THE BUILDING OF A DAM

FRED R. JELLIFF
Daily Register-Mail, Galesburg.

March 13, 1928, St. Francis dam, a year old, spanning Santa Clara valley, California, and behind which was a large reservoir, constituting part of the water supply of Los Angeles, gave way, and the contents swept on to the ocean, destroying cities and causing the death of three hundred people and damages estimated at $15,000,000. Investigations were started and eminent geologists and civil engineers were summoned to examine the site and its formations and rumors of earthquake and fault disturbances, to ascertain if possible the cause of the catastrophe. Early reports indicated that one end of the dam was anchored in shale, susceptible to aqueous action, and the other in a conglomerate. On March 28th, the commission appointed by the governor, found that the dam had a defective foundation. Los Angeles recognized its responsibility in the premises and honorably prepared to meet the bill for damages. It seems that a more thorough examination by expert geologists before the dam was built might have revealed the unsuitability of the shale, and resulted in a different type of construction or the selection of a different site.

In the same year floods destroyed dams in New England, while southern Atlantic seaboard states were in dread lest sundry large dams that were put to a severe strain would collapse.

ILLINOIS EXPERIENCE

To this time dams built in our section of Illinois have not been permanent, as is shown by the experience in the vicinity of Galesburg where there are six reservoirs, the largest of which is Lake Bracken built by the Chicago, Burlington, and Quincy railroad company five years ago. The dams of four of these have at various times been swept away. In June, 1924, there were exceptionally heavy rainfalls, which resulted in the destruction of three dams that subsequently were rebuilt. On September 1, 1926, an unusually heavy rain flooded the Lake Bracken reservoir, tearing up the rip-rap of the spillway and the clays and shales underneath and causing the company a $50,000 expense in concreting the spillway.

When therefore the Atchison, Topeka, and Santa Fe railroad company started last summer to construct a dam over the south fork of Henderson Creek in the north half of sections 32 and 33, Henderson township, northwest of Galesburg, it occurred to us that it would be worth while to note what the preliminary work would be, how extensive would be the effort to ascertain the nature of the formations on which the dam must rest, and what steps would be taken to make the dam secure and permanent. It was learned that the surveys and plans were prepared under the direction of H. W. Wagner, chief engineer of the company, at Topeka, Kas., and that the contract had been let to the Cook-O'Brien construction company.

Topography of the Region

The south fork of Henderson Creek originates at an elevation of 806 feet four miles east of the dam and runs due west. The elevation of the creek at the dam site is 715 feet, so that there is a fall of 91 feet when the dam site is reached. The longer watershed lies to the south of the creek and approximates a mile in width, while that at the north is about half a mile in width. The four longer streams come in from the south, and the shorter from the north. Those from the south descend from an elevation varying from 800 to 789 feet, and those from the north descend from elevations ranging from 800 to 771. There are, in addition, on each side a number of small ravines that reach the creek bottom. As the dam is approached the depth of these tributary valleys and ravines increases until the stream that descends on the south side nearest the end of the dam has a fall (from the watershed) of approximately seventy feet. The topography for two miles above the dam is therefore rough, and the nearer the dam is approached, the more broken it becomes. The steepness of the descent over much of the area means that in case of heavy rains, the volume of the stream is rapidly increased.

The stream near its source is in a very shallow channel at the 806 level, and its bed is composed of soil and subsoil. In the Lincoln park area and east of it there are rounding hills, and after entering the park the stream cuts more deeply, exposing the subsoil and yellow clays. West of the park the creek runs most of the way to the dam on the south side of the valley, and the bluffs display glacial deposits and, farther west, Coal Measure formations, as is proved by the coal vein exposure at the dam site. There is a constriction of the valley as the dam site is neared. The more westerly ravines on the north side show glacial drift and Coal Measure shales, while the existence of the shales and coal below the bottom land is disclosed by the existence of the debris of a coal mine and the well logs made by the company.

PROBLEMS OF CONSTRUCTION

In this Coal Measure valley, with but little actual rock formation for anchorage, the problem of the Santa Fe was to avoid flood damage, to guard the dam as much as possible from leakage or from penetration by burrowing animals, and the shale formations from water in old coal mines, to make sure that these mines did not pass under the dam, and to satisfy itself that there was available a sufficient quantity of impermeable glacial clay for the up-stream side of the dam.

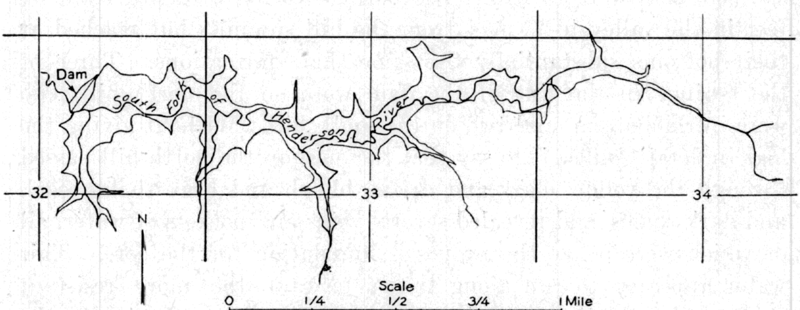

FIG. 1. Sketch map of Santa Fé reservoir northwest of Galesburg.

To ascertain the surface conditions, the engineers went over every foot of the ground to be covered by the reservoir, with a length of a mile and a half and an average width of seven hundred feet, with a drainage district of 7.7 miles, a flood area of approximately 150 acres, and with a capacity of 600,000,000 gallons. They charted every peculiarity of the surface, every sink caused by a coal mine—for the region had been mined extensively—every spring, the lines along which the sheet water appeared, and every soggy place, and took a multitude of levels. For example, all along the north side of the valley sheet water was escaping at a level five to six feet above the valley floor. One quarter of a mile east of the site of the dam, they found the slack of an old mine operated on the bottom itself, and from which a bitter spring was issuing, while on the south side of the valley still farther east they discovered a copious spring the water of which was excellent.

Again, along a ravine a few rods east of the east end of the proposed spillway they located old coal mine workings, and just above the creek level and included in the dam site they discovered a seam of coal exposed with a layer of niggerheads not far above, the only really hard rock encountered.

Borings

As a further precaution, the company caused the sinking of seven borings across the valley along the line of the dam, three across the dam site along the line of the supply pipe and four along the direction that the spillway was to take. Logs were kept of all these borings, and notes were made on the nature of all materials penerated, the levels at which water appeared and in what quantity, and the nature of the formations on which the footings of the concrete core were to rest. The borings varied in depth from 34 feet in the valley to 77 feet from the hill summits but reached at their bottoms substantially the same shale formations. Three of the borings in the line of the dam were on the north hill, two were in the bottom, and two on the south hill. Without giving the logs in detail, suffice it to say that the ones on the north hill passed through the yellow clays and drifts, bluish and gray shales, coal, and dark shales, and revealed several veins and pockets of water, all of which were below the proposed foundation for the core. This water appeared to run along the surface of the more resistant shales and make its way to lower levels. The deepest boring on the south hill showed a deeper layer of drift, then shales, and next an abandoned coal mine, the seam of which was displayed in the creek bank. The north hill side, starting from its summit, was covered with soil, which increased in depth to the valley. The borings in the bottom showed alluvium to the depth of eight to ten feet and, under this, blue and brown shales that were judged hard and durable enough to serve as the foundation of the concrete core across the bottom.

As to the character of the material at the sides of the spillway, a general section, kindly furnished me by Dr. George E. Ekblaw of the State Geological Survey, shows soil, subsoil, silty clay, slightly calcareous silty clay, sandy dense clay, gravel, sand, and finally brown, blue, and mottled and calcareous tills, altogether representing a thickness of thirty feet, with some bowlders of coal and numerous igneous and metamorphic rocks. The till comprises eighteen feet of the section and is of Illinois age.

Having these data on the formation derived from a study of the logs, the engineers felt that the dam to be permanent must be securely anchored, that it must be safeguarded against water seeping through and undermining it, that the abandoned coal mine rooms must be sealed up, and that the reservoir side of the dam must be made as impermeable as possible.

CONCRETE CORE

The main trouble was met in the construction of the fortified concrete core for the dam clear across the valley, a distance of 860 feet. Over most of the bottom this wall, two feet in thickness at the base and one at the top, and fifty-three feet high, extends thirteen feet below the surface of the bottom, and for 330 feet it rests on brown and blue shales. From this central portion, the trench for the bottom of the core extends by a series of steps upward. There are thirteen of these treads, so to speak, on the

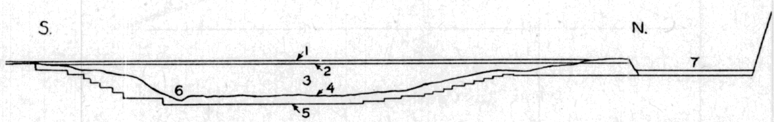

FIG. 2. Lengthwise section of dam, showing step-construction core.

1. Top of dam; elevation, 762 feet.
2. Top concrete core, elevation, 757 feet.
3. Concrete core; length, 860 feet.
4. Ground line; elevation, in bottom, 715 feet.
5. Bottom of core; elevation, central part, 703.2 feet.
6. Stream channel.
7. Spillway; elevation at weir, 752 feet; width at weir, 190 feet.

north side. The lowest two rest on tough, brown shale, the next two on a crumbly brown clay, and the rest evidently on drift and yellow clay, until the last section is reached, which is fourteen feet in height and 160 feet long and is tied into the concrete spillway, and rests on yellow clay. In the south hill the footings of the concrete core rest on shale for seventy feet and on glacial deposits the rest of the way up. The core is anchored in the north hill a distance of 340 feet and in the south hill a distance of 180 feet, with the creek running close to this south bluff.

The dam itself overtops the core five feet, having an elevation of 762. It is 18 feet wide at the top and 256 at the base. The dam is therefore built against this concrete core. From the core the base of the dam extends 134 feet on the reservoir side, with a slope of three to one, and 122 feet on the downstream side, with a slope of two to one. The top of the dam is 45 to 47 feet above the varying ground line of the creek bottom and 51 feet above the pipe line, which extends under the dam. It required 132,000 cubic yards of material to make the dam. On each side of the concrete core there is a layer of puddled clay fifteen feet in thickness at the base and tapering to seven feet at the top. The upstream side of the dam is composed of comparatively impervious glacial clay with a coating of six inches of gravel and twelve inches of hard rock rip- rap. In preparing the ground for the dam, the soil in the bottom was removed to the depth of a foot and the alluvium underneath was then ploughed deeply in paralleled ridges so as to give it a corrugated appearance and then the tough clay of the superstructure was dovetailed into this.

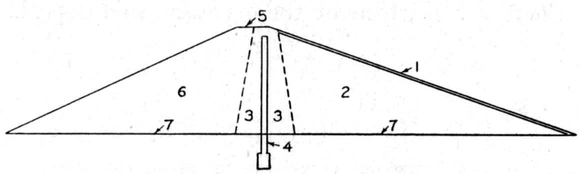

FIG. 3. Cross-section of dam.

1. Reservoir side of dam, paved with six inches of sand and one foot of riprap.
2. Impervious material.
3. Puddled clay core, 15 feet thick at base, narrowing at top.
4. Concrete core, 2 feet thick at base; remainder one foot thick.
5. Top of dam, 18 feet across.
6. Down-stream side of dam, less impervious material.
7. Base of dam, 256 feet across; 134 reservoir side, 122 down-stream side.

Elevations: top of dam, 762 feet; bottom, 715 feet; top of core wall, 757 feet; bottom of core wall, 703.2 feet; normal water level, 752 feet.
Slope: reservoir side, three to one; down-stream side, two to one.

Borings along the line of the 24-inch supply pipe, which extends under the dam, show soil, sand, gravel, and clay before the shales are reached on which the core at this point rests.

TROUBLE WITH WATER

The characteristic feature of this dam is the concrete core. In the construction of this core there was little trouble until the trenching from the north end reached a point about three hundred feet north of the creek, and then a great volume of water gushed up. The logs especially on the north side had shown water at higher levels and also a common water level at the 700 elevation, and it looked as if the water, disseminated throughout the formations and seeking this lower level, had found an outlet at the 712 level when the trench reached that level. Two pumps were set to work and for several months were kept busy, until the concrete wall could be built, extending below this influx stream and cutting it off.

The digging of the trench on the south side was attended with great difficulty. The greatest depth attained was 36 feet, and it was near the bottom at this depth that the old coal mine was struck, with five penetrable rooms in which the props were still standing. Much of this distance was in drift, but the coal mine was some eight feet below this, with niggerheads and a dense blue shale above the coal. The sealing off of these rooms before building the concrete core was no slight task, and extensive propping had to be done. There is still some apprehension, judging from the sink holes, that the mine workings may honeycomb the entire hill, and perhaps cause trouble in the future.

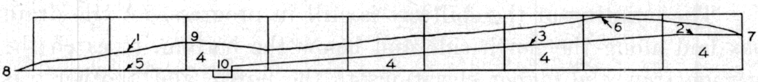

FIG. 4. Profile, north side of spillway.

Scale approximately natural. Vertical lines 100 feet apart.
Length of spillway, 930 feet. Total descent of spillway, 40 feet; elevation at weir, 752 feet; height of weir, 2 feet.

1. Ground line of hill.
2. Floor of spillway, horizontal.
3. Floor of spillway, descent.
4. Flacial clay.
5. Floor of spillway, after leaving well.

6–9. Elevations: *6*, 768 feet; *7*, 750 feet; *8*, 710 feet; *9*, 732.7 feet.

10. Spillway well.

IMPORTANCE OF SPILLWAY

The construction of the spillway on the 750 contour line on the north side of the dam from the summit of the hill was most carefully planned, the engineers realizing that a poorly built and inadequate spillway is a chief source of danger from flood. The per cent of failures from this source is put as high as ninety. The structure is 930 feet long, extending from the contour mentioned to a few rods from the creek. The upper end flares out to a width of 310 feet and a width of 190 feet at the weir, the elevation of which is 752 feet at its crest, the normal water level. The east end of the spillway is level for 100 feet, and from the weir there is a fall of 50 feet to the end of the spillway. The excavation through the hill is deepest, about 24 feet, at the center of the east hill, and about 20 feet, at the center of the west elevation.

From the weir the spillway tapers to a width of 120 feet and then gradually narrows to 50 feet, from which extend the fish tails, which are 88 feet long and 210 feet across at their far end.

It was when the excavation of this spillway was well along that Dr. Ekblaw made his visit and saw the superficial and drift clays exposed, the excavation the entire length of the spillway being in this material, until the alluvium deposits of the bottom were reached. His observations do not appear to differ materially from the logs, save that the logs do not differentiate the clays closely. The engineers tell us that the check-up on the logs during the progress of the work shows that the logs are approximately accurate, and this was our own observation.

It was estimated that 92,000 cubic yards of material were contained in the spillway, and this was largely available for dam construction. Borings going below the glacial clay on the spillway site penerated the Coal Measure formations, and the boring at the crest of the hill disclosed 40 feet of surface materials and clays.

The building of the spillway is still in progress. A tile drain was laid along the north side and below the bottom, to catch the seepage from the higher elevations to the north, and another was laid under the surface of the spillway. The floor of the structure is of fortified concrete nine inches in thickness to the 716 level, where there is a fall of seven feet to a paving two feet in thickness, whence the water flows over the concreted fish tails area to the bottom adjacent to the creek. The sloping sides of the spillway are also protected by a wall of fortified concrete seven feet high and nine inches in thickness.

SAFEGUARDS AGAINST FLOODS

To prevent any possibility of a flood forcing the water over the top of the dam, its top is built ten feet higher than the normal water level, at elevation of 752. The curved weir at the upper end of the spillway is two feet in height. The spillway is ample to carry four feet of water above the weir. To go over the top of the dam the water would have to rise six feet higher.

The engineers believe that they have a dam that can stand the test. They have realized the dangers. It is true that the shales, brought up on the south side of the dam during the core trenching, soon disintegrated when exposed to the rains, because of their lime and possibly sulfur contents, disclosing that such shales have their weak points, but the belief is that the concrete core and the substantial and close construction of the dam will safeguard this material against exposure. It is admitted that there may be some slight seepage through even the concrete, and that the usual swampy place may be found on the down-stream side.

A recent statement in the Decatur Herald says that the concrete apron of the comparatively new dam at Decatur had sprung a leak and that plans were being made to stop it. While the lake Bracken dam south of Galesburg has to date resisted the floods that have assailed it, yet shortly after it was built it developed at its east end a serious leak, which is causing the loss of 500,000 gallons of water daily, and what produces this leak is not yet determined, although the company has spent a large sum in trying to close it.

One cannot see why there should be any considerable seepage through the Santa Fe dam with its concrete core, its hard packed, puddled clay covering, and its glacial clay front, with rip-rap imbedded in gravel.

It must be remembered that the collapse of even a small dam may be a costly thing for a corporation, and that it is likely to cause large damage. We believe that the Santa Fe has exercised great scientific care in the construction of this dam to safeguard it at every point.

Need of Geological Data

All this leads to the conclusion that before the construction of a dam there should first be procured just such topographical and geological information as that obtained by the Santa Fe, and that it would be best for a careful investigation of the site and area to be made early, under the direction of the State Geological Survey, that there may be acquired accurate information regarding the formations and their adaptability for such a structure. It is believed that if this were done and the Survey were kept informed of developments as the work progressed, and its advice sought, dangers arising from underground causes would be largely reduced. This is of especial importance now that reservoirs are multiplying, since both cities and corporations are seeking them more and more as sources of water supply.

All the indications are that when the dam is completed and the reservoir is full it will constitute an addition to the beautiful scenery in the vicinity of Galesburg.