GEOLOGICAL REPORT

on

MATILIJA DAM

Dr. Berkey

ROBERT L. RYAN
County Surveyor
R. L. STUMP
Principal Engineer
KATHRYN NEVILLE
Deputy

COUNTY OF VENTURA
STATE OF CALIFORNIA

OFFICE OF
COUNTY SURVEYOR
COURTHOUSE, ROOM 4
VENTURA, CALIFORNIA

R. E. RICHARDSON
Chief Deputy Surveyor
RICHARD H. JAMISON
Hydraulic Engineer
CHAS. H. MANGOLD
Structural Engineer

July 1, 1947

Honorable Board of Supervisors
Ventura County Flood Control District
Ventura, California

Gentlemen:

Herewith is submitted the official copy of the report of Dr. Chas. P. Berkey relative to Matilija Dam. It is substantially the same as the advance copy, but with some additional memoranda relative to Matilija Dam.

The Matilija Report consists of:

a- Geological report as of May 25, 1947
b- Supplemental memoranda
   1- Rock samples
   2- Field sketches
   3- Photographic record

Attached to the report are the following:

1- A note on Casitas Dam Site
2- Observations on Dam Site of Lower Piru Creek

This report is offered for acceptance and filing for records of the Ventura County Flood Control District.

Yours very truly,

Robert L. Ryan

ROBERT L. RYAN
Engineer Ventura County
Flood Control District

RLR/s
encl.

Filed July 1, 1947
L. R. Hallowell Clerk
by Jamott Deputy

Report

on

GEOLOGICAL CONDITIONS AT MATILIJA DAM

A Report as of May 25, 1947 Pages 1 - 12

with
SUPPLEMENTARY MEMORANDA

No. 1 - On Rock Samples from Matilija Damsite Pages 13 - 15

No. 2 - On Field Sketches of Foundation Structures Under Matilija Dam with Drawings Pages 16 - 17

No. 3 - On Photographic Records and evidence Pages 18 - 22

Attached Hereto Also
The Following Additional Memoranda

A Note on Casitas Damsite Pages 23 - 24

Together with Side Observations on

Damsites of Lower Piru Creek Pages 25 - 28

by
Charles P. Berkey
Geologist

Ventura County Flood Control District

Geological Conditions at Matilija Dam

A Report as of May 25, 1947

by

Charles P. Berkey, Geologist

Matilija Dam is already largely constructed. The occasion for this inspection is doubtless the finding of unexpected physical weakness in the rock formation under a portion of the dam on the left side of the gorge, and consequent reconsideration of the question of safety and procedure.

The importance of the structural condition thus uncovered inevitably revives the whole question of physical stability. In these circumstances it is a fair question whether there may be other equally disturbing and even more obscure features of similar significance, which the very limited exploratory search carried out at this site has failed to reveal.

In this connection it should be noted that the bottom of the gorge was and still is so heavily covered with natural debris that the rock floor condition could not be directly observed. In view of this situation it appears that there has not been at any time an adequate exploratory investigation of the site. Superficial examination and random subsurface tests were apparently considered adequate despite the fact that the local rock formations are well known to be strongly folded and deformed internally with development of minor structures in the form of slips, crush-zones and local displacements, all of which when exposed are potential weaknesses. Even the natural undisturbed formations are not of uniform quality, but are made up of a succession of beds of alternating sandstone and shale of differing quality.

Thus hard members are associated with comparatively weak ones, repeated one set after another in succession.

When such a formation is deformed by folding and powerful crowding as this one has been, it is inevitable that internal adjustments must result in just such structural complexities as are seen almost everywhere in the Matilija district. Under such conditions, no one can predict with full assurance just where the next weakness will be encountered, and in consequence it is more important than usual to make rather detailed exploratory tests before venturing upon an important construction undertaking.

For these reasons, it seems to me, a more systematic program of foundation exploration ought to have been adopted in the beginning. It would have found at an earlier stage the weakness now attracting special attention and perhaps others that have not been discovered. Such a program was evidently not thought necessary and clearly was not done, with the result that it can not be done as thoroughly as is desirable. The dam is placed, the foundation is occupied, the structure is half finished; the practical question is not what should have been done, but what can be done now to advantage in finishing the present structure and in further treatment to make it safe.

The Present Situation

As it stands now only the upper portion of the two abutments can be seen to advantage. There the strata have been exposed by excavation sufficiently for judgement of their character and quality.

The central portion of the foundation can not now be seen although it had been excavated to place the dam, and since there are no core borings, its character and quality has to be judged on the evidence of other observers and such random records as are available.

The dam itself is not involved in this study. This applies to both its fitness in the circumstances and its adequacy in design. It has already been accepted by the State and is clearly out of my field of investigation except as to the competence of the abutments to carry the load and the thrust to come on them.

These parts together with certain other features require additional description and comment, as follows:

The Right Abutment

The rock forming the right abutment is the most substantial and most free from evident internal weakness of any on the site. The sandstone beds are hard and durable and of almost the character of quartzite. The observable weaknesses are only those due to deformation which is registered in part in the fact that all of the strata there are turned up on edge and stand almost vertical or slightly over - turned beyond the vertical. It is noted also that most of the sandstone beds are broken by numerous fractures across the bedding. These latter are the only important internal weaknesses in the individual sandstone beds. In this respect these beds are not at all different from the others of the site except that they appear to be a little more substantial on this right abutment than the other, and stand out in strong relief as a rugged rock-ribbed cliff on the right side of the gorge.

Against these sandstone beds, which are comparatively massive, the dam abuts, and the thrusts of the dam will come almost squarely against them, pressing one bed against another, or against shale beds between, so that the whole adjacent series has to take the load.

This situation introduces the only question of consequence, because the individual sandstone beds of this abutment are separated one from another by thinner interbeds of shale, which is a weaker rock. The chief

question, therefore, is how much will these first two or three interlayed shale beds stand without giving way.

Everyone will agree that the shales are less strong than the sandstones and are more likely to give by squeezing. This is indicated by the fact that they now show thicker and thinner portions as if squeezed to that form by regional deformation. It is also evident everywhere that these shale layers are much more easily affected by exposure to the weather than the sandstones are, and in consequence tend to crumble and soften. Under those conditions they sometimes lose virtually all their normal strength.

Clearly they have to be discounted somewhat as strong resistant members where they have been long exposed. But that is just the situation they are in almost everywhere at the outcrop because they stand on edge, andif one is to bank on them for support against load or pressure, one must remove the affected portion down to a comparitively fresh unaffected level.

This is precisely the condition to be met in the right abutment. The weakened portion of the first two or three shale layers between the sandstone beds at the end of the dam will have to be mined out down to sound conditions across the whole width of the dam section and backfilled with concrete so as to stabilize the abutment at that point.

How deep such mining operation must go cannot be pre-determined. One must judge it as excavation proceeds, and not be over-optimistic or take an unjustified risk,because any failure at such a point would introduce difficulty with the whole dam.

The Left Abutment

The left abutment is somewhat less strong and somewhat less fully

backed by substantial mountain mass than the other. Weathering and disintegration is in evidence more, and there appears to have been more deformation in the form of fracturing and slipping and crushing on this abutment than on the other. This has been realized by the engineers and contractors, and considerable excavation and clearing has been undertaken at this end.

Since being cleaned up by excavation, the face of this abutment shows a succession of conformable reasonably substantial sandstone and shale beds in normal order standing on end or slight over-turned. The quality of the rock is as good as the locality affords, and the bedding structure is not greatly disturbed by minor deformation. Clearly the sandstone beds are the larger and more substantial members, and they are the competent members of this abutment, much as they are on the other one, and apparently strong enough to carry the thrusts of the dam. In order, however, to make doubly sure that the thrusts of the dam, which comes in on this side at an angle, to the strike of the up-standing beds will be amply provided for, it is planned to carry the load by means of a gravity block of concrete covering larger area than the dam section. In this manner the figured load is reduced to such reasonable amount that there is no doubt of its competence.

Such weaknesses as the shale beds, the cross fractures in the sandstone strata, and minor slips, will thus be covered by the new structure, and are not expected to introduce any difficulty whatever. Even the crush-zone of blocks "M" and "N" next to be discussed, has been excavated down and back to firm foundation where it is confined between firm ledges and finally dips down out of the immediate foundation area. At higher levels the rock ledges of this abutment are much weakened by weathering action of the badly deformed formation, but to the proposed height of the dam the better quality continues. The provision made, therefore, for receiving the dam at the left abutment seems to be

entirely adequate, and the proposal to proceed with this portion of the dam at once seems to be a proper step.

The Crush-Zone on The Left Slope

Excavation for blocks M and N uncovered a three-foot crush-zone cutting diagonally across heavy sandstone beds and dipping deeper and deeper down into the rock floor in a down-stream direction. Laterally, to the left, this zone can be traced halfway up the abutment slope where its continuation, somewhat reduced in prominence, slips out of the foundation area and is not considered to be of enough practical consequence to warrant much further treatment.

Laterally, to the right, the crush-zone cuts under present blocks N and M so near to their present bases that it has to be mined out and replaced by concrete, while in farther continuation to the right on strike its outcrop seems to pass out of the foundation area. But it dips down-stream and must continue in that direction, where, because of increasing depth, its influence is lost. Therefore, at depth, beyond the influence of weathering action, its quality for mere support is not questioned.

But what condition it is in under block L is not now known. When the mining-out under block M reaches that area its condition can be seen clearly enough to indicate what to do about further excavation treatment. To my best belief the treatment proposed for blocks M and N is on right lines and ought to establish their stability and protection against failure from foundation trouble. After that is done further treatment in that direction does not seem to be required. But if the zone is too soft to supply firm foundation, more of it must come out.

The Deeper Foundation

The floor sloping down from the left abutment flattens out in the bottom, and, although it gradually deepens to the right toward the right abutment, there is no deep notch or trench. This topography and profile is somewhat surprising in view of the fact that very friable sugary sand rock was found for a stretch of a hundred feet or more on that side. As a matter of fact, the deepest excavation was made over toward and next to the right abutment where sound hard sandstone ledges standing on edge bring in an abrubt change. At that point the bedding structures of the abutment were found to be discordant with the bedding structures of that floor. Traces of deformed bedding structure under the dam head in against the abutment at almost a right angle and are crushed against it. In that area, as shown by crude sketches made on the ground at the time by the engineers and other observers, there was markedly more deformation than anywhere else on this foundation, and in this area much of the rock was crushed and softened. This condition is under blocks D, E, and F, as shown by the field record just referred to above. It is indicated also in certain photographs taken at the time by the engineers, and by samples of the material picked up on the spot.

Furthermore, there is good field evidence of displacement and deformation and much weakening of rock in open view in the gorge wall on the right side just above the right abutment. A sharp re-entrant on that side is literally filled with talus to a depth of 40 or 50 feet at that place. The notch carrying that deposit must have been eroded out to river level at some period before this talus fill could have been accumulated. With that evidence it is certain that one would find some kind of weakness in the floor at that point. The same conditions that accounted for the notch and re-entrant account also for the deformation

and broken condition of the floor in that quarter under blocks C, D, E, and F.

The reason why there is no sharp notch for the channel at this place is because a rib of harder rock, which is essentially a continuation of the right abutment ledges, crosses the stream just below this point,and this barrier tends to hold back rapid erosion by its own protecting resistance.

In my opinion, there is no doubt about the presence of a structural weakness and the reason for its crushed and deformed condition. But that does not fully account for the softened and sugary condition of rock which ought to be firm sandstone. That, I think, must have been due to escaping water, and I believe they were hot waters, not very unlike many other occurances in the region. These waters have leached the natural rock and have further softened it at this point of escape out of the broken zone.

Treatment Problems

On the question of Leaking

Of course there will be some escape of water through the crevices, joints, and bedding planes of the rock, but I do not think it will be excessive or dangerous unless it is allowed to develop an escape channel under the dam. In the course of time most of the bottom leakage will be blocked by silting of the reservoir. But early leakage should be further checked by grouting. Such treatment not only helps prevent escape of water but also serves to solidify and stabilize the foundation and abutments,- all of the rock members of which are considerably cross-fractured.

The grout pattern, both in distribution and in depth, should be worked out to accomplish an effective job of certain grouting along the

forward line of the dam. If confined to a single line, the holes should be close enough together to insure continuous treatment of all weaknesses to an agreed-upon depth. I would think that 25 feet for depth of grout holes would be a minimum requirement. Because of the up-stream dip of these beds, it appears that the grout holes would be much more effective if they are run at an angle directed down-stream, so as to cut slantingly across the bedding structures of the foundation, and thus avoid landing a hole in the same bed on which it was begun. Unless some care is taken in this respect it would be possible, in case of a particularly pervious bed, for the water to pass under the grout curtains, rise along a pervious bed and escape behind the dam.

At most points along the line of the dam such water movement probably would not cause material damage, but, in the section near the right abutment, under blocks D, E, and F, where deformed rock and soft condition is well known to exist, such leakage might develop a dangerous escape channel. At that place a determined effort ought to be made to secure an effective barrier by grouting. In my opinion this place deserves more extended treatment than any other portion of the foundation.

A well thought-out program of grouting is in the interest of tightness, increased stability, and protection against deterioration and damage.

On the Question of Core Borings

There should have been a program of exploratory core-boring in the beginning. Since that was not done I think that a certain number of borings intended for use in grouting should be made with a coring rig to deeper levels than the rest of the series. They will serve the double purpose of exploration and also grouting. One such hole to each block , from blocks C to L carried to greater depth than the regular run of grout holes, is a minimum, I would think. And if any of them encounter questionable conditions

Supplementary Memorandum No. 2

On Field Sketches of Foundation Structure Under Matilija Dam

The accompanying crude field sketches have been copied from the originals recorded in field notes made on the ground, when these portions of the foundation under Blocks C, D, E, F and G were open to observation, by responsible members of the working engineer force engaged on the work.

They are of the nature of private documents in my hands, and, although copied by permission, are in no sense my own discovery, and I do not feel justified in reproducing them as a part of my report, or modifying them in any way.

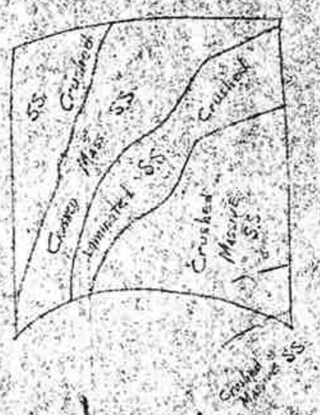
The conditions shown by them, however, are fully supported by the samples of rock referred to in a preceding memorandum, and both lines of evidence have been used in discussing the problems of this site in my report of May 25, 1947. These sketches must be in all essential respects true to life as expressions of what could be seen when the ground was excavated into the rock floor. They constitute a peculiarly valuable form of record in this case. They establish adequate evidence of the nature of the disturbance in a certain quarter of the site occupied by the Matilija Dam. These sketches together with the rock samples submitted herewith constitute the best record we now have of these local conditions.

They should be preserved for future reference because it is more than likely that the physical condition and structural features of this site will be under discussion for some years to come.

Charles P. Berkey
Geologist

Checked and re-edited
June 20th, 1947

BLOCK "D"



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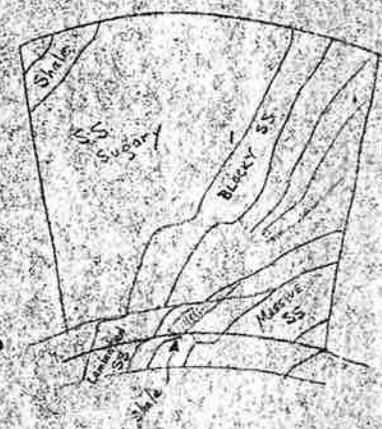

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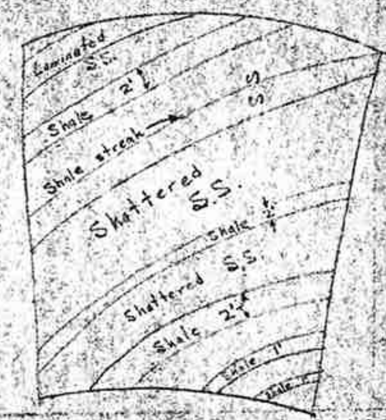


BLOCK "G"

To be attached to memo, No. 2
E.R.A.

Supplementary Memorandum No. 3

on

PHOTOGRAPHIC EVIDENCE

In view of the apparent fact that the weakest portion of the formation was completely covered at the time of my visit to the Matilija damsite and could not be seen, I have followed every line of evidence that seemed to promise any definite information about its actual physical condition. The search has been reasonably well rewarded by turning up several bits of information and factual evidence which together seem to me to establish satisfactorily what the character of this deformed and softened zone under the right quarter of the dam is, and what it means.

These individual discoveries were developed one after another as more or less independent contributions, and as they came, I have described them, telling as well as I could what I think they mean. This accounts for the several Supplementary Memoranda, which now to the number of four are attached to the original advisory report. They should be regarded now as a part of the report.

If I had had the information they carry at the time the original was written, the material they contain could have been incorporated in a single factual and advisory report. Fortunately the situation on the ground showed its character well enough at the time the advance conclusions were given so that no revision or reversal of advice is required. These data simply increase the certainty of the conclusions arrived at and on that account entire re-writing of the advance report is quite unnecessary.

The report is probably more serviceable as it stands, for it shows in that form just how the evidence has to be pieced together to make sense.

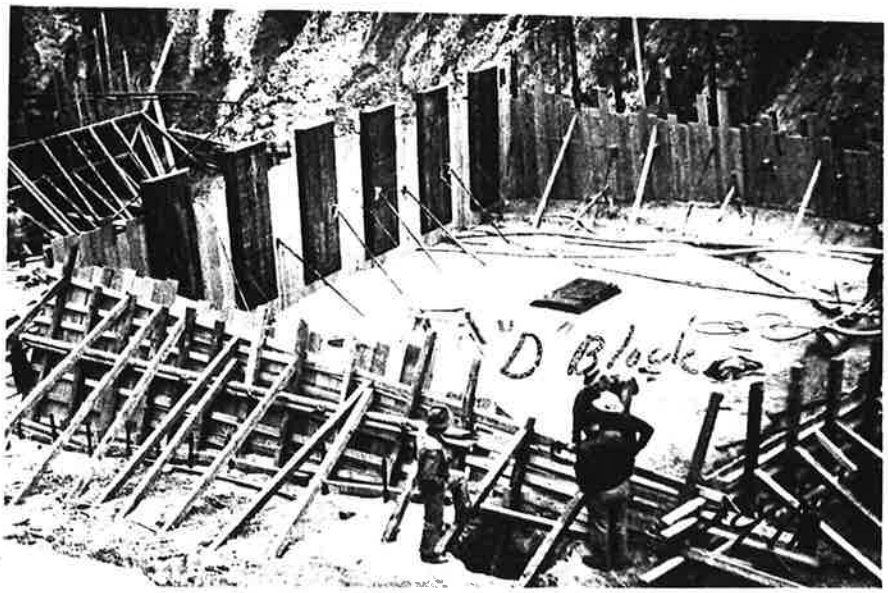
Of course the first line of evidence is from factual observation on the ground,- both the physiographic and the structural features of the site. Those are covered in the advance report, but the rest then had to be inferred. The evidence at that time indicated that there ought to be a very weak deformed zone under the right quarter of the dam; but the inference needed proof.

The required visual proof has been furnished from three very satisfactory sources. The first was rock samples. They finally were forth coming and have been described in Supplementary Memorandum No. 1.

The second was field note book sketches. A very satisfactory sample of these also was found in the field office, and a selected group is reproduced herewith as explained in Supplementary Memorandum No. 2.

Lastly, a few snap shot prints were found among those made by different persons visiting the site, including the engineers on the ground, which show some of the questionable ground fairly well.

They are simply progress records but since they cover some of the critical spots and are consistent with all of the other lines of evidence, they may be regarded as valuable factual data bearing on this matter. They support the verbal reports of the failure to find substantial ledges under certain blocks, the occurrence of softened condition, of whitened sugary sand and of the placing of the first lift of concrete directly on these weakened materials.



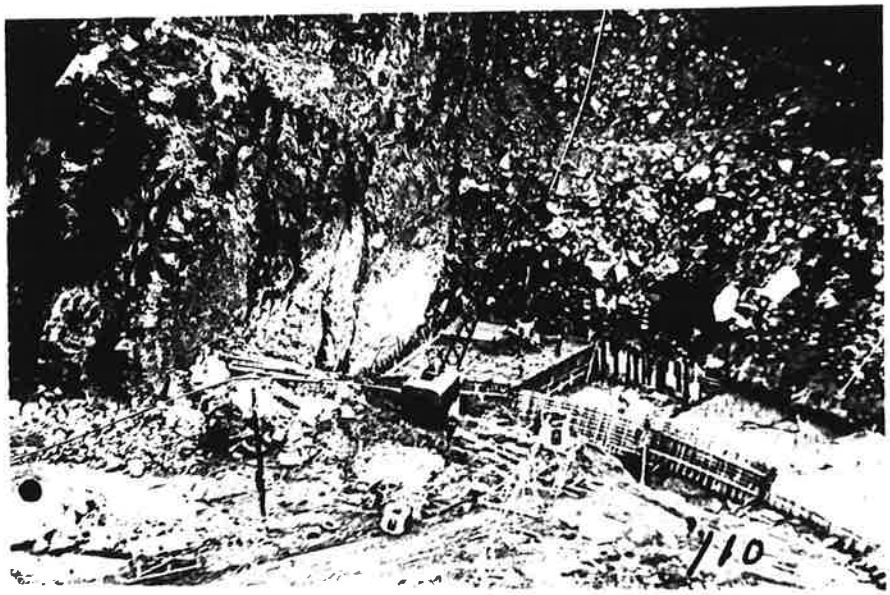
PHOTOGRAPH NO. 1

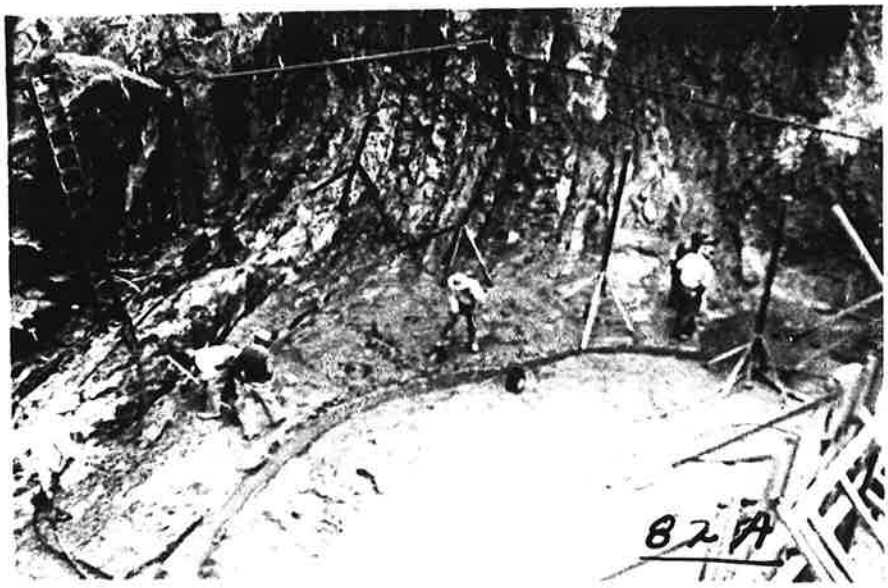
Photograph of the Base and Block D showing only white sand with entire lack of sound rock ledges of any kind. In places such ground as this was said to be have been so soft that marks would be made if one simply walked across the floor. It is such condition that suggests the probability that hot waters and gases have in former time issued from this ground.

PHOTOGRAPH NO. 2

This photograph shows the first 3 or 4 of the blocks beginning at the strong up-standing ledges forming the right abutment. Note that no real rock ledges are to be seen either within or at the edges of these first blocks.

The material on the right far side (the up stream side) is clearly just talus debris, which is a part of the same mass that can be seen at the present surface in the sharp side gulch on the right side of the gorge at that point. It is the occurrence of such materials, coming squarely against sound ledges abruptly in such form as this, that indicates the existence of structural weakness here. Otherside ledges of some kind would show up in somewhat the same manner that they do in the left half of the view.





PHOTOGRAPH NO.3

This is a photograph of an excavation at a point where up-standing ledges of more or less stability begin to come in and take the place of superficial talus and river debris and over-soft rock. Exact location not given.

With these few bits of evidence this contribution is closed. They constitute the only visual evidence now available of the condition of the ground under a portion of the dam.

Although many other similar snap-shots were made, no others as expressive and useful for this study have come to my notice. These few were furnished by the engineers on the ground. But I have not asked the privilege of reproducing them. They are submitted with the official report only and are intended for filing with the records of the Flood Control District.

Charles P. Berkey

Written, June 24, 1947

Charles P. Berkey
Geologist

Supplementary Memorandum No. 4

on

CASITAS DAMSITE

The very brief and rather casual visit made to the Casitas Site was not carried through with sufficient thoroughness to warrant any kind of report claiming independent authority. But I am sure of the broad features and have seen enough of the ground myself to feel confident that a safe dame could be constructed at this place.

The situation is not very complicated. The necessary factual data needed for estimates and planning can be readily secured.

Although it appears that there are certain structural weaknesses in the site, including a small displacement and a land slide, it would not be very difficult to locate and determine their practical significance by a few well placed test pits and borings. I known of course, that some preliminary work has been done. But some additional will be required, including further search for structural material.

With that information I am sure that the important features would be outlined, and that no insurmountable difficulties would be discovered.

An earth-fill dam is indicated. Such a dam with proper cut-off would be certain I think to prevent objectionable leakage. With that provision there would be no danger to any establishments downstream from the dam. A suitably sloped earth dam would not even be very noticeable, for it would appear essentially as a continuation of the ridge already coming up to the gap on either side.

I can see that the owner of the land at the gap might prefer to have the site unoccupied; but, with proper construction, there would be no

danger involved. Whatever other objections are raised of course would have to be met by other offsetting provisions which I know nothing about.

I am aware of the fact that Dr. Bailey, a well known capable geologist and resident of Ventura, has been retained by local interests to make an examination of this site and advise the owners. I would think that his report would present the factual situation correctly, and that his report could be accepted for your own guidance. In any case, it would have to be taken into full account sooner or later even if outside advice were sought. I have had opportunity to visit the site with him, and I am fully convinced that he understands all features of the problem and appreciates what further steps should be taken to eliminate such few remaining uncertainties as there are.

Little more need be said. The site is a feasible one; the difficulties are not great, but should not be ignored. The chief points to guard or cover are:-

(1) the fault zone, which may be pervious and need treatment;

(2) the land slide, which of course shows some local instability of the ground on that side and may involve considerable excavation;

(3) a good dam design, with special attention to
   (a) an effective cut-off structure;
   (b) stability of the dam itself;
   (c) selection of construction material for the interior and shell portions; and
   (d) an approved method of placing.

These latter are not strictly geological matters, but they all figure together in establishing a safe dam.

Palisade, New Jersey
June 20th, 1947

Charles P. Berkey
Geologist

Memorandum

on

THE DAMSITES OF LOWER PIRU CREEK

Opportunity was found under the guidance of Mr. V. E. Freeman to make a reconnaissance of possible damsites of the lower Piru Creek on May 27, 1947. The immediate purpose was to inspect the lower-most of the possible sites for a prospective dam which might be used for conservation of water from stream run-off, and to compare its geological setting with others already considered farther upstream.

The three sites visited include, Blue Point, Devil Canyon, and San Felicia. The farthest one upstream visited at this time was Blue Point, which has attracted attention before and has been partially explored by borings. The next one down stream, known as Devil Canyon, has been under study before also, and appears to have been regarded with some favor. Still further down stream, below the next two tributaries, a new location referred to as the San Felicia site, appears not to have been seriously considered thus far. But, in view of the additional watershed area that could be controlled at this point, and in view of other apparent advantages, this new location seems to deserve enough study to determine its possibilities and make comparison of cost. The following comment is directed to that purpose.

There is no reasonable doubt but that a safe dam of appropriate design could be constructed at any one of these three sites. But whether the amount of water thus controlled is sufficient to warrant the cost, and whether the increase in yield with the respective moves down stream is sufficient to offset the increased cost would require more data than are now available and further study. The cost depends on the local physical

situation in each case, and clearly rises with each move down stream, the chief factor being the increasing width of stream gorge. To this as the chief factor must be added the probable increase of depth of the gorge, character of overburden or river-fill, capacity of the reservoir and availability of good construction material.

The other major matter is amount of water that can be put to use beyond the present usable supply. This latter question is not covered in this present discussion since the necessary data on that matter are not presently available. But, it is realized that the demand for water is increasing and it is assumed that the value placed on supply for the future is increasing in like manner. Perhaps its future value cannot be closely estimated. On the other hand the cost of creating a catchment reservoir can be figured somewhat more directly when the controlling physical conditions are known.

As a step in the right direction therefore, my attention has been given to those geological features which seem to govern whatever development may be undertaken.

Features of the San Felicia Site

At the site inspected, Piru Creek has eroded a broad trench directly across folded sedimentary strata of late geologic age. These strata are foldedand the same beds are repeated at least three times within the range of these three sites. One group of beds of sandstone character is more substantial than the rest and stands out prominently in strong relief with abrupt walls on both sides of the gorge where that formation crosses. Thus it happens that the geology is much the same at both of the lower sites,- San Felicia and Devil Canyon. The same strata are involved

and at both places the beds of rock that would form the abutments are virtually on end and stand out boldly as massive cliffs. The same beds continue under the gorge from one side to the other but are covered.

In each case the valley widens out above the dam site because of weaker rock and side tributaries enter in these areas also, thus providing reservoir capacity.

It appears therefore, that in both cases the topography and surrounding conditions are favorable. The lower one, San Felicia is evidently a good site for a dam. But the gorge looks wider at this site than at the other and there is as yet no basis for judging the depth of overburden on the floor. The only evidence bearing on that question is to be seen down stream a mile or so, where the rock is exposed in a flat floor at very shallow depth.

Clearly the first thing to do is to map the site, measure the width of the gap between the natural abutments, and make tests of depth of cover and shape of floor profile. Until that is done, estimates can not be made of cost.

The abutments are sound to any height likely to be required. I see no danger of any important leakage though the abutments and the floor beneath the overburden must be the same kind of rock. All such water would have to cross these strata consisting of massive sandstones and shale bands and I am sure that there would be very little loss. Whether there is a deeper trench somewhere within this flat looking valley bottom is not known. That matter as well as average depth of cover would have to be proven by borings. There probably is a deeper notch somewhere.

The only defensible type of dam would be an "Earth-fill" type. Such a dam could be made safe against earthquakes and would find suitable construction material in the vicinity.

In view of the possibilities at this place, I would think it desirable to make the preliminary tests and measurements required for estimates of prospective cost as compared with available water supply.

Charles P. Berkey

Charles P. Berkey
consultant