7 image" refers to an image representing reflected energy in the more red of the two infrared wavelength bands monitored.

Each wavelength band monitored was chosen for its utility for different aspects of resource and land use analysis: band 5, for instance, monitors cultural features while band 4 (green) monitors suspended sediments.

The satellite travels around the earth approximately every 90 minutes on a polar orbit. The relationship between the orbit and field of view (about 100 miles) is such that at the equator the satellite images adjacent locations on successive days providing an overlap of about ten percent. A given "scene" is repeated every eighteen days. At central Alaskan latitudes, because of convergence of the polar orbit paths and the resulting greater image overlap, a given location may be imaged three days in succession. At this time there are two LANDSATs in operation with their orbits arranged so that it is technically possible to image a given location in Alaska three of every nine days.

III. Aufeis

Ice-forming situations occur all winter in the arctic and subarctic wherever there are continuous sources of water and freezing temperatures exist.[1] An obvious example of this situation is that of a stream fed by an active, year-round spring: The spring water will be subjected to freezing temperatures and under most conditions will freeze somewhere along the stream. When new ice continues to form on top of older ice, this condition is described by the German term, aufeis (literally "upon ice"). Aufeis can build up to fill normal stream channels and cause the stream to flow onto the nearby flood plain. If this happens during winter months, the flooding waters freeze nearby. If, however, the flooding occurs during spring it often does not freeze but rather behaves in a normal flood fashion subject to diversion resulting from the aufeis formations which may have built up during the winter.

IV. Detection of Flooding as a Result of Aufeis in the Vicinity of Delta Junction, Alaska

As part of the search for historical flood data in the Big Delta area, all existing LANDSAT images available for that area were examined. Images acquired on April 25 and 26, 1974, showed a large dark area (particularly on the infrared band images) several miles in length lying to the east of Delta Junction. This condition was interpreted as flooding because of the very strong indicated absorption of band 6 and 7 infrared radiation.

As part of the joint program of flood hazard analysis, a flood history report of the Delta area was compiled[3] based on existing records and interviews of persons living in the area. This report made note of a yearly flooding situation which was recognized as describing what had been identified on the LANDSAT images:

> Jarvis Creek, also a tributary of the Delta River, has created problems in the populated Delta Junction area for a number of years. During break-up it jumps its channel as a result of ice blockage, and several times has flowed in an alternate route to the Delta River, running through a subdivision and past the airport. In the last ten years, however, a U. S. Army-built block of this alternate channel has prevented flooding in the airport area. Since the Jarvis continues to jump its banks yearly, it was forced to find another channel, and now flows for approximately two weeks each spring along the west side of a (north-south) ridge which terminates just north of Jack Warren Road. Several hundred feet beyond this the stream sinks into porous ground, and is lost in a bog which stretches north to the Tanana River. Although this only happens once a year, the flow of water is great enough that two large culverts are needed, and are frequently inadequate, to channel it under Jack Warren Road.

Often flooding resulting from aufeis remains localized because freezing temperatures cause freezing of the flooding waters in the immediate vicinity of the location of the stream diversion. In this particular case, during the period in question the daily temperatures ranged from near freezing at night to 50°F during the day.[2] Hence, the flood waters were free to flow with little restriction.

Although this springtime flooding condition had long been recognized in the Delta area, the source and extent of the flooding was not mapped prior to the analysis of the Spring 1974 LANDSAT imagery. Similar flooding was noted exactly one year later when at least one local resident found it necessary to take action to divert similar flood waters. Unfortunately, because of cloudy conditions at the time, LANDSAT data is not available to document the flooding that year.

V. Data Enhancement Techniques

Although the flooded areas could be partially identified on LANDSAT band 7 images, the identification was somewhat ambiguous. In order to produce a data product of more utility, a multi-spectral approach was taken. After considerable experimentation, it was found that clearest distinction between features of interest could be obtained using imagery from two of the LANDSAT sensors. The technique used combined data from these two sensors by simultaneously projecting data from the two wavelength bands through colored filters onto a screen.* Band 5 (positive transparency) was projected as green, band 7 (positive transparency) as red and band 7 (negative transparency) as white. The resulting colors of surface objects had no relationship to their true colors, however, the flooded area could be distinguished as light green while bare river beds were brown and ice (including aufeis) red. This combination of projected images was photographed and enlarged to one-inch-to-the-mile scale, and is reproduced here at approximately half that scale.

Figure 2 shows the multispectral data product used to map aufeis and flooding in the Big Delta area. For aid in identifying locations, several cultural features have been transferred to this product from

*A commercial optical device was used for this process. The instrument used is called a "color-additive viewer" and is manufactured by I^{2}S Corp.

standard maps. Aufeis can be identified on both Jarvis Creek and the Delta River as red while the snow-free bare river beds below these ice formations appear brown. Several ice-covered lakes and ice pans on the Tanana River also appear red.

Water and forests appear various shades of green. The flooding waters have been delineated on this product and it can be seen that the distinction between these two features was clean everywhere except for one location. Here, topographic and vegetational data was used to distinguish between the flood waters and adjacent forest. Only areas that could clearly be identified as flooded were delineated. The problem of linking these areas with flowing floodwaters is addressed below.

VI. Field Reconnaissance

On April 23, 1976, approximately two years after the flooding event which is mapped here, a reconnaissance of the Jarvis Creek area was made by light aircraft. The repetitive nature of Jarvis Creek flooding resulting from aufeis obstruction was borne out by discovery of the aufeis formation and resulting flooding at the same location observed on the LANDSAT imagery.

Figure 3 shows the lower (north) end of the aufeis formation on Jarvis Creek. The actual stream diversion (toward the left) takes place at the location seen approximately in the center of the photograph. Figure 4 shows the bank-full ice conditions at the point of overflow.

At the time of this reconnaissance, the flooding could be followed from the point of diversion to and beyond the Alaska Highway. Generally, the flood waters follow tree-lined stream channels between these two points, spreading out occasionally to fill low areas. Thus it is possible for the flood waters to be confined within the narrow stream channels for portions of their path, escaping detection by LANDSAT because the width of these channels is too small to be detected by the sensors on the satellite. This explains why the flood cannot be followed continuously on Figure 2 from the point of diversion to the highway.

VII. Discussion

This type of ice formation and flooding is common to Arctic and sub-Arctic climates and is a major source of springtime highway maintenance problems in these climatological areas. Flooding resulting from aufeis formations is often the cause of washouts on secondary roads during spring in Alaska. Aufeis-related flooding can be quite dangerous to structures and equipment because it often occurs when temperatures are below freezing or can change to below freezing. To date, despite extensive research, the only truly effective remedy to problems due to aufeis is to avoid placing structures and roads in aufeis or aufeis-flood prone areas. Aufeis formation and related flooding should be a major consideration in the design of any construction project.[4] For these reasons, location of aufeis formation should be a major consideration for land-use planning decisions in Alaska. A typical product for this purpose is shown in Figure 5 where the known flood and aufeis data from Figure 2 has been transcribed onto a standard USGS inch-to-the-mile map. Because only one flooding event of unknown relative magnitude was observed and since it is known that repeated floodings have taken place, statistical hydrologic considerations should be used to project flood hazard onto adjacent potentially flooded lands.

The availability of several year's LANDSAT data should make possible this type of flood hazard analysis for the many areas of Alaska where human activity is anticipated.

Acknowledgments

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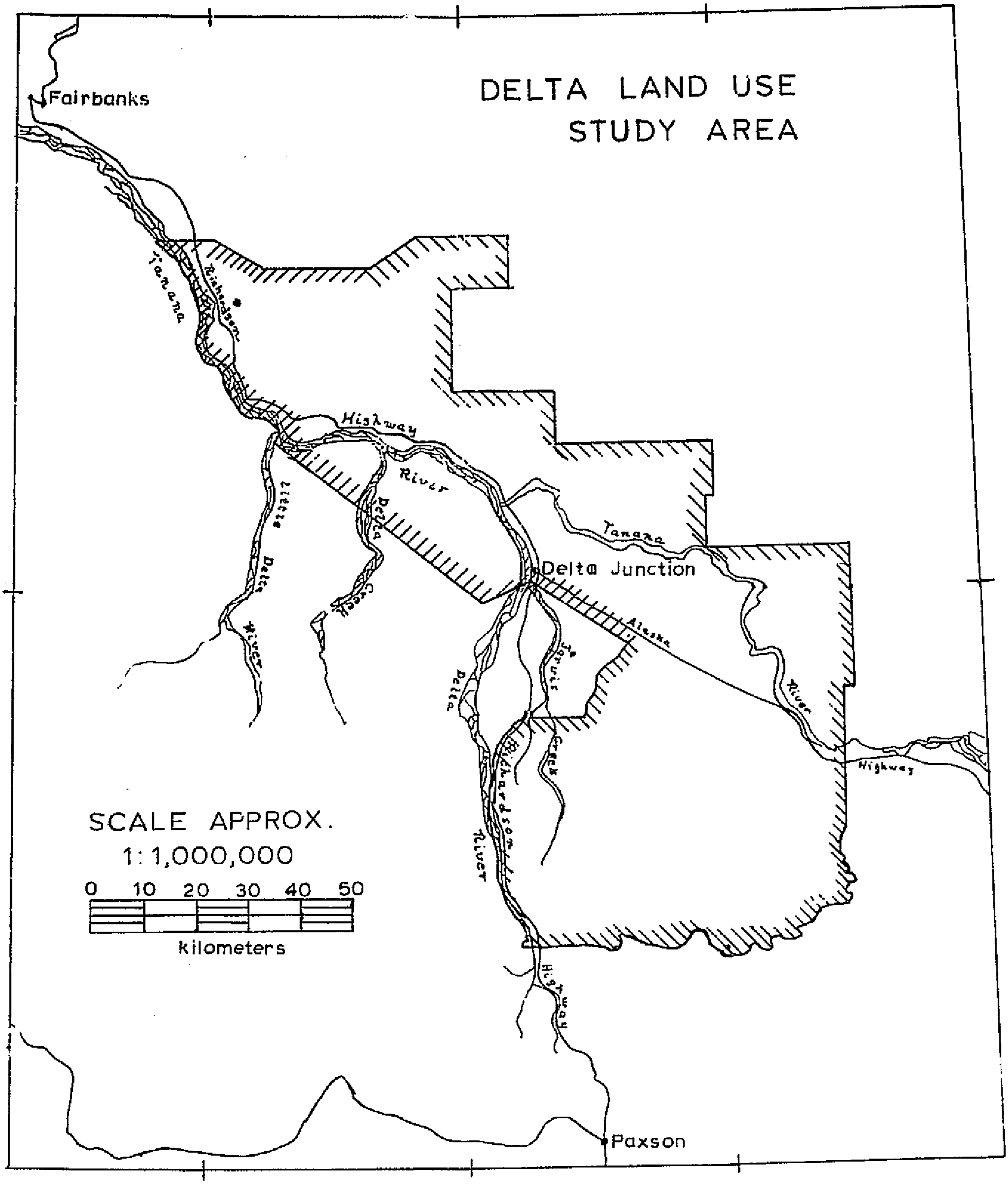

Figure 1. Map showing location and extent of the delta land use study area.


lake ice
Big Delta
Richardson Highway
Lake
Tanana River
Clearwater Creek
FLOOD
Jack Warren Road
Delta Junction
Delta River Bed
Alaska Highway
Old Jarvis Creek
FLOOD
Ft. Greely Airport
Jarvis Creek
LAKES
FLOOD
outlets
outlets
Color Reconstitution
Big Delta, Alaska
LANDSAT Scene 1642-20390
26 April 1974
1mile
PREPARED BY:
THE GEOPHYSICAL INSTITUTE
UNIVERSITY OF ALASKA

Figure 3. Oblique aerial photograph showing lower (north) end of Jarvis Creek aufeis formation. Diversion of Jarvis Creek waters takes place toward the left at the left extreme of Jarvis Creek in this photograph.

Figure 4. Oblique aerial photograph showing bank-full ice conditions in region of actual overflow.

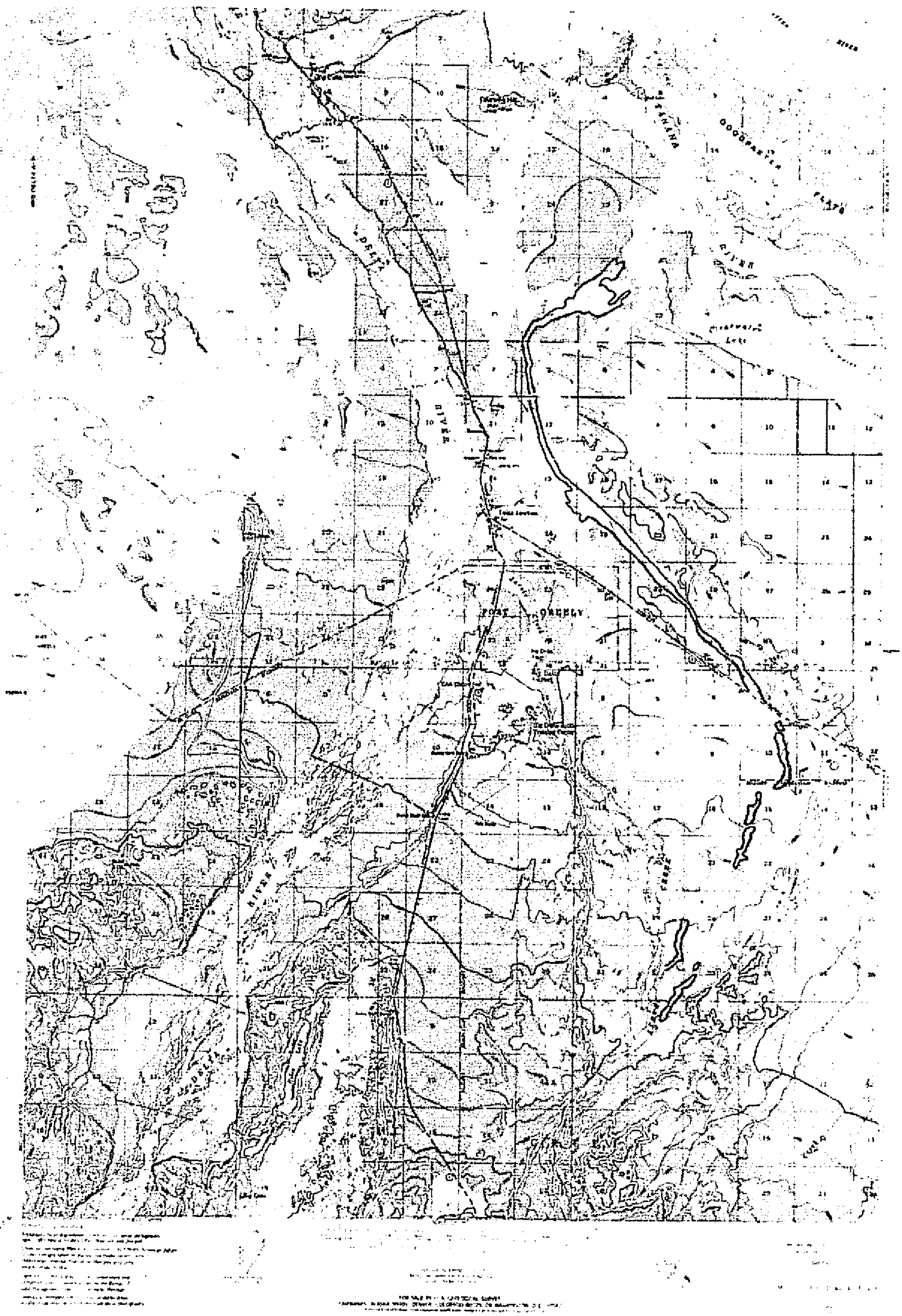

Figure 5. A standard USGS inch-to-the-mile map showing known flood and aufeis data from Figure 2.

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