STATE OF MONTANA

STATE WATER CONSERVATION BOARD

HELENA, MONTANA

April 29, 1952

re:.....

State Water Conservation Board
Mitchell Building
Helena, Montana

Gentlemen:

According to reports, the Frenchman Creek Dam failed at about 5:45 P.M. on April 15, 1952, by breaching the embankment along the east side wall of the spillway structure when the water surface in the reservoir was within one foot of over topping the spillway.

The cause of breaching is not definitely known, but it is believed that piping underneath and along the spillway wall made a cavity and the weight of the water caused the embankment to settle. On the day of failure a spring under pressure was observed coming out of the ground at the spillway wall some distance below the dam embankment, which may have been the direct cause of the breach in the embankment.

It is conservative to say that the failure was due to circumstances brought about by extreme high creek run-off. According to reports the spillway structure would have over topped if the embankment had held.

The dam and spillway were designed and constructed on conservative engineering principles for a reservoir of this size. The spillway with a three foot freeboard was designed for a probable 1,000 year flood as computed by a reputable formula with a basic run-off record of thirty-five years. According to the formula the discharge before dam failure equaled a probable 10,000 year flood. Before dam failure it is estimated that 11,150 second feet were flowing through the spillway and 1,000 second feet flowing over the west dyke, which was left one foot low for an emergency spillway. During the thirty-five years of run-off record there was one peak flow of 5,450 second feet and the average for that day was 4,820 second feet.

An inspection of the site will be made as soon as the water in Frenchman Creek has receded sufficiently to make an examination of conditions that might have caused the failure.

I am attaching some pictures at the dam after failure.

Yours very truly,

STATE WATER CONSERVATION BOARD

R. H. Fifield

R. H. Fifield
Chief Engineer

RHF/1

Chronology of Events leading up to the failure of the Frenchman Creek dam on April 15, 1952.

On April 1, the gates on the dam were closed, with the water in the reservoir standing at an elevation of slightly over 3627, just covering the top of the Intake Structure.

On April 4, the water had reached an elevation of 3639, on which date a temporary footbridge across the spillway was completed.

On April 6, the water overflowed the spillway (elevation 3645) for the first time, and by April 7 was spilling to a depth of 8 inches. This flow gradually increased and by April 12 had reached a depth over the spillway of from four to four and one-half feet, a discharge of between 2800 and 3400 second feet.

On the morning of April 14, a close measurement showed a head over the spillway crest of 4 feet 8 inches, indicating a flow of 3600 second feet. By late afternoon this head had increased to 8 feet six inches and the flow to 9350 second feet.

Before early morning of April 15, water had begun spilling over the west dike, indicating a depth of 9 feet at the spillway, or a flow over the spillway alone of 10,250 second feet. By noon water marks on the main fill indicated a depth of six inches over the west dike, and 9 feet 6 inches over the spillway crest. These depths mean a discharge over the spillway of 11,150 feet, and over the dike of 1000 second feet, making a total discharge at that time of more than 12000 second feet. This was the maximum height reached on the dam and the water level then began falling a little and holding its own somewhere between elevation 3654 and 3654½.

Shortly after noon, the Water Conservation Board in Helena was notified that a one foot stream of water had broken through the dam just east of the spillway and at an elevation of between 3640 and 3645. This stream was under considerable pressure and was shooting out and cutting the downstream slope of the dam rapidly. There were no visible signs as to where this stream was entering the dam, and no way to cut off its flow. This stream increased in flow rapidly, and around 6:00 P.M. the dam along the east wall of the spillway suddenly collapsed, loosing a volume of water that rapidly washed out the entire spillway, with the exception of the west retaining wall, which on April 16 was still standing though badly undercut for the entire length visible above the water. In addition to the spillway, approximately 120 feet of fill immediately to the east was carried away leaving a breach through the dam approximately 220 feet in width.

Discharge of Frenchman Creek continued to increase April 16 and 17 as the water upstream from the reservoir rose higher and higher. No measurements are available as to the maximum discharge, but estimates place it at around 15000 second feet.

Information furnished the State Water Conservation Board from outside sources:

April 14: About 9:00 A.M. Talked with F. C. Mavencamp of Saco Water Users' Association, who reported from four to four and one-half feet of water flowing over spillway the afternoon of April 13.

April 14: About 11:30 A.M. Army engineers called State Water Conservation Board office, stating dam was failing as water was flowing through east end of main fill.

April 14: About 1:30 P.M. Contacted F. C. Mavencamp and told him of army engineers report. He stated they were mistaken as he had just returned from dam and everything appeared O.K. He measured depth of water over spillway crest at 4 feet 8 inches.

April 14: About 5:30 P.M. Mavencamp called again. Stated water had risen very rapidly during day, and was now discharging about 8½ feet of water over spillway. Dam still appears O.K.

April 14: About 8:30 P.M. C. S. Heidel of U.S.G.S. called to inform Water Conservation Board of water conditions on Frenchman Creek upstream from the dam. Stated vast amount of water flowing in Frenchman Valley from as far north as Val Marie, 75 miles north of Canadian border, and that water held in Val Marie, East End, and other Canadian dams might have to be released to prevent flooding of some small Canadian towns. Stated Orin Folsom of U.S.G.S. had flown over that area during the day reporting miles of snow over the drainage area.

April 14: About 9 P.M. Talked to R. H. Fifield in Havre and reported to him all the above information.

April 14: About 9:30 P.M. Talked with Orin Folsom in Havre about his trip over Frenchman Creek Valley. He stated there was a large, new crest on Frenchman Creek about 10 miles north of the dam, which should reach the reservoir before morning. Said Frenchman Creek in places was 3/4 of a mile wide. I requested him to call Mr. Fifield and impart this information to him.

April 15: About 8:45 A.M. Talked with F. C. Mavencamp, who stated water now flowing over west dike at dam indicating a depth over spillway of 9 feet or more. Said dam still seemed o.k., and water was no longer rising and even dropping a little since going over the west dike. Thought everything would be o.k. without cutting out some of the dike. Army engineers at dam agreed.

April 15: About 9:30 A.M. Army engineers called. Said 5 inches of water running over east dike. I asked if they did not mean the west dike, but they said "No - the east one." I called Mavencamp telling him the army engineers report. He said no water running over any place except west dike.

April 15: About 11:30 A.M. Army engineers called Water Board office. Stated dam was breached just east of spillway and dam was falling apart.

April 15: About noon. Got in touch with Mavencamp and told him army engineers report. He said still no water going over top, but serious piping had developed just east of spillway part way down the fill. Said a 1 foot stream was shooting out under alot of pressure, and rapidly cutting out the downstream side of fill. Could find no indication of where water was entering fill and there was nothing he could do to shut it off.

April 15: About 3:30 P.M. Talked once more with Mavencamp, who said fill had cut out badly at the breakout, and it looked like the dam would go out. (it went out about 6:00 P.M.)

Preliminary Report on damage to dam:

April 16: 8:A.M. I arrived in Saco and talked with F. C. Mavencamp. He did not see actual failure of dam, as he left there shortly before the actual breach occurred. Said no one felt the dam failed because of defective construction - there was just too much water. Mr. McChesney made a similar statement.

April 16: 10 A.M. Secured a plane and flew out to the dam from Hinsdale. Water all around west, north and south sides of Hinsdale, but did not get into town. Pilot of plane, Norman Mavencamp, witnessed collapse of the dam. He said it seemed to occur all at once, with the fill all along the east side of the spillway seeming to drop down and allow the water to wash through. Said all the east side of the spillway fell in first, then each bridge pier in turn collapsed and fell into the roaring water one by one as the floor slab beneath them broke up. He said that before the actual collapse, the water coming through the dam was shooting out so violently that no one could get near it. There were many spectators present, and these were all kept back away from the danger zone. No one was allowed to cross the spillway bridge after it appeared the dam was liable to fail.

April 16: 11 A.M. Landed on field just downstream from east dike. All east dike and main fill to 110 feet west of control tower appear to be intact, except that backwash below the dam has eaten out some of the gravel on the downstream slope. It does not appear to have cut into the impervious section of the dam. Upstream face of fill shows no damage whatsoever - riprap still in place and no cutting action shown anywhere. Water line on dam shows water never topped the dam or dike at any point east of spillway.

There is a breach through the dam about 220 feet in width of which 100 feet was the spillway. The spillway concrete was completely washed away with the exception of the west retaining wall, which still stands (4/16/52). Present water surface above the dam is about 3636 or 3637, and below the dam about 3634 or 3635. Frenchman Creek is still flowing at a rate of about 15000 cfs. There was no safe landing place for the plane west of the spillway, but as seen from the plane flying very low, there was no damage whatsoever to the west fill or west dike built to elevation 3655, and only slight washing away of the downstream side of the dike built to elevation 3654, which was over-flowed for nearly 24 hours -preceding the failure of the dam.

Too much water is still flowing to determine the cause of the dam's failure, but indications point to an undercutting beneath the spillway through natural ground. It may be several weeks before the water drops low enough to make a thorough investigation.

After looking over everything at the dam as thoroughly as possible under present water conditions, I flew 15 miles upstream to observe water conditions above the dam. Frenchman Creek is at its highest level yet, and still rising. Snow cover is gone for fifteen miles, from the north are lots of drifts, and pools of water in all directions. There on

My calculations of damage caused by the sudden release of waters impounded in the reservoir indicate it would cause a rise of approximately 1 foot over the immense area already under water around the junction of Frenchman Creek with the Milk river. Mr. McChesney estimated the rise at about 2 feet at his ranch on lower Frenchman Creek.

The entire volume liberated by the failure of the dam amounts to less than the 12 hour discharge of Frenchman Creek at its present rate of flow. The maximum volume released from the reservoir could not have exceeded 14000 acre-feet. Maximum discharge possibly may have reached a flow of 50,000 second-feet for the first hour after the break, gradually dropping over a period of several hours to the estimated flow of 15,000 second-feet still coming from Canada.

Paul K. Williams
Engineer

December 18, 1952

MRPGF

Erland A. Tillman
Lt. Col, Corps of Engineers
Fort Peck District
Fort Peck, Montana

Gentlemen:

We thank you for your letter of November 21, 1952, and for the copy of your office report on the failure of the Frenchmen Creek Dam occuring April 15, 1952.

I believe the failure was caused by piping resulting from seepage passing under the east sloping wing wall and following the vertical concrete wall of the spillway structure to the place of first water appearance on the down stream face of the dam adjacent to the east wall of the structure.

A channel for the seepage could have been caused by unequal settlement between embankment and structure, by shrinkage of embankment at contact with the concrete wall, by a poorly compacted layer of embankment, or by a combination of these conditions. It is possible that some of the embankment in front and under the sloping east wing wall washed away thus exposing the structure backfill to direct water pressure and materially shortening the line of flow along the concrete walls. There is no certain knowledge on what caused the piping and from my view point one conjecture is as good as any other.

I believe that there would have been no failure of the structure if we had an opportunity to fill the reservoir gradually.

Thanks for your suggestion pertaining to precautions to be taken in priming the reconstructed structure. We appreciate the existing unfavorable foundation conditions for dam construction and for reservoir storage at this site and shall watch carefully for seepage conditions during the filling and future operation of the reservoir. At this time water in the reservoir is being raised gradually and we sincerely hope we will not have flood conditions until after the reservoir has been filled.

I just recently returned to the office from several weeks vacation, otherwise would have acknowledged your letter before this time.

This office appreciates your very fair and considerate report of the Frenchman Creek failure.

Yours very truly,

STATE WATER CONSERVATION BOARD

R. H. Fifield
Chief Engineer

rhf/1

ADDRESS REPLY TO:
DISTRICT ENGINEER
FORT PECK DISTRICT
CORPS OF ENGINEER
FORT PECK, MONTANA

CORPS OF ENGINEERS, U.S. ARMY
OFFICE OF THE DISTRICT ENGINEER
FORT PECK DISTRICT
FORT PECK, MONTANA

REFER TO FILE NO. MRPGF

21 November 1952

Mr. R. H. Fifield, Chief Engineer
Montana State Water Conservation Board
Sam Mitchell Building
Helena, Montana

Dear Sir:

Inclosed for your files is a copy of a report on the failure of Frenchman Creek Dam which has been prepared by this office. Copies of the report have been reviewed by offices of the Corps of Engineers, and Mr. T. A. Middlebrooks, Chief of the Soils Branch of the Office of the Chief of Engineers, Washington, D. C. personally visited the site of Frenchman Dam on 17 November 1952.

Personnel within the Corps of Engineers who have reviewed the report concur generally in the conclusions cited therein, but have made the following additional comment: "It appears that the seepage adjacent to the spillway wall may have been due to unequal settlement between the concrete structure and the adjacent embankment producing horizontal or vertical cracks in the fill. These cracks might have extended through the cutoff rendering it ineffective."

So far as reconstruction of the dam is concerned, this office concurs in the decision to widen the spillway and to provide a more positive cutoff beneath this structure. However, since the presently installed cutoff does not extend beneath the total length of the fill and because of the presence of the extensive gravel zone, it is suggested that portions of the embankment be closely observed during periods of initial storage in order to detect possible underseepage, as it is believed that there is still a possibility of developing a path of flow beneath the portion of the embankment which does not have a cutoff to shale. Such seepage could conceivably initiate a piping action, when the reservoir is at full pool, resulting in a consequent erosion of the fill and undermining of the spillway structure. As a matter of information, there are several cases on record where underseepage has been successfully diminished or stopped by draining the reservoir and extending an impervious clay blanket for a distance of

several hundred feet upstream from the upstream toe of the fill. It is also suggested that points of contact between the fill and retaining walls of the spillway should be checked periodically to ascertain whether there is any apparent differential settlement or shrinkage cracks in the embankment in these areas.

This office desires to express its appreciation to you and your personnel for the friendly cooperation you have extended during the course of this investigation.

Very truly yours,

ERLAND A. TILLMAN
Lt Col, Corps of Engineers
District Engineer

1 Incl
Report

REPORT ON THE FAILURE OF FRENCHMAN CREEK DAM

1. Introduction. Frenchman Creek, a tributary of the Milk River is 322 miles in length and drains an area of 2,200 square miles of which 2020 square miles are in Canada. Stream flow records acquired from discharge measurements taken at the International Boundary are available from 1907 to the present time. Prior to the flood flows of 1952, the previous peak flow measured during the period of record was 5440 cfs on 29 March 1925. The average daily discharge at the International Boundary is 102 cfs.

2. Three discharge measurements were taken on Frenchman Creek during the flood of April 1952, the results of which are tabulated below.

LOCATION	DATE	DISCHARGE (cfs)
2 miles above mouth	15 April 1952	7,580
2 miles above mouth	18 April 1952	9,700
4-5 miles above mouth	22 April 1952	9,600

3. Maximum flow on Frenchman Creek below Frenchman Dam occurred on the evening of 15 April 1952. At 5:45 P.M. on this date a 100 foot section of Frenchman Dam on the east side of the spillway failed, thus releasing waters impounded by the reservoir. In a short time the failed section rapidly widened and the concrete spillway structure and a portion of the abutment to the right of the spillway also failed and was washed out. The water level of the reservoir at the time of failure of the dam was approximately one foot below the crest of the main section of the dam and was overtopping the west dike section which had a crest elevation one foot lower than the crest of the main dam. No measurement has been made of the high flow which occurred downstream on Frenchman Creek after the failure

of the dam, although it is estimated to have been higher than the three measurements listed in the preceding paragraph. The water surface of the reservoir was lowered approximately 20 feet in 12 hours.

4. Although the Frenchman Creek Dam and Reservoir was built and operated by interests other than the Corps of Engineers, an inspection of the dam failure was made by personnel from the Fort Peck District, Corps of Engineers for the purpose of attempting to ascertain the reason or reasons for the failure and thus provide this agency with valuable information relevant to the cause of failure of this particular dam. The following report therefore presents the results of this inspection and investigation and includes a brief description of the dam and reservoir, geology of the dam site, and a discussion of the factors involved in the ultimate failure of the structure.

5. Frenchman Dam. Frenchman Dam is situated on Frenchman Creek in Sec. 23, T34N, R34E, MM, approximately 22 miles upstream from the confluence of Frenchman Creek and the Milk River. (See Plate No. 1) Construction of the dam was initiated in 1950 by the Montana State Water Conservation Board and was completed in August 1951. The dam which was used and operated by the Frenchman Creek Irrigation Company, a cooperative, was an earth fill structure having an overflow type concrete spillway. The reservoir had a capacity of 7,010 acre-feet at the spillway crest level.

6. The essential features of the dam and spillway are shown on Plates Nos. 2 to 4 accompanying this report. Plate No. 2 shows the plan, profile and typical cross-sections of the dam and dike sections.

The entire length of the structure was 2,965 feet from the east to the west abutment and was composed, as shown on the profile, of three dike sections, an ungated spillway section and two embankment or fill sections. One fill was placed across the present creek bed and a secondary fill was constructed across a tributary drainage located west of the middle dike section. The impervious embankment material for the dikes and fill sections consisted of glacial till composed of clay, silt, sand and gravel. This material was borrowed from an area adjacent to the east dike section on the upstream side of the dam and also from material excavated from the spillway section. All embankment materials were rolled and compacted with sheeps foot rollers, except near concrete structures where pneumatic hand tampers were used to attain compaction. The crest elevation of the main dam was at 3655.0 and the crest elevation of the spillway was at 3645.0.

7. The dike extending westerly from the secondary fill section between stations 19+86 and 29+65 (See profile Plate No. 2) had a crest elevation at 3654.0 to provide for release of water from the reservoir when flood flows caused the storage level to raise above this elevation. It was designed to act as an emergency spillway and to fail in the event that the discharge capacity of the main spillway exceeded the design discharge of 8,000 cfs.

8. The main dam was approximately 240 feet wide at the base and had a crest width of 20 feet. It consisted of an impervious rolled earth embankment having a 1 on 3 upstream slope protected by a 48-inch sand and gravel blanket overlain by a 24-inch layer of hand-placed rip rap, a 1 on 1 downstream slope overlain by a protective layer of pervious gravelly material with a 1 on 2 finished slope, and an impervious cut-off up to 24 feet deep and 8 feet wide at the base with 1 on 1 side

slopes located beneath and on the axis of the embankment. In addition to the cut off shown on the profile Plate No. 2, a second cut off was excavated to shale along the line indicated in red on the plan map, Plate No. 2, as it was discovered during field operations that a seam of coarse sand and gravel was present across the valley in this area. The top of the gravel zone occurred at about elevation 3614.0 and shale was generally encountered between elevation 3608.0 and 3604.0. A 20 foot wide berm was located on the upstream slope at elevation 3630.0. A waste berm 45 feet wide was located at the toe of the upstream slope at elevation 3620.0. The secondary fill was constructed similar to the main dam. The dike sections consisted of a rolled fill embankment having 1 on 2 side slopes and a protective upstream sand and gravel blanket laid on a 1 on 4 slope.

9. Details of the spillway are shown on Plates Nos. 3 and 4. This structure, which was built on the west side of the main fill, had a crest elevation of 3645.0 (10 feet lower than the crest elevation of the dam) and a crest width of 100 feet divided by upright concrete piers into four bays, each 25 feet wide. Examination of the topographic plan map, Plate No. 2, shows that the upstream approach channel of the spillway was excavated in alluvium to elevation 3642.0. Note that the alignment of this channel with respect to the main embankment has resulted in a condition wherein a wedge of natural ground remained between the east side of the approach channel and the main embankment. The configuration of this wedge is such that there is a gradual upward slope from the original stream bed to elevation 3645.0. This is the same elevation as the spillway crest, however the approach channel elevation is at 3642.0, as mentioned previously, and the sides of the channel are cut back on a 1 on 1½ slope to elevation 3645.0. This condition provided for an increased

velocity of approach to the spillway from this direction when storage level exceeded 3645.0. The above item is mentioned at this time for it is believed that this condition was one of the factors causing the drawdown pattern that can be observed on the numerous pictures taken from the air prior to the failure of the dam.

10. The cut-off trench mentioned previously also extended beneath the axis of the spillway as shown on the profile Plate No. 2. The upstream end of the spillway crest slab extended vertically four feet below the approach channel elevation to elevation 3638.0, thus providing additional cut-off protection. This concrete wall extended along the entire width of the spillway between the end retaining walls. A concrete triangular shaped wing wall extended from the ends of the retaining walls a distance of 26 feet into the rolled embankment on the east side and into the natural ground on the west side of the spillway channel. Details of the wing walls and cutoff wall are shown on Plates Nos. 3 and 4. A 177 foot long concrete lined escape channel extended from the crest to the downstream cutoff, which was similar in construction to the upstream cutoff, and extended to elevation 3607.0. Concrete wing walls also comprised part of this toe cutoff and extended 28.0 feet into the downstream abutments. A concrete stilling basin provided with two rows of concrete baffles as shown on Plate No. 3 extended upstream from the cutoff wall. The floor elevation of the stilling basin was at 3611.0 and the elevation of the discharge channel was 3613.0.

11. Reservoir Regulation. Release of water from the reservoir for normal operating purposes was effected through a 227 foot long conduit located approximately 280 feet east of the center line of the spillway.

The conduit is a reinforced concrete structure, circular in cross-section, with an inside diameter of 5.0 feet. The invert of the conduit is at elevation 3613.0. A rectangular, double compartmented (two compartments in series) concrete control tower extends upwards through the fill to a wooden control building located on the crest of the dam. Each compartment in the control tower is 6.5 feet by 3.5 feet in cross-section with 10-inch concrete walls. Discharges were controlled by means of two 60-inch sluice gates, one in each compartment. A 24-inch diameter pre-cast concrete pipe extends horizontally through the fill at elevation 3635.0 from the downstream control compartment out to the face of the fill. Release of water could be effected through the main conduit by raising both sluice gates. Water could also be released through the 24-inch diameter turnout at elevation 3635.0 by lowering the circular sluice gate in the downstream compartment to a closed or partially closed position in the outlet conduit and forcing the water upward in this compartment and into the turnout at elevation 3635.0. Generally, usage of the water for irrigating purposes was predicated on maintaining the storage level of the reservoir above elevation 3635.0. Flood flows which raised the storage level above elevation 3645.0 were diverted over the spillway.

GEOLOGY OF THE DAMSITE

12. General. Because of lack of detailed subsurface data in the vicinity of Frenchman Creek Dam, this discussion of the geology of the site must of necessity be confined to data obtained as a result of visual observation of surficial geologic and topographic features of the area. Some correlation of the surficial and sub-surface geology has been obtained by referring to published geologic maps and known stratigraphic relationships which are characteristic of the vast physiographic

sedimentary province of eastern Montana and western North Dakota. Statements made in regard to depth of foundation rock under portions of the dam and spillway are based on conditions found elsewhere in the physiographic province of which the valley under discussion is an integral part. Some of the surmises made may prove to be at variance with actual conditions, however they serve to point out the general geologic pattern and the significance of this pattern with respect to the ultimate failure of the dam.

13. Stratigraphy. The Montana portion of Frenchman Creek Valley has become entrenched in a series of sedimentary rocks of Cretaeceous age. The oldest formation exposed in the vicinity of the dam site is the Claggett Shale, which is a dark gray, clayey, marine shale, containing numerous limestone concretions. This shale which readily weathers to a typical gumbo soil constitutes the bed rock beneath the valley and extends upward for some distance on the valley slopes. It is overlain by the Judith River Formation which consists of a series of fresh water sandstones and shales. This formation is readily identifiable in the area as a series of steep grass covered slopes and plateau like benches which stand out prominently above the rounded and gentle slopes formed on the softer underlying Claggett Shale. The Judith River formation outcrops well above the maximum storage level of the reservoir and is not found in the immediate vicinity of the dam.

14. Structure. The portion of Frenchman Creek valley in which the Frenchman Dam and reservoir site is situated is located on the north flanks of a broad, gentle uplift known as the Bowdoin Dome. This uplift which is of pre-glacial age has caused the removal by erosion of the Bearpaw shale, Lance and Fort Union Formations and has exposed the older

Judith River and Claggett Formations. The regional dip of these units is to the southeast, however some variation in the strike and dip can be expected in the area of Frenchman Dam because of the influence of the Bowdoin uplift.

15. Recent Geological History. The valley of Frenchman Creek lies within a glaciated area, consequently much of the bed rock in the region is overlain by surficial deposits of glacial till of varying thickness. The topography of the valley, which is wide and flat in cross-section, indicates that the Frenchman drainage is pre-glacial in origin. During the period of time between the epoch preceding the advent of the latest ice-age and the present, Frenchman Creek and other northern tributaries of the Milk River have undergone several cycles of erosion and deposition all of which have exerted a profound influence on the physical characteristics and configuration of the present valleys. In the epoch prior to the last onslaught of glaciation, Frenchman Creek flowed southward to the Milk River maintaining its gradient close to bed rock - in this instance the Claggett shale. During this period Frenchman Creek and other streams in the area had been slowly downcutting and at the same time depositing coarse gravel material on the stream beds and transporting the finer constituents downstream.

16. As the continental ice-sheet advanced over the area, the streams, at first continued to cut deeper into the shale in order to maintain concordant slope relationships with the parent streams which were gradually steepening their declivities because of lowering of sea level caused by the withdrawal of waters from the oceanic basins due to the accumulation of ice on the continents. Later, the ice sheet completely

covered the Frenchman Creek region and surrounding areas and forced the major stream drainages to cut temporary channels along the forefront of the advancing ice sheet. The retreat of the ice sheet, constituting the next cycle of events in the history of the region, initiated a period of alluviation on all major and tributary stream drainages including the Frenchman Creek drainage. As the ice slowly retreated northward new drainages were formed and older drainages were reactivated. The wastage of the ice masses caused deposition of the detrital materials in the form of ground moraines. Ice wastage and consequent run-off of water into oceanic basins initiated a renewed rise in sea level and a contemporaneous alluviation of continental stream drainages. This alluviation of Frenchman Creek followed a definite pattern characterized by deposition of coarse gravels during the early stages of upbuilding and then progressively finer materials in the stream bed until the sea level again reached its present condition in recent geologic times when a general equilibrium was attained between melting and ice accumulation on present ice caps. Subsequently, a new cycle of downcutting was initiated and the stream began to slowly cut deep channels through the fine grained alluvial materials deposited during the period of upbuilding.

17. The foregoing paragraphs present a brief and very generalized narration of past geologic events which have formed the present valley. The depth of alluvial materials within the valley is not fully known, however it is believed that the Claggett shale is present at a depth of about 60 to 80 feet in the deepest portion of the valley cross section. The shale is undoubtedly overlain by a considerable thickness of coarse gravel which was partially deposited during the pre-glacial epoch and

partially during the early stages of post-glacial alluviation. The alluvial materials above the gravel consist of inter-bedded zones of clays, silts and sands deposited during the final stages of the valley alluviation.

18. Dam Foundation. The description of the geology in the vicinity of Frenchman Creek Dam cited in the preceding paragraphs indicates that the major portion of this dam was founded on alluvial materials. The plan map of the dam site (Plate No. 2) shows that the left or east abutment of the main fill is keyed into a prominent spur of ground extending outward from the east slope of the valley and it appears from a study of the topography in this area that this spur is an erosive resistant knoll of Claggett shale which is overlain by a relatively thin mantle of glacial till. Further study of the topography and examination of the aerial photo No. 21382 accompanying this report indicates that the present stream bed across which the main fill was placed has cut deeply into the alluvium bordering the shale spur or east slope of the valley at the axis of the dam. The glacial till and underlying shale therefore are undoubtedly the foundation materials beneath that section of the dike between stations 0+00 and 5+60. (See profile Plate No. 2) The portion of the dam, spillway and dike sections extending westward from station 5+60 to station 29+65, approximately, were all within the alluvial flood plain of the valley, consequently the foundation beneath these sections consisted of inter-bedded clays, silts, sand and gravels overlying the bed rock or Claggett Shale.

19. Flood Conditions. The flooding of the Frenchman Creek Valley during the month of April 1952 was brought about as a result of a combination of a number of unusual conditions which prevailed in the Milk

River drainage prior to the flood, which are listed as follows: (1) above normal precipitation occurred during August, September and October 1951; (2) below normal temperature prevailed from October 1951 through January 1952 causing the upper layers of soil to become frozen before being covered with snow; (3) a heavy accumulation of snow on this frozen ground occurred during the months of February and March 1952 and extensive snow melt was delayed by cool weather until the end of March and early April. As the temperature increased and started snow melt run-off early in April, Frenchman Creek began rising and on 6 April was at overbank stage. A temporary recession of the rise occurred on 7 and 8 April because of the presence of a cold wave over the drainage area. The temperature began to increase again on 9 April and maximum flows occurred on Frenchman Creek on 14 and 15 April. The reservoir above Frenchman Dam had attained its maximum storage during the early stages of run-off and on 15 April water had risen to within one foot of the crest of the dam and was discharging freely through the spillway and over the dike section of the west side of the dam.

20. About 9:05 AM on 15 April, personnel from Fort Peck District, who were at that time making an aerial reconnaissance of flood conditions at Frenchman Reservoir, noted a wet area on the downstream slopes of the main fill at the contact between the fill and the east retaining wall of the spillway. (See Photo No. 21351) This condition worsened through out the day and by 5:00 PM a large segment of the fill and natural ground adjacent to the spillway retaining wall had been eroded out. (See Photo No. 21364) At 5:40 PM the remaining portion of the fill adjacent to the spillway had washed out and in a short time a crevasse 100 feet

wide was opened up in the fill. A short time later the spillway, which had also been undermined by erosion, failed and was washed downstream. Photos Nos. 21367, 70 and 71 show what the conditions were at the time the dam failed and Photo No. 21372 shows the conditions at 6:45 AM on the morning of 16 April. Note that at this time the right retaining wall of the spillway was still intact. Photo No. 21901, taken on 24 April, shows that the right retaining wall had by this date been undermined by erosion and had dropped approximately 25 feet from its original position. Also, by this date, the breach had widened to approximately 255 feet and the entire spillway had been washed out as well as a 130 foot section of the main fill to the east of the spillway and a 25 foot section of dike and natural ground on the west side of the spillway.

21. Cause of Failure. On 4 June 1952 the undersigned inspected the site of Frenchman Dam for the purpose of attempting to ascertain the reason or reasons for the failure. On this date, flow in Frenchman Creek was nearly normal and well below flood stage. A wrecking crew from the Montana State Water Conservation Board was removing portions of the concrete from the stream bed preparatory to rebuilding the structure. The base of the section where the failure occurred was covered by a pool of water to an estimated depth of 10 feet. It was estimated that the water surface of this pool was at about elevation 3610.0 which would place the base of the breached section beneath the pool at elevation 3600.0. The elevation of the base of the impervious cutoff beneath the spillway was approximately 3627.0, (See profile, Plate No. 2) thus indicating that a 27 foot vertical section of foundation material had been scoured out of the area beneath the spillway and the breached section of the main fill.

22. As a result of the break in the dam and the subsequent erosion and removal of the foundation material beneath the spillway, a complete section of the embankment on the east side of the crevasse between the crest elevation 3655.0 and elevation 3610.0 was visible for inspection. (See Photo No. 22159) Likewise, a 35 foot vertical section of the natural ground and embankment on the west side of the break was exposed. (Photo No. 22157) The material in the exposed 35 feet on the west side consisted of a top 5 feet of rolled fill and a lower 30 feet of alluvium composed of interstratified zones of silty clay, fine sands and sandy silts. This alluvial zone was present beneath the spillway and beneath that portion of the main fill where the failure occurred, as explained in paragraph 17 of this report. The alluvium exposed on the west end of the breached section of the dam is well consolidated but contains seams of fine sand throughout the section. Typically, fine-grained deposits of this type lose cohesion and strength rapidly when wet and are readily susceptible to erosion. Mechanical analyses curves of two samples of this material are shown on Plate No. 5, Curves 2 and 3.

23. The rolled fill exposed in the vertical section on the east end of the failed section appeared to be well compacted and highly impervious. Personnel from the State Water Conservation Board have stated that a portion of the fill on the downstream slope adjacent to the failed section was examined on the day following the failure by excavating into the fill for some distance. The material in this excavation was dry at the time of the examination and showed that no appreciable seepage had occurred throughout the major portion of the rolled fill. (See Plate No. 5, curve No. 1 for M A curve of embankment material).

24. A seam of coarse sand and gravel was exposed near the water's edge approximately 200 feet upstream from the axis of the destroyed spillway and it was estimated that the top of the gravel was at elevation 3613.0. Gravel was also exposed at about the same elevation in the vicinity of the axis, underlying that portion of the west wall of the spillway which had not yet been removed. These gravel seams are shown on Photos Nos. 22156 and 22157. Large boulders were also noted elsewhere throughout the breached area. This gravel and boulder strata then is undoubtedly present beneath the fine grained alluvium upon which the spillway and main embankment was founded and it is estimated that the pervious gravel strata is at least 10 to 15 feet thick and is underlain by Claggett shale. It was stated in paragraph 14 of this report that deposition of sands and gravels occurred in Frenchman valley prior to the glacial period and during the early stages of alluviation of the post-glacial epoch, and it is reasonable to assume that the gravel strata in the vicinity of the dam site is continuous throughout the valley upstream from the dam and forms a highly pervious subsurface zone. It has been mentioned in paragraph 8 of this report that this gravel zone was discovered during construction and an attempt was made to prevent seepage through the gravel by excavating a second earth cutoff into shale. This cutoff extended on the upstream side of the axis of the main embankment and across the spillway approach channel as shown by the red line on Plate No. 2.

25. Considering the above mentioned evidence, it appears that the main cutoff beneath the west section of the main fill and the spillway section (Station 8+60 to Station 10+80 approximately) did not extend down through the gravel zone since the base elevation of the cutoff

between these stations varied between 3618.0 and 3628.0 and the top of the gravel zone cited in the preceding paragraph was at elevation 3613.0, approximately. Construction of the secondary earth cutoff to shale, as mentioned in the preceding paragraph, did perhaps help to prevent percolation of water through the gravel zone. However, the cutoff was not a positive one; i.e., it did not extend sufficiently far in a westerly direction to provide for a complete cutoff beneath the entire structure. Thus, it seems probable that considerable underseepage and consequent uplift pressure occurred beneath the structure during the period when the reservoir was at full pool. Interrogation of witnesses present at the site on the day of the failure discloses that the first indication of failure of the embankment occurred at 9:00 AM when a small flow of water was seen issuing from the embankment at a point about two feet east of the east retaining wall of the spillway at about elevation 3644.0 on the fill. Seepage this high on the embankment could not be reasonably attributed to percolation of water from the pervious gravel overlying the shale. Logically, failure due to percolation of water through this gravel layer should first appear at or near the downstream toe where resistance to uplift was at a minimum. Since there was no evidence of seepage in the downstream toe area, failure directly as a result of foundation underseepage can be discounted.

26. A study of the topographical plan map of the dam and spillway shows that the point where seepage first started (Elevation 3644) was approximately at the line of contact of the rolled embankment and the natural ground. This indicates that the water had developed a path of seepage from the upstream side of the dam and out along the plane of

contact of the fill and natural ground. It has been pointed out in paragraph 9 of this report that a wedge of natural ground existed upstream from the embankment at a point just east of the spillway approach channel and that the configuration of this wedge and back-sloping of the east side of the approach channel created a condition wherein water approaching the spillway channel from this direction would increase in velocity due to the sharp drawdown at the point where the top of the back slope intersected the level ground. Evidences of this drawdown and the velocity pattern of the water are shown on Photo No. 21364. Note that the drawdown and resultant increased velocity had scoured out all the embankment on the upstream face of the east wing wall by the time the photograph was taken.

27. It is believed that erosion of this embankment and possible underscouring of the wing wall allowed a path of seepage to develop around this wall. It is likely that the initial seepage first followed along the contact of the wall and the embankment, moving laterally from the east limits of the wall to its junction with the main spillway retaining wall and thence downstream along the contact line of the retaining wall and the fill to the plane of contact of the fill and the natural ground. As soon as this path of seepage was established a piping action commenced at the point where the seepage flowed out of the fill. From evidences of photographs of the failure, it appears that the effects of the piping action were, first to remove the alluvial materials beneath the rolled fill at this point and thence to progress in an upstream direction gradually eroding out the rolled fill until complete failure occurred. By 5:00 PM the piping action had progressed to a point where

a very large volume of water was flowing through the section of the embankment where seepage first started and it appears that the pipe had by this time progressed completely through the embankment leaving an arch of rolled fill above. (See Photo No. 21364) Complete failure occurred at 5:40 PM and a short time later a large portion of the spillway structure failed due to erosion of the underlying foundation material.

28. The foregoing paragraphs present the undersigned's analysis of failure of Frenchman Dam. From all evidence presented, it appears that failure occurred as a direct result of seepage around the east wing wall of the spillway and thence along the line of contact of the east retaining wall and the embankment. This resulted in a piping and erosion of the natural alluvium constituting a part of the embankment foundation and as the piping action increased and the flow became larger, erosion of the embankment was initiated and progressed until failure occurred. In connection with the failure it is well to point out that the embankment material evidently possessed a remarkable resistance to erosion for complete failure did not ensue until approximately nine or ten hours after piping first started. It is possible that consolidation of the fill since it was placed, had resulted in the development of a small shrinkage crack between the fill and the concrete walls of the spillway which provided for an initial path of seepage. It should be pointed out, however, that there is one primary extraneous factor which contributed to the failure, that is, the subjecting of the structure to the effects of a record flood flow within a few months after its completion. It has been stated that the structure was completed in August 1951, therefore because of low flow conditions which prevailed

during the fall and winter, it was not possible to bring the reservoir to full operating level until the following spring. Full storage was not attained in a gradual manner, but occurred in a very short period of time during the flood flows. This rapid buildup of the pool level undoubtedly subjected the newly built structure to abnormal stresses, and it is to be noted that the hydrostatic head which caused the initial seepage and eventual piping action and subsequent failure was caused by the head of water above the base of the concrete of the spillway crest. It is probable that under less severe circumstances this leak would have developed very slowly and corrective measures could have been initiated in plenty of time to prevent serious consequences. This failure does however point to the importance of checking every contact zone between two materials as well as between fill material and foundation material and to make sure that any seepage path that could conceivably develop is of sufficient length so that corrective measures can be initiated before serious piping action can develop.

J. B. King

JAMES B. KING
Engineer, Civil

BUREAU OF SOILS GRAIN SIZE DIVISIONS

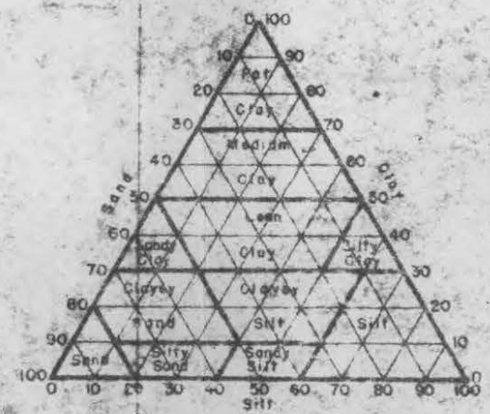
CLAY | SILT | VERY FINE | FINE | MEDIUM | COARSE SAND | MEDIUM | LARGE GRAVEL

SIEVE — MILLIMETERS

PERCENT COARSER

PERCENT FINER

SAMPLE	DEPTH	ELEVATION	DATE	
1				Embankment Material
2				Foundation Alluvium
3				Foundation Alluvium



SOIL CLASSIFICATION TRIANGLE

M.A CURVES
To Accompany
Report on the Failure
of
Frenchman Dam
Fort Peck District
Corps of Engineers

Compiled by	Checked by	Traced by	Transmitted with report	File No.
			Dated:	

Plate No 5

CORPS OF ENGINEERS
FORT PECK DISTRICT
FORT PECK, MONTANA

PHOTO NO. 21382
DATE 4/16/52
TIME 8:15 A.M.

FRENCHMAN CREEK DAM FAILURE

Aerial view of Dam taken the morning after the failure.

CORPS OF ENGINEERS
FORT PECK DISTRICT
FORT PECK, MONTANA

PHOTO NO. 21901
DATE 4/24/52

FRENCHMAN CREEK DAM FAILURE

General view of breached section looking upstream.

CORPS OF ENGINEERS
FORT PECK DISTRICT
FORT PECK, MONTANA

PHOTO NO. 21372
DATE 4/16/52
TIME 6:45 A.M.

FRENCHMAN CREEK DAM FAILURE

Aerial view looking downstream at breached section of dam. By this hour, almost the entire spillway structure had been washed out.

CORPS OF ENGINEERS
FORT PECK DISTRICT
FORT PECK, MONTANA

PHOTO NO. 21370
DATE 4/15/52
TIME 5:45 P.M.

FRENCHMAN CREEK DAM FAILURE

Aerial view at time of failure showing water pouring over breached section of fill on east side of spillway.

CORPS OF ENGINEERS
FORT PECK DISTRICT
FORT PECK, MONTANA

PHOTO NO. 21371
DATE 4/15/52
TIME 5:45 P.M.

FRENCHMAN CREEK DAM FAILURE

Same as photo No. 21370; looking east
from upstream side of spillway.

CORPS OF ENGINEERS
FORT PECK DISTRICT
FORT PECK, MONTANA

PHOTO NO. 21367
DATE 4/15/52
TIME 5:10 P.M.

FRENCHMAN CREEK DAM FAILURE

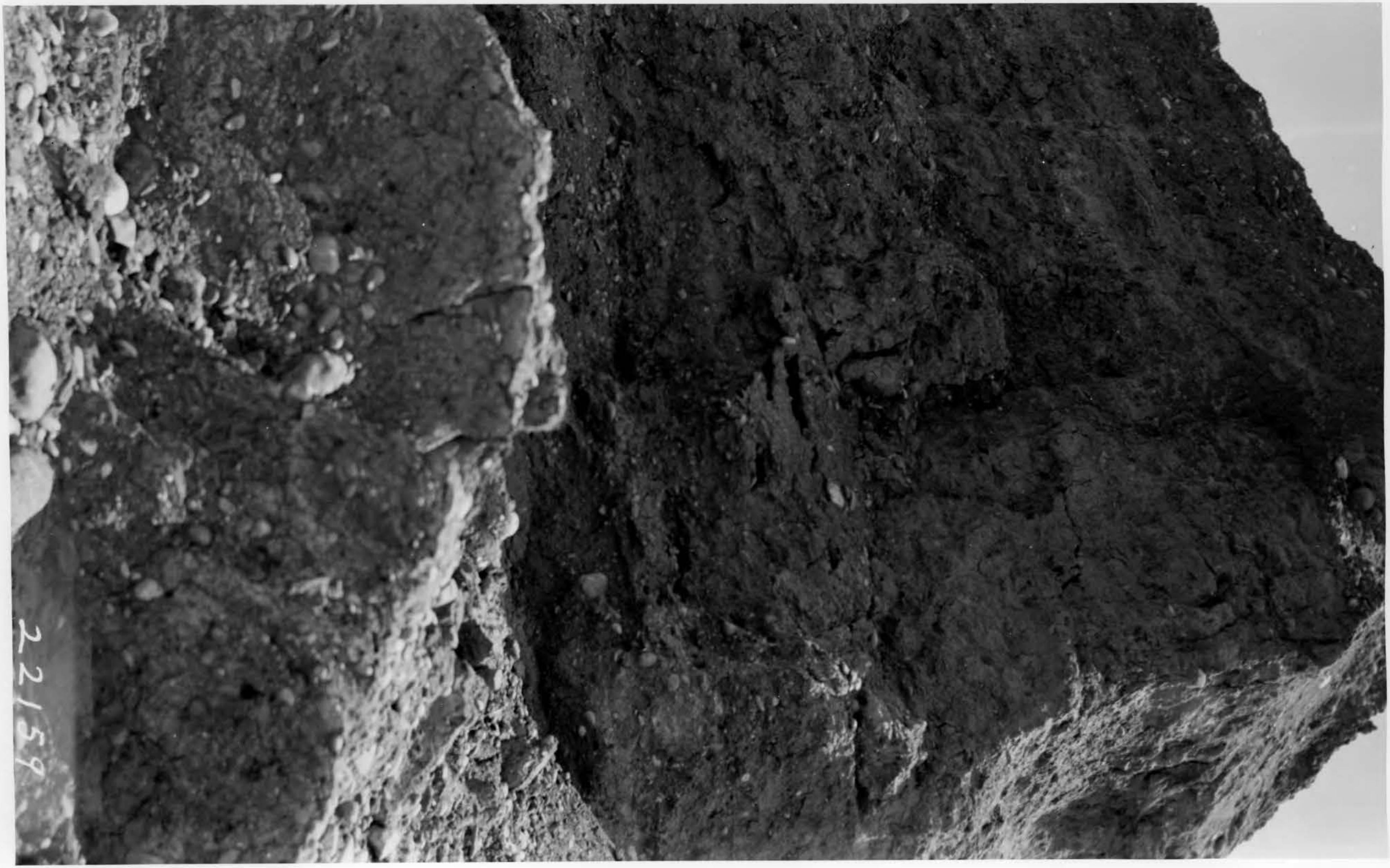
Same as Photo 21364, showing conditions
a short time prior to complete failure.

CORPS OF ENGINEERS
FORT PECK DISTRICT
FORT PECK, MONTANA

PHOTO NO. 21351
DATE 4/15/52
TIME 12:28 P.M.

FRENCHMAN CREEK DAM FAILURE

Aerial view of Dam looking upstream at point where seepage was first noticed.


22/59

CORPS OF ENGINEERS
FORT PECK DISTRICT
FORT PECK, MONTANA

PHOTO NO. 22156 ~~21961~~
DATE 6/4/52

FRENCHMAN CREEK DAM FAILURE

View showing gravel strata exposed in eroded portion of upstream approach channel of spillway.


22156

CORPS OF ENGINEERS
FORT PECK DISTRICT
FORT PECK, MONTANA

PHOTO NO. 22157
DATE 6/4/52

FRENCHMAN CREEK DAM FAILURE

View looking west toward the west spillway retaining wall. Top of wall was originally at same elevation as top of fill in background. Note gravel strata exposed along training wall.


21901

CORPS OF ENGINEERS
FORT PECK DISTRICT
FORT PECK, MONTANA

PHOTO NO. 21364
DATE 4/15/52
TIME 5:00 P.M.

FRENCHMAN CREEK DAM FAILURE

Aerial view looking upstream toward spillway and earth fill showing progress of piping and erosion at 5:00 P.M.

CORPS OF ENGINEERS
FORT PECK, DISTRICT
FORT PECK, MONTANA

PHOTO NO. 22159
DATE 6/4/52

FRENCHMAN CREEK DAM FAILURE

View looking east at portion of rolled fill at east limits of breached section.