PRELIMINARY STORM DRAINAGE INVESTIGATIONS AND RECOMMENDATIONS FOR EMERGENCY REMEDIAL MEASURES

UNIVERSITY OF CALIFORNIA
AT BERKELEY

UNIVERSITY OF CALIFORNIA
Office of
Architects and Engineers
Berkeley 4, California

May 3, 1963

CHANCELLOR STRONG: (Attention: Vice-Chancellor Kragen)
VICE-PRESIDENT MORGAN:

Via Mr. O. W. Campbell

Master Drainage Plan
University of California, Berkeley

Attached for your information and retention is the report of Lennert and Associates, dated April 11, 1963, entitled Preliminary Storm Drainage Investigations and Recommendations for Emergency Remedial Measures, University of California at Berkeley.

Because the City of Berkeley will soon be underway on part of its storm sewer system which is affected by our storm drainage system, it is urged that The Regents consider it for adoption at their May meeting. I understand that the matter of funding the project, Storm Drainage System Development, will also be considered by The Regents in May.

By copy of this letter I am transmitting the report to each of the other members of the Campus Planning Committee. Discussion of this report will be an item for the CPC agenda of May 28, 1963.

L A DeMonte

L. A. DeMonte
Campus Architect

LAD:km
Enc.

cc: Mr. T. D. Church, w/enc.
Mr. D. W. Reed, w/enc.
Mr. W. W. Wurster, w/enc.

LENNERT AND ASSOCIATES
SOILS ENGINEERS
310 FOREST STREET, OAKLAND 18, CALIFORNIA
TELEPHONE: OLYMPIC 3-6223

Job Number 260

April 11, 1963

Office of Architects and Engineers
University of California at Berkeley
Berkeley 4, California

Attn: Mr. George H. Kimball, Principal Engineer

Re: Preliminary storm drainage investigations and emergency remedial measures at the University of California at Berkeley.

Gentlemen:

Transmitted herewith are the final sections of our report covering the services of this office in the subject matter under your authorization of September 18, 1962. The various sections of this report have been transmitted as completed over the course of the past winter, and two complete bound copies of the entire report are transmitted herewith for your records. As of the date of this letter we feel that the program of necessary emergency remedial work is well defined and that the most critical items have been completed; and that our composite report defines the overall storm drainage conditions on the campus sufficiently clearly so that you may proceed with long-term planning and interim remedial work. The purposes of the work covered by this authorization have thus been accomplished.

Certain important matters have come to our attention which are not clearly pointed out in our formal report, either because they have only recently arisen and/or because they have only recently become apparent as our grasp of the overall picture has improved during the course of preparation of the summary of our findings. These matters cover aspects of the program of "emergency remedial measures", the long-term improvement of campus storm drainage facilities, and certain considerations regarding interim measures if construction under the long-term program cannot be started this year. A brief discussion of these items is given hereafter.

Comments are given concerning certain aspects of the emergency remedial program, as follows:

The program of removing groins in lower Strawberry Creek has been progressively carried forward during this winter, as runoff from the rains has degraded the creek, removing accumulated bed material and revealing the new bottom at each stage of groin removal, and allowing the planning of further controlled deepening of the creek. The initial "emergency" program originally envisioned is now essentially completed, and we are entering a new phase of permanent rehabilitation of the stream channel. We have now arrived at the point where further removal of groins should be done with considerable caution, as further deepening of the channel without overall planning will begin to create unstable embankments in some areas, and require the underpinning of some abutting facilities. The stream channel is still grossly inadequate, and much further work is still required, but some corollary embankment stabilization and similar measures must now accompany further deepening of the channel.

The existing remains of the original "grizzly" at the inlet to the Big Inch storm sewer has been purposely left in place, so as to reduce the inlet capacity of the system and give some protection to lower Strawberry Creek from a large increase in peak discharge rate from the storm sewer. This remaining structure should not be removed, nor the inlet system modified, until corollary improvements in the lower Strawberry Creek system have been completed such that the resulting increased peak flow rate can be handled by the lower creek system.

The inlet system, and especially the wooden "grizzly", at the entrance to the City storm sewer at Oxford Street must not be altered until the effects of increased injection of peak campus runoff into the sewer have been carefully studied, and measures have been taken to assure that such changes will not produce severe problems in the City system below.

The program of construction of rock groins in Chicken Creek, to stabilize the slide conditions, halt erosion, and stabilize the creek bed, has been gratifyingly successful to date. Helped by the erosion and deposition from recent rains, this groin system is rapidly becoming effective and is stabilizing the lower section of the creek. The program of construction of these groins should be continued without interruption, as described in our letter dated March 25, 1963.

With regard to the initiation of a program of long-term improvement of campus drainage facilities the following comments are given:

The item of highest priority is the construction of a new inlet system to the Big Inch storm sewer and the simultaneous reconstruction of lower Strawberry Creek; as this will provide a system adequate to carry the presently large and continually increasing peak flow rates from Zone IV to Oxford Street without flooding and damage in between. The reconstruction of lower Strawberry Creek must be completed prior to putting flow from the new inlet system into the creek, as the creek could not conceivably carry this flow rate at this time, and disastrous flooding, erosion and damage to lower campus facilities would result if this were attempted.

The new inlet system to the Big Inch storm sewer should be moved upstream and raised in elevation, as discussed in our report, and should include a surface diversion of peak flow rate in excess of that calculated for a "ten year" storm, down North Canyon Road to Gayley Road, thence to University Drive, and thence to Oxford Street.

The new inlet system and culvert at Chicken Creek must be constructed at the same time that the new inlet system to the Big Inch storm sewer is constructed, since this new culvert must then connect directly to the storm sewer conduit.

The reconstruction of lower Strawberry Creek must be such that the creek can carry the peak output of the Big Inch storm sewer, plus any other injected flow, without flooding or damage to adjoining campus facilities. This will involve major channel improvements down to about Dana Street, and a combination of channel improvements and intentionally permitted overtopping and area flooding below. Whatever peak flow rate is developed in the watershed area which is in excess of that which can be carried in lower Strawberry Creek without turning the creek into an esthetically repulsive "open storm sewer", will have to be handled in a peak-flow bypass system involving flow down Gayley Road and University Drive to Oxford Street.

The existing diversion of peak runoff from the Rad. Lab. area into the "Gayley Road Area" must be re-diverted to the Blackberry Creek system, but only after necessary measures are taken to assure that severe flooding and damage will not result in lower areas.

All of the above measures must be taken in correlation with the master drainage plan discussed in our report, and can not be designed and executed until at least part of the master drainage plan is completed.

Considering the time available for preparation of a master drainage plan and the design and construction of improvements in campus storm drainage facilities prior to the coming winter, it seems doubtful that the above measures can be completed in this period under an orderly and efficient program. It therefore seems wise to consider what interim measures might be taken this year to provide maximum protection during the winter of 1963-64, without overlapping with later permanent measures or wasting of funds. In this regard we offer the following comments:

It seems unlikely that it will be possible to complete construction of the long term items described above prior to the coming winter. We will thus face the hazards of both flooding down Strawberry Canyon, as happened this year, and the gross overloading of lower Strawberry Creek. We could greatly reduce the danger to Strawberry Canyon by removing the remains of the original "grizzly" at the entrance to the Big Inch storm sewer, thus considerably increasing the inlet capacity of the system; but this will entail greatly worsening the dangers in lower Strawberry Creek due to the injection of a greatly increased peak flow rate. Comparing the potential damage inherent in the two choices, we feel that it is far preferable to pass unmanageable peak flow rates down Strawberry Canyon, flooding the Haas Recreation area again, than to put this flow into lower Strawberry Creek with the virtual certainty of truly disastrous results. "Splitting" the flow by allowing a large part to go down the storm sewer, as it is now set up, greatly reduces the potential peak flow in the canyon, limiting possible flooding and damage. We therefore recommend that if the permanent measures discussed for lower Strawberry Creek are not taken prior to the coming winter, that the existing obstructive remains of the original "grizzly" at the entrance to the storm sewer be left in place to limit the input of flow to the lower campus area via the storm sewer. If some reconstruction of lower Strawberry Creek is accomplished this year, the matter will have to be considered this fall in consideration of the work actually accomplished.

The flow from the Rad. Lab. area into the Gayley Road area, causing the erosion at Stern Hall and the flooding at Cowell Hospital, cannot be returned to the Blackberry Creek system until the City has had ample time to take necessary measures to handle the increased flow. In the light of recent developments it does not seem likely that the City can or will move rapidly in this matter, and this seems to preclude the early re-diversion of this flow, making interim measures necessary. We therefore recommend that the emergency measures described in our report be taken at Stern Hall and Cowell Hospital prior to next winter.

If nothing else in the way of actual physical improvements of the campus storm drainage system can be accomplished prior to the coming winter, we strongly urge that at the least some further interim remedial work be done in lower Strawberry Creek in the area between Faculty Glade and Dana Street, as this area appears to be the most likely location of serious trouble next winter.

We have been fortunate in not experiencing a repetition this winter of the heavy peak flow rates which occurred in October 1962; and thus, though there has been a considerable amount of well distributed precipitation this winter, no further severe flooding conditions have occurred. It must, however, be expected that the next winter will produce peak flow rates comparable to those experienced in October, and that the campus drainage system will once again be tested in its capabilities to handle the peak flow and avoid the flooding and damage seen this past winter. In addition the continuing developments in the Rad. Lab. area, and particularly the construction of the new road to Grizzly Peak Boulevard this summer, will further increase peak flow rates and the "pressure" on the campus drainage facilities. While the emergency measures taken thus far have improved the situation considerably, they in no way represent a final solution to present drainage problems, exclusive of future increases in peak runoff rates. We therefore most strongly recommend that the present program of improvement of campus drainage facilities be continued in one form or another without interruption, and on an orderly basis, with the work scheduled so as to resolve the most serious problems first to the extent that the overall campus drainage picture will permit.

Respectfully submitted,

B. J. Lennert
Registered Civil Engineer
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BJL:cz

LENNERT AND ASSOCIATES
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Job Number 260

March 30, 1963

Office of Architects and Engineers
University of California at Berkeley
Berkeley 4, California

Attn: Mr. George H. Kimball, Principal Engineer

Re: Preliminary evaluation of storm drainage conditions at the University of California at Berkeley.

Gentlemen:

Final report is hereby rendered upon a preliminary evaluation of storm drainage conditions on the Berkeley campus, begun in October 1962, continued through the winter of 1962-63 with observations of the actual performance of the watershed and drainage facilities, and brought to completion on this date. Our work has had two basic purposes, the first being to determine the major sources of immediate danger of severe flooding and erosion and to recommend immediate emergency remedial measures to prevent or minimize flooding and damage during this winter. The second purpose has been to roughly define the fundamental aspects of storm drainage and related problems of flooding and erosion on an overall campus-wide basis, to allow the formulation of a long-term program which will solve existing problems and prevent the development of still worse difficulties in the future. The first purpose has been accomplished by the issuance of recommendations for emergency remedial measures during the course of our work, and these measures are essentially completed at this date. The second purpose has been effected through the gradual development of an overall picture of the storm drainage regime on the campus, and the presentation of this picture is the primary purpose of part of the sub-sections of this report and of this letter of transmittal and summary.

The scope of the area, problems and technology covered in this report is both extensive and complex; and the accompanying sub-reports, while limited in extent, together represent a somewhat voluminous presentation. This office has spent many months in gathering and digesting information, forming an understanding of the overall picture of the problems or area involved, and in preparing these reports; and our work has involved much material not included in the reports for the purpose of brevity. In addition, the composite overall picture evolved in the mind of the principal of this office is difficult to present in company of the detail given in the sub-reports. In consequence of these considerations, we have prepared a summary of our findings with regard to the overall campus storm drainage regime, and present this summary below. Reference is made to the individual sub-reports for the detailed background of the summary given hereafter.

The campus as viewed from the geographic-geologic-hydrologic viewpoint has a different appearance than might be seen when thinking only in terms of cultural-architectural considerations. The area is thus briefly described from these engineering aspects, important to the understanding of the storm drainage regime at the campus, as follows:

> The campus can be divided on a geographical-geological-hydrologic basis into two separate areas, one the flatter alluvial fan area of the lower campus, in which most of the existing development is located; and two, the steeper bedrock hill area to the east, in which development is now becoming important hydrologically. For general purposes Gayley Road can be considered to be the dividing line between the two areas, and this road does in fact form an artificial diversion line of considerable importance to the existing storm runoff pattern.
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> Referring to the contours shown on the general site plan it is seen that the area west of Gayley Road is nearly flat, the area to the east lies in the steep westerly slope of the Berkeley Hills, and the two areas are thus quite dissimilar geographically. The upper area is characterized by steep slopes, relatively high relief and a well developed ridge-canyon topography, resulting in rapid concentration of runoff. The area is separated into two basic watersheds, one that of Strawberry Creek, and the other of Blackberry Creek. The lower area is essentially tabular, with a gentle slope to the west, showing little relief and a broad runoff flow pattern in the natural condition.
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> Geologically the two areas are quite dissimilar in both subsoil-bedrock and structure. The Hayward Rift Zone passes nearly parallel to and quite close to Gayley Road, and produces a discontinuity in the bedrock across the Rift. West of Gayley Road the subsoil consists of Pleistocene alluvial deposits resting non-conformally upon bedrock of the Franciscan Formation of Jurassic age.

The alluviums vary from soft geologically Recent sediments of the Temescal Formation to quite firm, moderately indurated older alluviums of the Cal Formation of earlier Pleistocene age. The Temescal Formation sediments are soft, highly erodible, and show poor stability in stream embankments. The Cal Formation strata are generally clayey, resist erosion, and are relatively stable when excised by stream erosion. In areas where campus stream beds are eroded down to the Cal Formation the stream bed generally stabilizes in this more resistant sediment. The Franciscan Formation rocks are generally hard and well indurated, are stable at steep slopes, and are nearly non-erodible except where highly sheared along the Rift zone. East of the Rift zone the bedrock is generally very shallow, and geologically Recent sediments are found only in existing stream beds. The rock ranges from hard, resistant Franciscan Formation at the base of the sequence, through marine sediments of the Monterey or Claremont Formations (Miocene), through fluvial and lacustrian sediments of the Orinda Formation (Pliocene) to the basaltic volcanics and associated sediments of the Grizzly Peak Formation (late Pliocene) at the top. The rocks of the Franciscan, Claremont and Monterey Formations are generally well indurated, resist erosion and are stable at quite steep slopes. The rocks of the Orinda Formation, and the sediments and tuffaceous members of the Grizzly Peak Formation, are generally poorly indurated, soft, relatively easily eroded, and unstable at steep slopes. The Orinda sediments and the sediments and tuffaceous members of the Grizzly Peak Formation form the bulk of the upper campus area, and the generally poor soils properties of these materials predominate east of Gayley Road. Thus the lower area is generally stable soils-wise, with little erosion, sliding or sloughing; while the upper area is grossly unstable, with much erosion and numerous landslides, producing heavy bedloads in the streams at peak runoff.

Reference is made to reports of this office covering soils design recommendations for Residence Hall Number Three and the Environmental Design Building, dated July 21, 1961 and March 7, 1962, respectively, for a more complete discussion of the geology of the Berkeley campus.

Hydraulically, the lower campus area is essentially fully developed, with no appreciable increase in runoff for many years, and local runoff has long since been taken care of as far as the overall drainage pattern is concerned. Excepting for local difficulties due to undesirable local geometry, the only major flooding problems in the lower campus area are due to the heavy peak runoff now resulting from development of the upper campus area; and without storm flow from the upper area the lower campus area would not now have any major storm drainage problems. In comparison, the upper campus area has only recently been appreciably developed, old established runoff patterns and runoff rates have been and are being grossly altered, and much flooding and erosion has occurred and is currently worsening. Due to the large area, steep slopes, relatively impermeable soil, and rapid concentration of flow in the gullys, roads and other high-velocity flow channels, the peak runoff potential of the upper area is much greater than the lower area, with attendant greater hazards of erosion and flooding as development progresses. In addition, all storm runoff from the upper area passes through the lower campus, via either Strawberry Creek, Blackberry Creek, or by other routes due to artificial diversion, eventually reaching the inlet to the City storm sewer at Oxford Street. Thus in the lower campus area the major present storm runoff problem is the transmission of flow from the upper area without flooding or erosion; while in the upper campus area there are now, or will be in the future as development progresses, many local problems in addition to the necessity of controlling flow through the lower campus area so as to eliminate existing problems and avoid the creation of new ones as development of the upper area progresses.

Thus when viewed from the standpoint of disposal of storm runoff the campus is naturally divided into two areas: the lower area, now nearly fully developed and without major local problems, but experiencing severe distress from runoff from above: and the upper area, which is not only experiencing local difficulties from storm runoff problems, but in addition, the runoff from this area has severely damaged the lower area to date and much worse results are to be expected as development of the upper area progresses, unless adequate preventative measures are taken. The lower area has no effect upon the upper area, excepting as it poses the danger of flooding and damage from runoff from the upper area. In the upper area we must consider not only the local problems of storm drainage disposal, but in addition, the effects which this storm flow is now having or will have upon the lower campus area. It is suggested that the reader refer to the General Site Plan, herewith, to visualize the above information. Attention is called to the upper Strawberry Creek watershed, Zone IV, which is outlined in green, and to the Blackberry Creek watershed, Zone VI, which is outlined in blue. Note that these two zones, together with the Gayley Road Area and the small area above the lower portion of North Canyon Road, constitute the upper campus area.

In the course of our investigations in this matter, we have divided the campus into natural subdivisions as dictated by considerations of storm runoff. As previously described, these zones were established in order of the severity of present danger of flooding and the necessity for emergency remedial measures, but each zone represents a logical, natural unit as seen from the standpoint of storm runoff. Referring to the General Site Plan, on which these zones are shown, and to the discussion of each of these zones given in the subsections of this report, a cursory description of each zone and its hydrologic aspects is given in logical sequence, without regard for the original numerical order.

Zone IV covers the watershed area of Strawberry Creek above the entrance to the Big Inch storm sewer, an area of some 700 acres, or about two-thirds of the total upper campus area. Only a small portion of the area is developed at this time, but due to the steep slopes, low soil permeability, and rapid concentration of flow along roads and in relatively mature canyons, accumulation times are short, runoff coefficients are high, and peak storm flows are now severe. As the area is developed and roads are built the peak runoff quantities will steadily increase. We estimate that at this time the peak runoff from this watershed for a "ten year" storm will exceed the capacity of the Big Inch storm sewer. It is the runoff, and bed and float loads, from Zone IV which have plugged the Big Inch storm sewer inlet, flooded the Haas Recreation area and International House in recent years, and which currently threatens lower Strawberry Creek in the highly developed lower campus area.

Zone I covers the Chicken Creek watershed within the bounds of Zone IV. Chicken Creek was separately considered because of the severe flooding, erosion and landslides in this canyon, due to diversions of flow into the canyon from the Rad. Lab. area. The flow from Chicken Creek was the cause of the first flooding of the Haas Recreation area during the storm in October 1962. Note that Chicken Creek empties into Strawberry Creek just above the inlet to the Big Inch storm sewer.

Zone V covers the watershed area above the Botanical Gardens. It was investigated because of the severe damage to the Botanical Gardens during the storm of October 1962. We concluded that the heavy bedload of coarse boulders which was carried down the creek and destroyed the Japanese Pool was due to the end-cutting of a rock groin upstream of the Garden, with resulting release of the coarse bed materials entrapped above the groin. In addition, the inlet to the twenty-four inch diameter culvert through the Garden is grossly inadequate. The Garden area will undoubtedly flood again if not properly protected; but we do not think that a heavy boulder-load will again come down the creek, considering the recent repair and strengthening of the groin.

Zone VI covers the watershed of Blackberry Creek above the outlet of the City storm sewer just southwest of North Gate, and together with the Gayley Road Area comprises the westerly portion of the upper campus area. Zone VI encompasses some 160 acres, or about 15 percent of the upper campus area, and drains to Blackberry Creek. This creek is in turn intercepted by a City storm sewer at Highland Court, which in turn empties into Blackberry Creek in the lower campus area just southwest of the North Gate. Due to diversions of storm flow from the Rad. Lab. area into the Gayley Road Area, this zone does not now carry its rightful share of storm runoff into Blackberry Creek, resulting in an artificially low peak storm runoff in Blackberry Creek at this time. The runoff from this area will normally reach the City storm sewer at Oxford Street via Blackberry Creek in the lower campus area, but we believe that at peak storm runoff much of the flow from the "City" area of the watershed is diverted via Hearst Avenue to Oxford Street, without passing through the storm sewer or the lower portion of Blackberry Creek. Blackberry Creek and the interceptor sewer from Highland Court to North Gate are important at this time mainly because they will have to take a greatly increased peak flow in the near future if the present diversions in the Rad. Lab. area are re-diverted into Blackberry Creek.

Zone III is the Big Inch storm sewer, which intercepts Strawberry Creek just above the Haas Recreation area and discharges the flow back into the creek at Faculty Glade. The sewer was built to replace the "Little Inch" storm sewer, a small diameter pipe that was laid to allow the filling of Strawberry Canyon and the construction of Memorial Stadium. The storm sewer wholely diverts Strawberry Creek when it functions properly, and has allowed the filling and development of a portion of the upper Strawberry Canyon area, with the most recent construction being the Haas Recreation Center. On the numerous occasions when the storm sewer inlet has plugged during periods of peak runoff, severe flooding has occurred in the canyon area below the inlet. As the inlet has always plugged during peak flow periods in recent years, there has been no valid demonstration of the hydraulic adequacy of the storm sewer, but we estimate that it is not now adequate to carry a "ten year" peak flow from the Zone IV watershed area.

Zone II consists of lower Strawberry Creek and that portion of the lower campus area which abuts the creek, with the north and south boundaries of the area being arbitrarily set at University Drive and Bancroft Way, respectively. The runoff from this area adds to the flow in lower Strawberry Creek, and it is this area which is threatened by flooding, erosion and deposition of bed and float loads by peak flows from upper Strawberry Creek. As the storm sewer has always malfunctioned during peak flows in recent years, diverting peak flows down Strawberry Canyon and into the Haas Recreation area and International House, the effects of the dumping of the full peak runoff of a heavy storm, and accompanying bed and float load, from the storm sewer in lower Strawberry Creek at Faculty Glade has yet to be seen. Recommended emergency remedial measures were set up to try to at least partially prepare lower Strawberry Creek to carry the flow, as well as the bed and float loads which will accompany the peak runoff. Note that with the emergency remedial measures taken to improve the functioning of the inlet system of the Big Inch storm sewer, peak flow and accompanying bed and float loads will reach lower Strawberry Creek during the next severe storm.

The "Gayley Road Area" was set up because it is unique hydrologically, as explained in the sub-section of this report entitled Zone VII. This area is isolated hydrologically, should not be subjected to flooding, and is presently the site of severe erosion and flooding only because of artificial diversions of peak runoff.

The area above North Canyon Road, east of the Gayley Road Area and west of Zone IV, is an isolated side-slope of the main ridge which separates the watersheds of Strawberry and Blackberry Creeks. Except for diversions from the Rad. Lab. area above, the indigenous rainfall on and natural runoff from this area is minor. Runoff from this area enters culverts leading to the Big Inch storm sewer at low runoff rates, and flows down North Canyon Road toward International House during periods of peak runoff. Hydrologically this area is not important at this time.

The area lying between Zone II and Hearst Avenue drains to lower Blackberry Creek. At this time we find no storm runoff problems in this area except for minor flooding due to adverse local geometry.

The above discussion very briefly covers the campus area in terms of the zones set up during the course of our work. Reference is made to the sub-sections of this report covering these areas, in which each area is more fully discussed. Note that these areas form a "converging" runoff geometry which "focuses" at the entrance to the City storm sewer at Oxford Street, the final outlet for all campus storm drainage. Note further that the key areas in the campus runoff regime are Zones IV and VI, as yet largely undeveloped, and that they are the source of most of the present serious storm drainage problems, as well as the potential source of much more severe problems in the future. Note that these two areas encompass some 800 acres, or about three-quarters of the total campus area, and that only about twenty percent of this area is now fully developed, in comparison to almost total development of the lower campus area.

With the foregoing information as a basis, a very brief summary of the outstanding aspects of the campus storm drainage regime and the most important existing and potential flooding-erosion problems is given below. In order to make the summary as brief as possible the background information from which these opinions were formed has been excluded, and the reader is referred to the sub-sections of this report for substantiating information. Reference to the General Site Plan will help in visualizing the following material.

All storm drainage from the campus finally enters the City storm sewer at Oxford Street. This flow enters via lower Strawberry Creek, which passes through the lower campus area, is intercepted by the Big Inch storm sewer between Faculty Glade and the Haas Recreation area, and then drains Zone IV, an area comprising about two-thirds of the total campus watershed. In addition, Blackberry Creek joins lower Strawberry Creek just above Oxford Street, draining Zone VI, roughly one-eighth of the campus area. The bulk of the campus area thus drains directly through the two creek systems, of which Strawberry Creek is by far the largest and most important. All areas not included above, such as the "Gayley Road Area" and the northerly side of the lower campus area, drain to the creeks by devious routes, with various points of entry. Excepting for local flooding due to undesirable local geometry, all areas other than Zones IV and VI would be free from problems of flooding and erosion were it not for hazards due to the peak flows from IV and VI, either in the creeks or via artificial diversions.

The upper campus area, essentially Zones IV and VI, are just reaching the point of development where severe internal problems are developing. A typical example is that of Chicken Creek, Zone I, where massive diversions of peak runoff from the Rad. Lab. area have caused severe flooding and erosion in the canyon, triggered major earth sliding, produced serious bed and float load injection into Strawberry Creek, and threaten the poultry research facilities located in the canyon. Had emergency remedial measures not been taken in Zone I this past fall, very severe damage and loss would have resulted.

The flooding and destruction of the Botanical Gardens was due mainly to the end-cutting of an upstream rock groin, coupled with malfunction of the culvert which bypasses the creek under the Japanese Pool, with resulting release of a large quantity of peak flood flow and coarse bedload material into the garden area. This occurrence could be termed a "hydraulic accident", due to local inadequacies rather than to basic area drainage problems.

Greatly increased peak flows from development of the Rad. Lab. area, and artificial diversions of peak flow from the Rad. Lab. area into immature channels totally inadequate to carry the flow, accounts for a large part of the current flooding and erosion problems. The development of the upper campus area has created the basic causes for the erosion south of Stern Hall, the flooding at Cowell Hospital, the flooding along lower North Canyon Road, the erosion and flooding in Chicken Canyon, and the numerous developing points of erosion and flooding along North Canyon Road above Chicken Creek.

The recent flooding of the Haas Recreation area, and to some extent of International House, in October 1962, was due to malfunctions of the inlet system to the Big Inch storm sewer. The first occurrence took place because massive flood flow from Chicken Creek diverted around the inlet to the sewer and a <u>partial</u> diversion occurred down the canyon. The second occurrence took place because the "trash rack" at the inlet basin plugged, and <u>part</u> of the peak flow diverted around the inlet and down the canyon. In both instances we believe that if the diversions had not taken place as they did, the "grizzly" at the entrance to the pipe would have plugged anyway, and conceivably an even more destructive <u>total</u> diversion would have occurred. The inlet system to the Big Inch storm sewer was and is incapable of handling either the peak flows or the large bed and float loads transported thereby.

The inlet system to the Big Inch storm sewer is inadequate both because it is hydraulically inefficient and because it was designed to trap incoming bed and float load, and does so at the price of "plugging" and diverting peak flows down the canyon. The Big Inch storm sewer thus does not function at the times when it is most needed, namely during peak flows, and it has malfunctioned and caused flooding in the canyon during all three peak runoff periods of the past five years. The pipe is probably inadequate to carry the flow from a "ten year storm" at the present level of watershed development; but this cannot be judged by recent performance as the inlet has malfunctioned during every peak flow which might have "tested" the pipe capacity.

International House was flooded twice in October 1962 because no curb was existent along the shoulder of the road around Memorial Stadium which abuts a large "hole" in back of International House. Peak flow simply "jumped" the shoulder of the road, filled the "hole", burst through lower windows facing the "hole", and poured through the building.

The erosion gully south of Stern Hall is due to diversion of peak runoff from the Rad. Lab. area down the swale in the Cyclotron Road area. This erosion will cease when this peak flow is re-diverted to Blackberry Creek.

The flooding at Cowell Hospital occurs from flow down the ambulance entrance driveway, from Gayley Road into a "pocket" on the easterly side of the building. Most of the flood water comes from the Rad. Lab. area, via artificial diversions; and the flooding of the hospital is due to a combination of this peak flow and the unfortunate geometry of the ambulance entrance and the easterly courtyard of the hospital.

Lower Strawberry Creek, from the outlet of the Big Inch storm sewer to the City storm sewer at Oxford Street, is not adequate to carry a "ten year storm" with current watershed conditions. In addition, some areas are probably grossly inadequate to carry the flow and accompanying bed and float load from a "three year storm". We believe that the only reason that severe flooding, erosion, and re-channeling has not taken place during the past five years, is that malfunctioning of the inlet to the Big Inch storm sewer has "split" the peak flows, and the creek has thus not experienced a true peak flow for over five years. For example, during a period of heavy flow in the creek, the many sharp bends and narrow, constricted channel from the bridge at Stephens Union to below Sather Gate would dissipate much hydraulic head, cause a "back up" of flow, a rise in water levels, and a reduction in upstream velocities. We believe that if the full flow and bed load of the storms during October 1962 had reached this area, it is most probable that the channel from the outlet of the storm sewer to the bridge at Stephens Union would have filled with coarse bedload materials, and the creek would have cut a new channel through Faculty Glade, flooding a large area. Conditions conducive to such "hydraulic accidents", are seen all along the lower creek.

With the emergency remedial measures which have been taken at the inlet to the Big Inch storm sewer, the inlet will probably not "plug" during the next peak flow, and the full flow and bedload will reach lower Strawberry Creek. We have also taken all emergency remedial measures in lower

Strawberry Creek which we have felt were advisable at this time, in order to obtain the most favorable conditions in the creek which "quick" measures could produce. It is still very doubtful, however, that the lower creek could now take a "three year storm" peak flow without serious flooding, erosion, deposition and re-channeling in the lower creek area.

The upper reaches of Blackberry Creek and most especially the City storm sewer from Highland Court to North Gate, are not now receiving the peak flows they would receive if they were receiving all flow from their original watershed areas. This is due to diversions in the Rad. Lab. area which are now putting much extraneous peak flow into the "Gayley Road Area". Even so, it appears that the present Blackberry Creek system is now taking all of the peak flow which it can suitably handle. It is thus apparent that re-diverting flow back into the Blackberry Creek system can be done only after careful consideration of the effects of such re-diversion, especially with regard to flooding of the City area below Highland Court.

The "Gayley Road Area" is now suffering serious flooding and erosion due to peak runoff diverted from the Rad. Lab. area above. This flow must be re-diverted to the Blackberry Creek system or otherwise suitably intercepted, to alleviate the problems in the "Gayley Road Area".

It is pointed out that there are two basic aspects to storm drainage, one the low rate flows that occur many times a year and can be handled by small culvert-inlet systems, and two, the peak flows which occur once every one, five, or ten years, which require large facilities and cause severe flooding and damage when not controlled. There are few deficiencies in low flow rate drainage facilities on the campus, but many in the peak flow system. In many campus areas there is no resemblance between low flow patterns and those at peak flow, the low flow drainage being through culvert-inlet systems and the peak runoff moving in surface flow over different routes and to different accumulation points than does the low rate flow. For example, certain secondary canyons which fall to lower North Canyon Road are intercepted by culverts at low flow rates, draining directly into the Big Inch storm sewer; while at high flow rates the culverts are "plugged" or are hydraulically inadequate, and large runoff quantities bypass the culvert inlets and flow down North Canyon Road toward International House. The peak runoff flow pattern does not resemble that at low flow rates in any manner.

The City storm sewer from Oxford Street to the Bay appears to be adequate to carry present flow rates down to the first section of open channel flow at Sacramento Street. From this point down severe flooding, deposition and erosion took place during the storm of October 1962. The coarse bed and float load materials injected into the sewer by Strawberry Creek did not appear to be harmful in the pipe above Sacramento Street, but did appear to be "dropping out" and "shoaling" the stream channel at some locations in the open channel areas. It is pointed out that this sewer drains a large city area, with a short accumulation time and high runoff coefficient, as well as the campus area. In addition, the accumulation time for drainage from the campus must be much greater than that of the city area along the sewer alignment. Thus the peak campus flow may not coincide with the peak flow from the City area below, and the peak flows from the campus may thus not contribute to overloading of the sewer to the degree that a direct comparison of peak flow rates would indicate. The interaction of the City storm sewer and campus drainage is obscure at this time, and warrants much further serious study. It is our best judgment at this time that current peak campus flows may be troublesome, but do not now pose a critical problem for the City sewer; and that the injected bed and float loads are troublesome only in the open channel sections and in the old portion of the sewer around San Pablo Avenue, which are hydraulically inadequate in any case. We feel that if the City storm sewer, as it now exists between the campus and Sacramento Street, extended all the way to the Bay, that current input from the campus, both peak storm flow and bed and float loads, would not now be troublesome. The effects of this input upon sections of the City system which are hydraulically inadequate are too complex and obscure for evaluation in this report.

In considering the problems discussed above, and the general storm drainage picture at the campus, we have formed certain very preliminary concepts as to possible remedial measures which would most economically and suitably resolve the present runoff problems, and also prevent the occurrence of any serious problems in the future as development of the upper campus area continues. These preliminary concepts are given briefly as follows:

The inlet to the Big Inch storm sewer must be re-built and moved upstream, so as to both prevent malfunction of the inlet from either hydraulic inadequacy or plugging by bed and/or float load, and to provide greater hydraulic head upon the upper, flat portion of the existing pipe, and thus increase its hydraulic capacity.

Some combination of the reduction of peak flow now passing down Chicken Canyon from the Rad. Lab. area above and extension of the presently begun program of stabilizing the "stream bed" must be completed very soon, to halt further erosion and sliding in Chicken Canyon and the attendant hazard of a major mud flow down the canyon. In addition, the present dumping of thousands of yards of bedload material into Strawberry Creek, from erosion in Chicken Canyon, must be greatly reduced or halted. In combination with the above measures, a new inlet and culvert must be installed in Chicken Canyon at North Canyon Road, connecting directly to the Big Inch pipe, to handle the peak flow, bed and float loads pertaining after execution of the measures discussed above. The most obvious means of reducing the peak flow in Chicken Canyon is to use the new road from North Canyon Road to Grizzly Peak Boulevard (to be built this year) as a means of diverting all peak flow from areas above this road directly to Strawberry Creek. This can be done at little or no extra cost in construction of this road.

We feel that it may be most expeditious to use North Canyon Road as an emergency bypass for the Big Inch storm sewer and all secondary canyons falling to the road; thus allowing design of the sewer, and the culvert-inlet systems in the secondary canyons, for much smaller peak flows, producing a very large reduction in construction costs. The flow would be diverted northerly around Memorial Stadium to Gayley Road, thence to South Drive, and thence to Strawberry Creek at Faculty Glade. This would require minor regrading of small portions of North Canyon Road, Gayley Road, and South Drive, and the construction of low curb-walls in some areas.

Lower Strawberry Creek must be carefully analyzed and modified so as to carry peak flows and accompanying bed and float loads. This will require extensive modifications down to the lower end of the new Student Center building, and relatively moderate measures below this point. It may be necessary to eliminate or bypass some of the sharper bends in the upper area; and a considerable enlargement of the flow section, stabilization of the creek embankments, and underpinning of some abutting facilities will definitely be required. These measures will not change the creek appreciably from the architectural or esthetic standpoint, and can be done so as to improve these aspects of the stream; and the cost of these measures is so low in comparison with the alternate of extension of the Big Inch storm sewer to Oxford Street that we feel that this approach will be used.

The current diversion of peak runoff in the Rad. Lab. area from the Blackberry Creek watershed to the "Gayley Road Area" must be eliminated, and the flow returned to Blackberry

Creek. This can only be done after careful consideration of the effects of this re-diversion, and the simultaneous execution of necessary improvements in the Blackberry Creek system.

This office feels very strongly that the new road to be built between North Canyon Road just east of Building 77 and Grizzly Peak Boulevard must be used as a peak-flow diversion facility, to protect the present Rad. Lab. area from development of the area above, and to control peak flows in lower areas. Such use would involve the interception of peak flows by the road, and diversion to upper Strawberry Creek. Only peak flows would be diverted, and this can be easily and dependably done by proper sizing of the culvert-inlet systems carrying flows across the road. We believe that the added cost of construction of the road for such usage would be very small, and the savings in the avoidance of construction of major storm sewer facilities below would eventually run to hundreds of thousands of dollars. In addition, this measure will give relief now in areas currently bothered by flooding and erosion.

Gayley Road should be regraded in the area of Cowell Hospital, so as to divert all peak flows on Gayley Road to South Drive, and thence to Strawberry Creek at Faculty Glade. This can be done with moderate regrading of Gayley Road and South Drive, and at moderate cost, and flooding of Cowell Hospital will be completely eliminated. In addition, such re-grading would tie in with the use of North Canyon Road as an emergency, peak-flow diversion channel.

Numerous problems of local flooding of buildings must be remedied by minor changes of exterior grades. All known problems will require only minor measures for complete alleviation of the flooding problem.

In considering the overall drainage regime on the campus we have come to the conclusion that campus storm drainage facilities must entail a storm sewer system for low to moderate rates of runoff, and a supplementary surface-flow system for peak flows during rare storms. The cost of building a storm sewer system for, say, a "twenty year storm" at full campus development would be astronomical; and the investment of capital into a system which will be needed for only fifteen minutes every twenty years is unthinkable if it can be avoided without the danger of severe flooding, which can be done at the campus. This dual-channel concept is used in nearly all cities, as witness the curb-to-curb street flows during intense storms; and if the system is well-engineered, great savings in construction costs are achieved and no flooding or damage results. We believe that the final campus storm drainage system will involve the use of such a combination system, with, for example, North Canyon Road acting as a peak-flow bypass for the Big Inch storm sewer, and similar arrangements in other areas. Further, the use of University Drive as a peak-flow bypass to lower Strawberry Creek may well become part of the final campus storm drainage system. It is pointed out, that such a bypass system costs little to develop, mainly requiring good engineering and adequate advance planning, and is far more "sure" and dependable than an inlet-pipe system; while, for example, the cost of paralleling the Big Inch storm sewer, with existing improvements to circumvent, would be fantastic. We feel that every effort should be made to use available surface channels for peak storm flow, to prevent flooding and damage, and to lessen the cost of storm drainage facilities. Since the campus area has good "fall" throughout, this approach is a "natural", and must be used to the fullest practicable extent.

The above material briefly outlines our thinking regarding the permanent, long-term relief of storm drainage problems at the campus. We have already taken all emergency measures which we feel are proper at this time, and believe that further storm drainage work should be done as part of a well planned long-term, program of campus storm drainage, considering all future developments as well as present conditions.

In conclusion, we state in the strongest possible terms that we feel that the greatest need at this time with regard to storm drainage problems at the campus is a master drainage plan covering the entire campus area and considering all future campus development.

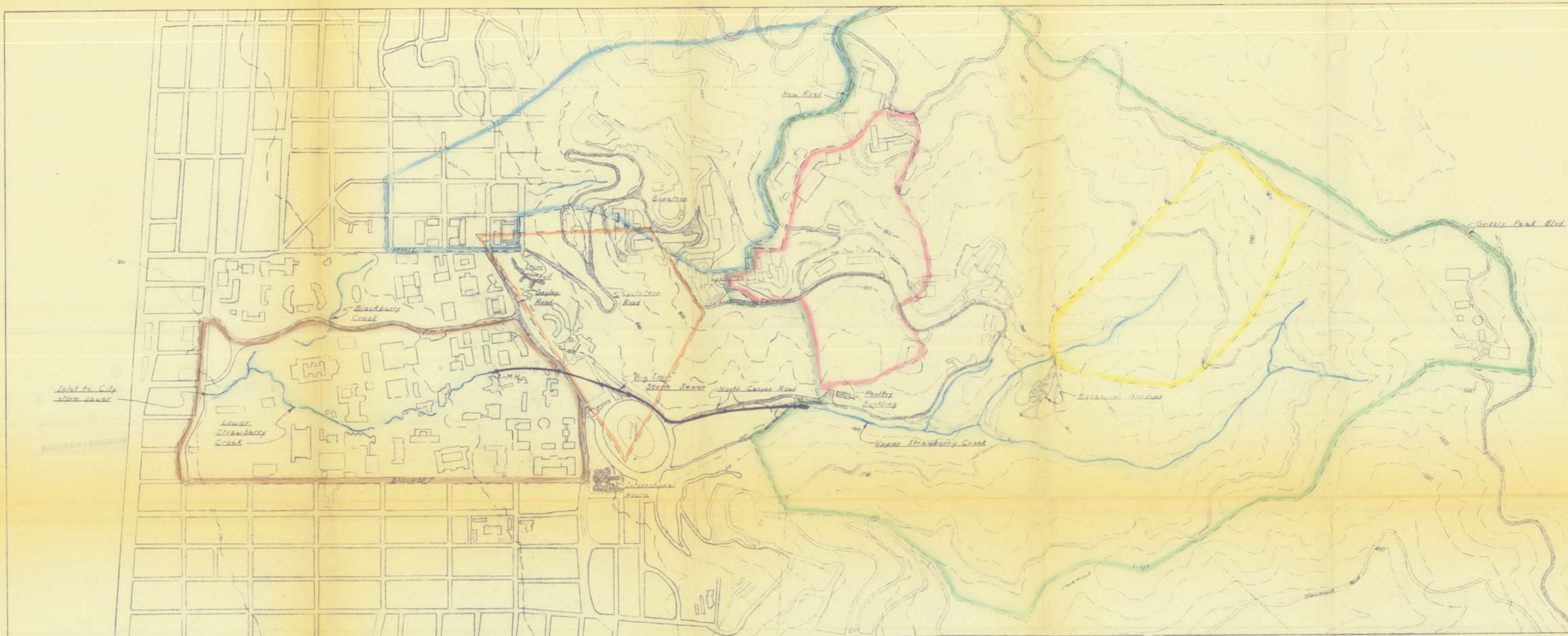
This plan would establish present and final watershed areas and drainage paths, present and future runoff loads on all creeks, culverts, roadways, etc., and the general location and type of present, modified and future drainage facilities. The plan would be the basis for "reshuffling" the present distorted drainage pattern, to allow the solution of existing problems at minimal cost, inconvenience, and future hazard. Such a plan will require a good topographic map of the campus and careful analyses and engineering; but the benefits of such a plan are so great and the potential losses without adequate planning <u>now</u> are so severe, that we feel that the preparation of a <u>master</u> drainage plan must be done at this time. We feel that current storm drainage problems can be solved at moderate cost, and the creation of drainage problems in the future can be completely prevented, if a complete master drainage plan is prepared <u>now</u>, and all further construction, as well as storm drainage work, is done in compliance with this plan. We feel that certain portions of the remedial work discussed above should be done this year, and that these measures can be intelligently designed only by reference to a master drainage plan for full campus development. Without such reference, facilities constructed this year may well be as inadequate and dangerous five years hence as certain existing facilities are now.

This office feels that due to the recent development of the upper watershed areas the problem of storm drainage at the campus has now become critical. Any delays in solving the existing problems will assuredly result in severe flooding and damage, as has occurred this winter, with progressive worsening of the situation as development of the upper area continues. The situation on the campus is similar to that of many surrounding cities, where recent development of upper areas has now produced critical storm drainage problems; and any unnecessary delay in dealing with these problems simply increases interim losses and final construction costs. We feel that by careful planning the campus storm drainage facilities can be improved in an orderly program spread over a period of several years, choosing the most necessary projects for each year's work. This will produce a more orderly construction procedure, lower costs, and less disruption of campus activities, as well as allowing more efficient budgeting. We therefore recommend that you prepare a master drainage plan for the entire campus area this year, encompassing all future campus development, including an overall plan for drainage distribution and disposal and the general aspects of design of facilities to be modified or constructed. The program of modification and new construction should then be spread over a period of years, correlated with the need for the facilities involved.

Respectfully submitted,

B. J. Lennert
Registered Civil Engineer
State of California #9232

BJL:cz



GAYLEY ROAD AREA

ZONE I — Chicken Ck

ZONE II

ZONE III - "Big Inch" Storm Sewer

ZONE IV — Canyon above Big Inch

ZONE V — Area above B...

ZONE VI — Blackberry Ck

UNIVERSITY OF CALIFORNIA AT BERKELEY
STORM DRAINAGE STUDIES
GENERAL SITE PLAN

LENNERT AND ASSOCIATES
310 ... Street
Oakland 8, California

Job No 260

12/17/62

LENNERT AND ASSOCIATES
SOILS ENGINEERS

Job Number 260

November 2, 1962

ZONE I -- CHICKEN CREEK AREA

RESUME OF PRELIMINARY OBSERVATIONS

Watershed and runoff

The original Chicken Creek watershed consisted of the tributary canyon area extending easterly to Grizzly Peak Boulevard and bounded to the north and south by adjoining ridges, a total of about seventy acres, as shown on the accompanying sheet. The area was covered with a dense growth of trees, brush and grass, with no improvements. Runoff coefficients were low and the peak accumulation time at Strawberry Creek was high, probably in excess of two hours. Historically, the flow has been low in Chicken Creek until recent years when the watershed area has been developed.

The present Chicken Creek watershed consists of the original watershed area plus a diversion from the Rad. Lab. area to the northeast of about eight acres, for a total of about eighty acres. In addition, a large portion of the watershed area is now developed, with buildings, paving and bare earth covering about thirty acres. This present watershed area is also shown on the accompanying sheet. Note that the Bldg. 77 fill area, of about seven acres, was constructed this year and contributed runoff to the system for the first time this winter.

In addition to the increased watershed area and development effects, roads of high hydraulic capacity and rapid flow now intersect much of the watershed. This results in a very large decrease in accumulation time at the lower canyon for the upper watershed, where large areas are involved.

In summary, it is seen that the watershed of Chicken Creek has gradually been changed as the upper area has been developed, from an area of seventy acres covered with dense vegetation, to an area of eighty acres, twenty-seven acres (or one-third) of which is now high runoff-low accumulation time area. Based on our brief work to date, consisting mainly of visual observations and "horseback" estimates, it is our best guess that the following runoff conditions now exist for Chicken Creek:

> The average runoff coefficient for short-term, high intensity storms has probably doubled and now is in the range of 75% or greater.

The accumulation time at the lower Chicken Canyon has probably decreased from over two hours to less than one-half hour.

Prior to development the most critical storm was probably one of two hour duration. By observation during the past storm the accumulation time at Strawberry Creek is now around one-half hour.

The intensity-length relationship of rainstorms in the Chicken Creek watershed area is not known, as the hills produce a "wringer" effect and probably alter the time-intensity variation in comparison to the overall Bay Area relationships. We guess that the estimated fourfold decrease in accumulation time would result in an increase in peak runoff rate of five to ten times the original value.

We feel that with the increase in watershed area, developments in the watershed, and decrease in accumulation time, that peak flows in the lower Chicken Canyon have probably been increased by a factor of at least ten.

Stream bed, bed-load and float-load conditions

Chicken Creek lies almost wholely in the Orinda Formation, a geologic group of sediments of basically poor soils properties, responsible for much of the landslides and other soils problems in Contra Costa County. In the site area these consist of clay-shales and siltstones of poor soils properties, with limited occurrences of sandstone and conglomerate of superior characteristics.

The Orinda Formation is Pliocene in age, and has been uplifted and distorted. Steep dips in the bedding are common, and relatively steep hills have been formed of the Orinda sediments. In these hills landslides are very common, and constitute one of the principle geologic processes of erosion. Consequently the hills are commonly covered with a mantle of landslide debris of considerable extent from geologic processes, which is at its "critical slope", and will immediately slide or "mud flow" upon being undercut, saturated, etc.

Chicken canyon is comparatively steep, both in the side-slopes and along the bottom profile, with an overall gradient of about 20 percent along the creek bed from Strawberry Creek to North Canyon Road, and sideslopes to about 1-1/2:1. Landslide deposits cover a large portion of the slope areas, "toeing out" into the creek channel and being undercut by erosion in the creek. During the recent storm it was estimated that over half of the creek sidewall area was unstable and moving into the stream bed. The creek is now seen to be incised into the landslide materials and the undisturbed Orinda sediments, and erosion was severe during the past storm.

The landslides and mud-flows coming into the creek from the sidewalls thus provide a source of silt, sand, gravel, cobbles and boulders, and of brush and tree limbs, which the stream picks up at heavy flow and carries down the canyon. In addition, at peak runoff, "mud-balls" of landslide material, retaining the original bedding and of up to twelve inch diameter, come down as part of the bed-load. In general, the amounts of cobble-boulder sizes will be low as a percentage of the total mass eroded, due to the nature of the material available; but with many thousands of cubic yards of material removed the quantity of very coarse material transported is still large. The float-load consists mainly of smaller branches and brush, with little heavy timber, due to the relatively small numbers of large trees found in the canyon.

Observations during the storm of October 11 through 13, 1962

During the storm, and particularly during the two periods of peak rainfall intensity on Friday night and Saturday noon, the following observations were made:

The creek showed only nominal flow during the three days of rainfall excepting during the two periods of peak rainfall. At these two times the creek flow increased rapidly after the high intensity rainfall began, apparently "peaking" in about one-half hour, and at maximum flow a depth of over one foot of water was flowing over the wall alongside the Poultry Building.

The creek showed a very heavy bed load at peak flow, with rocks and mud-balls up to 12 inches in size washing across North Canyon Road. We have estimated that a minimum of 5000 cy of material moved down the creek and into Strawberry Creek during the storm, and the actual figure could easily be four times this amount.

The float-load coming down the creek consisted mainly of branches, twigs, leaves and small logs, with little very large material. This is due mainly to the small amount of large debris in the creek area and the smallness of the channel.

Inspection of the creek from the Poultry Building up to North Canyon Road during the storm revealed that the creek was incising into the toes of many slides and mud flows. It was estimated that over half of the sidewalls were unstable and moving into the creek.

It was found that during the storm, runoff from Areas B and C ran down North Canyon Road by the Rad. Lab. South Gate, and emptied over the shoulder of the road and into Chicken Canyon.

During the peaks of the storm the road ran full, with rocks of over eight inches in size moving down the road.

The fill area at Building 77 produced large quantities of runoff during the storm, the culverts "plugged", and the water ran down the fill slopes, across North Canyon Road, and down the slope to the poultry sheds below. The fill eroded badly during the storm, and large quantities of silt, sand and rock were deposited in the area occupied by the poultry sheds, or washed down the creek.

General comments and conclusions

Based upon our observations during the storm and our cursory investigation and analyses of the area and drainage phenomena involved, we submit the following general comments and conclusions regarding the Chicken Creek watershed area and the storm flow phenomena pertaining:

Chicken Creek has been changed by the developments above from a heavily brushed canyon with low peak runoff flows and an essentially stable bed with little erosion, to an hydraulically overloaded water course, with severe erosion and resulting transport of bed and float-loads. Peak flows have increased at least ten-fold from the original stable condition, and the canyon is incapable of transmitting this water without severe erosion. This condition will worsen with time, rather than improve, due to the progressive undercutting of the side-slopes. There is no natural "hard bottom" over most of the length of Chicken Creek to limit encisement and erosion.

The quantity of water carried by Chicken Creek is not the prime source of difficulty in Strawberry Creek and the Big Inch storm sewer below, but rather the bed and float-load brought down by the high runoff intensities, which "plugs" the entrance to the Big Inch and is injecting a large load of sediment into the system below.

The problem in Chicken Creek can be solved by either reducing the flow therein to something in the order of its original flow conditions, or by artificially stabilizing the channel by the use of numerous groins or similar measures. Due to the fall in Chicken Creek (about 20% average) and the instability of the side-slopes, artificially stabilizing Chicken Creek for its present runoff conditions would be highly expensive, involving, we estimate, at least seventeen major groins. We feel at this time that the best solution for Chicken Creek is a combination of reducing the peak flow therein by diversion of a large portion of the flow from the developed areas above, combined with the artificial "maturing" of the stream bed for the reduced flows by the use of a limited groin program of moderate cost.

LENNERT AND ASSOCIATES
SOILS ENGINEERS

Job Number 260

November 2, 1960

ZONE I -- CHICKEN CREEK AREA

EMERGENCY FLOOD CONTROL MEASURES

(See Resume of Preliminary Observations and accompanying plan)

Problem

Chicken Creek is now carrying many times the peak flow rate which it experienced prior to development of this area. This has produced the following problems:

The existing culvert and inlet system at the Poultry Building is totally incapable of carrying the peak flow even when not clogged with bedload and debris.

The surface channel by the Poultry Building is barely capable of carrying the peak flow, and the Poultry Building is in danger of flooding during these periods.

A large amount of bed and float-load comes down the creek at peak flow. This plugs the culvert immediately and puts all flow over the wall alongside of the Poultry Building.

The bed and float-load coming down the creek is introduced into Strawberry Creek at the "stilling basin" at the entrance to the "Big Inch" pipe. All of this material therefore either collects in the "stilling basin" or goes down the pipe and into the lower Strawberry Creek system. This material formed a large part of the debris that plugged the "trash-rack" of the "stilling basin" during the last storm and caused the second flooding of the Haas Recreation Center.

The potential quantity of bed and float-load in the canyon in the form of slide material moving into the creek, and available for erosion and injection into Strawberry Creek and the "Big Inch" pipe, is in the range of 500,000 cy. A heavy storm at this time could easily put 25,000 to 75,000 cy into the system.

There is some hazard, if we have a severe winter, of a large mud-flow occuring in Chicken Canyon, due to removal of the toes of numerous mud-flows in the canyon slopes, which could structurally destroy the Poultry Building and completely block the "Big Inch" pipe. The "odds" of this happening are not great, but any additional incising of the Chicken Creek bed increases the hazard of such a major catastrophe.

Specific emergency remedial measures

The basic remedy of the problem in the Chicken Creek area lies in either reducing the peak flows in the creek to an acceptable limit, and/or in the stabilization of the creek bed for the expected flows, together with the construction of an adequate interception system in back of the Poultry Building, with disposal of the flow into the "Big Inch" pipe. Any effective remedial work sufficient to permanently and adequately resolve the problems is of such large scope as to be beyond the range of practicable remedial measures to be taken this fall. We have, therefore, performed as thorough analysis of the problem as time would permit, with the following results:

Our first approach was to attempt to divert the peak flows from areas B and C which are now entering Chicken Canyon along North Canyon Road at the South Gate to the Rad. Lab. area, by diverting the flow down other roads and eventually to Hearst or Gayley Avenues. After considerable field work it was found that no appreciable portion of the flow could be gotten by the low-point in North Canyon Road at the South Gate of the Rad. Lab. area by any but large-scale, permanent measures, except by dumping into "Ten Inch" Creek, and this approach thus had to be abandoned. This means that from the practical standpoint the flow in Chicken Canyon cannot be reduced this winter except by diversion into "Ten Inch" Creek.

Reviewing the bed conditions of "Ten Inch" Creek, it was found that the creek bottom is in sound bedrock (probably Cretaceous) over most of its length, with one large slide area in the upper portion of the creek. There is a new 24" ø RCP culvert draining "Ten Inch" Creek directly into the "Big Inch", but the inlet structure is inadequate and "plugs" immediately upon heavy flow in the Creek. "Ten Inch" Creek empties into North Canyon Road immediately opposite the Haas Recreation Center building, and major flows therein would be likely to break through a temporary barrier at the shoulder of the road and flood the Haas area. "Ten Inch" Creek can thus be used as a diversion of flow in Chicken Creek only as a last resort; say, if the "Big Inch" culvert plugged or a mud-flow threatened the Poultry Building.

With the above information in hand it is obvious that we will have to permit the full flow of areas A, B, C and D down Chicken Creek this winter, with a possible diversion of areas B and C down "Ten Inch" Creek in a case of dire emergency only.

A study of Chicken Creek has revealed that <u>at least</u> seventeen groins would be required to stabilize the channel for the existing flow conditions. In addition, access to the proposed groin sites varies from poor to extremely difficult, involving the cutting and filling of access roads which in themselves would not be stable. The complete stabilization of Chicken Creek this winter is thus unfeasable, and only a limited program can be practically accomplished this fall. We have selected four groin sites as being both reasonably accessible and effective, and are proposing that they be contructed immediately.

The inlet structure and culvert in Chicken Creek at the Poultry Building are both completely inadequate for the present flow conditions or for the future reduced flows as planned by this office. In addition, the existing culvert was undercut and "eroded out" during the last storm, and the bottom of the pipe is now gone in at least two places. As we believe that this entire unit must be replaced by new construction of totally different design, and as this construction may not be done this winter, we feel that heavy flows by the Poultry Building must be handled in a surface channel (as in the last storm) and have so recommended.

Based upon the above conditions we feel that there is no choice but to attempt to "ride out" the winter with the existing flow conditions in Chicken Creek. We are not happy at making this decision, and it does involve a risk of severe flooding of lower areas, the injection of heavy bed and float-loads into Strawberry Creek, and hazard to the Poultry Building, but we see no practicable alternate. We have therefor set up a series of recommendations which we feel constitute the minimum emergency measures which can and should be taken this winter, to "ride-out" the winter as best may be done, with the expectation of constructing permanent facilities which will solve the problem <u>next year</u>.

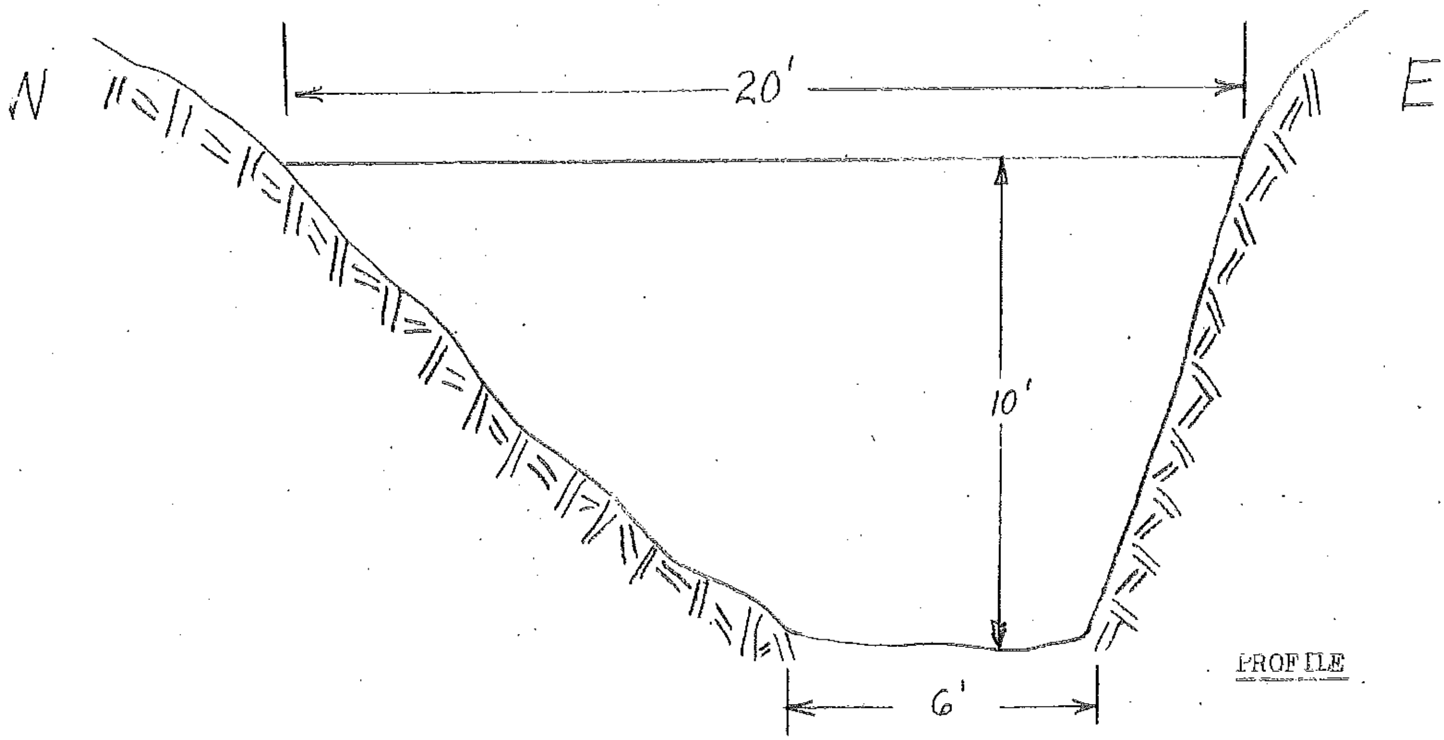
On the above basis we have set up a series of twelve emergency measures to be taken in the Chicken Creek watershed area. These are shown in drawing and note form on the sketches and text appended hereto, keyed to numbers shown on the plan. We have made these recommendations as explicit as time limitations will allow, and will supplement them with field control and supervision of the work.

General comments

The problem in Chicken Creek stems from progressive development of the watershed area, aggravated by the diversion of flow from additional areas into Chicken Creek by the construction of roads without regard to their effects upon peak intensity storm drainage. The final solution must entail the restoration of balance between the peak runoff carried by Chicken Creek and its capacity to transport the runoff without appreciable erosion. Due to the soils conditions in Chicken Canyon this must entail a reduction in creek flow coupled with creek bed stabilization measures.

For the permanent solution this office visualizes a large diameter reinforced concrete pipe being laid down "Ten Inch" Creek, where the pipe can be laid in the stable bedrock bed of the creek and thus be safe against landslide and/or undercutting. This pipe would carry the flow from Areas B and C in the Rad. Lab. area, thus diverting this water from Chicken Creek. The pipe would have to have properly designed inlet structures which could inject the peak intensity runoff from Areas B and C into the pipe, without plugging by debris. This pipe would be connected directly into the "Big Inch" pipe. The pipe should not be laid in Chicken Creek, as the instability of the creek bottom would almost assure disruption of the pipe during some severe future storm, with attendant flooding, erosion, and disastrous results below.

For the permanent solution all inlet structures must be designed to be adequate to inject the expected peak intensity flows into the pipes, and to be self-cleaning with regard to large bed and float-loads. Without these features a storm drainage system is useless during heavy storms when it is most needed and when heavy, expensive, damage occurs. This office has suggested the use of steeply sloping, self-cleaning, "grizzly" inlet units, with log-spiral transitional pipe inlet sections, to accomplish this purpose, and we envision the design of such units for the "Ten Inch" Creek, Chicken Creek, and all other canyons which empty onto lower North Canyon Road.



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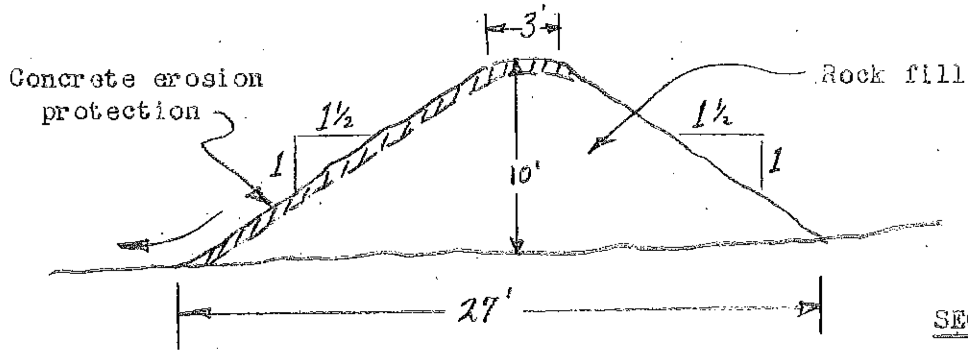


SECTION

Notes and estimated quantities

Rock fill, well graded from 2' size - 75 cy

Concrete erosion protection to equivalent 6" thickness - 7 cy

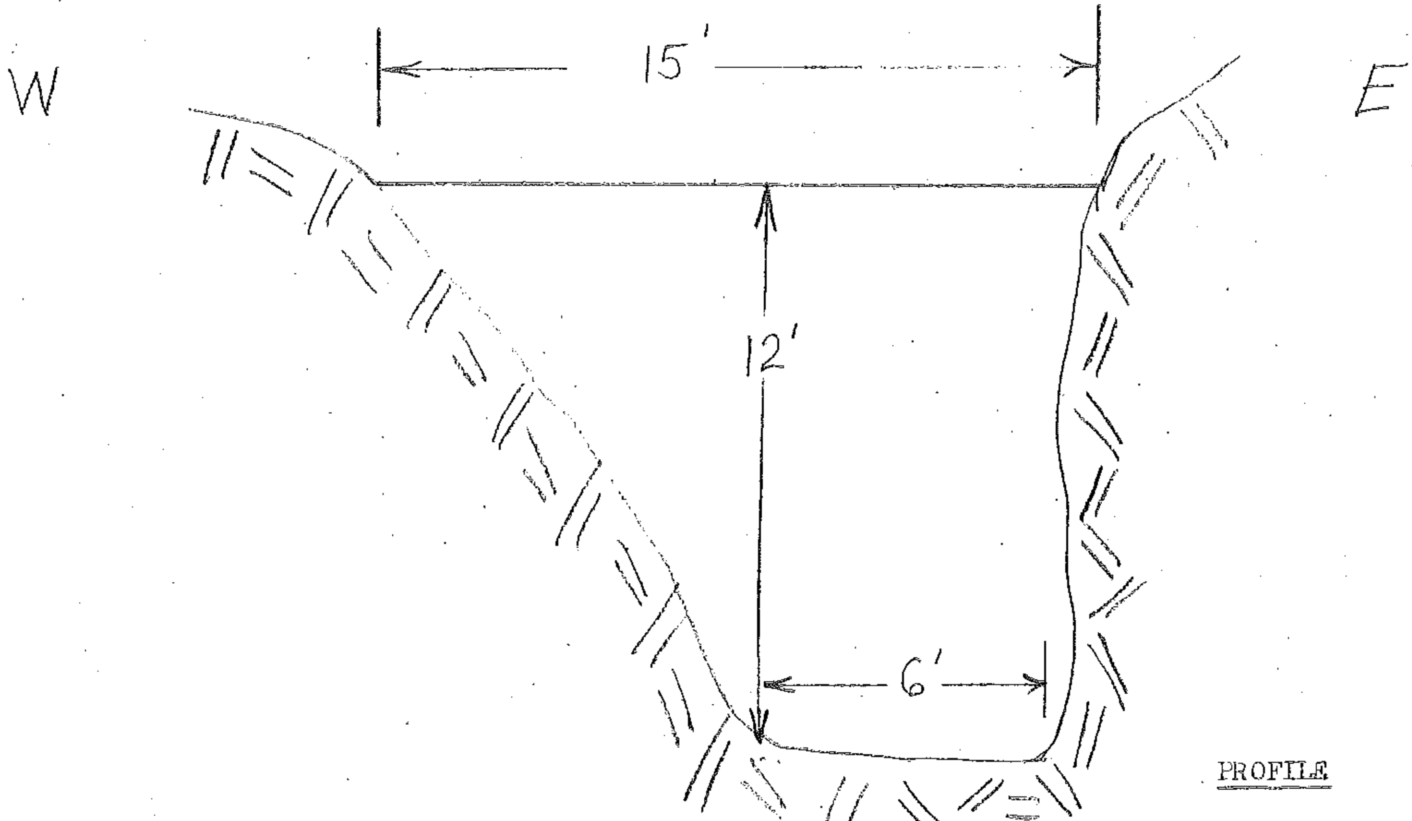
Earth fill for access as shown in the field -- no estimate

See staked layout in the field.

ZONE I EMERGENCY MEASURES, ITEM 1

Rock-Fill Groin

Job No. 260 11/2/62



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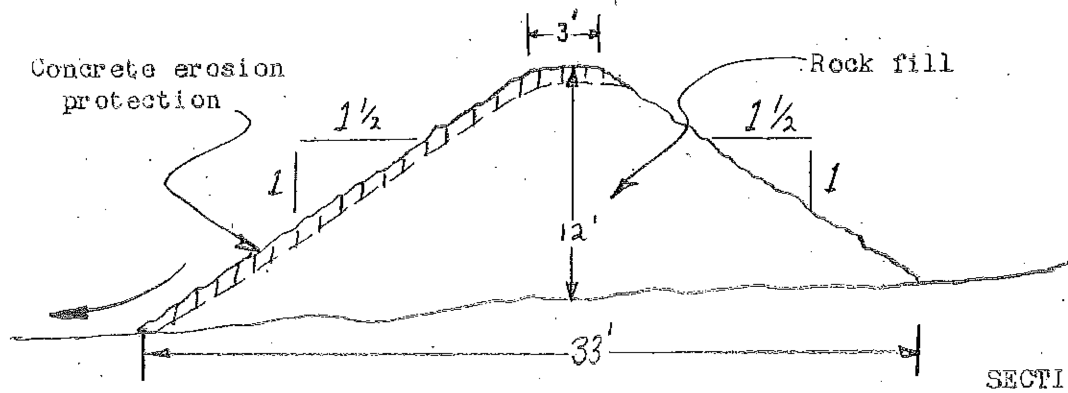


SECTION

Notes and estimated quantities

Rock fill, well graded from 2' size - 80 cy

Concrete erosion protection to equivalent 6" thickness - 5 cy

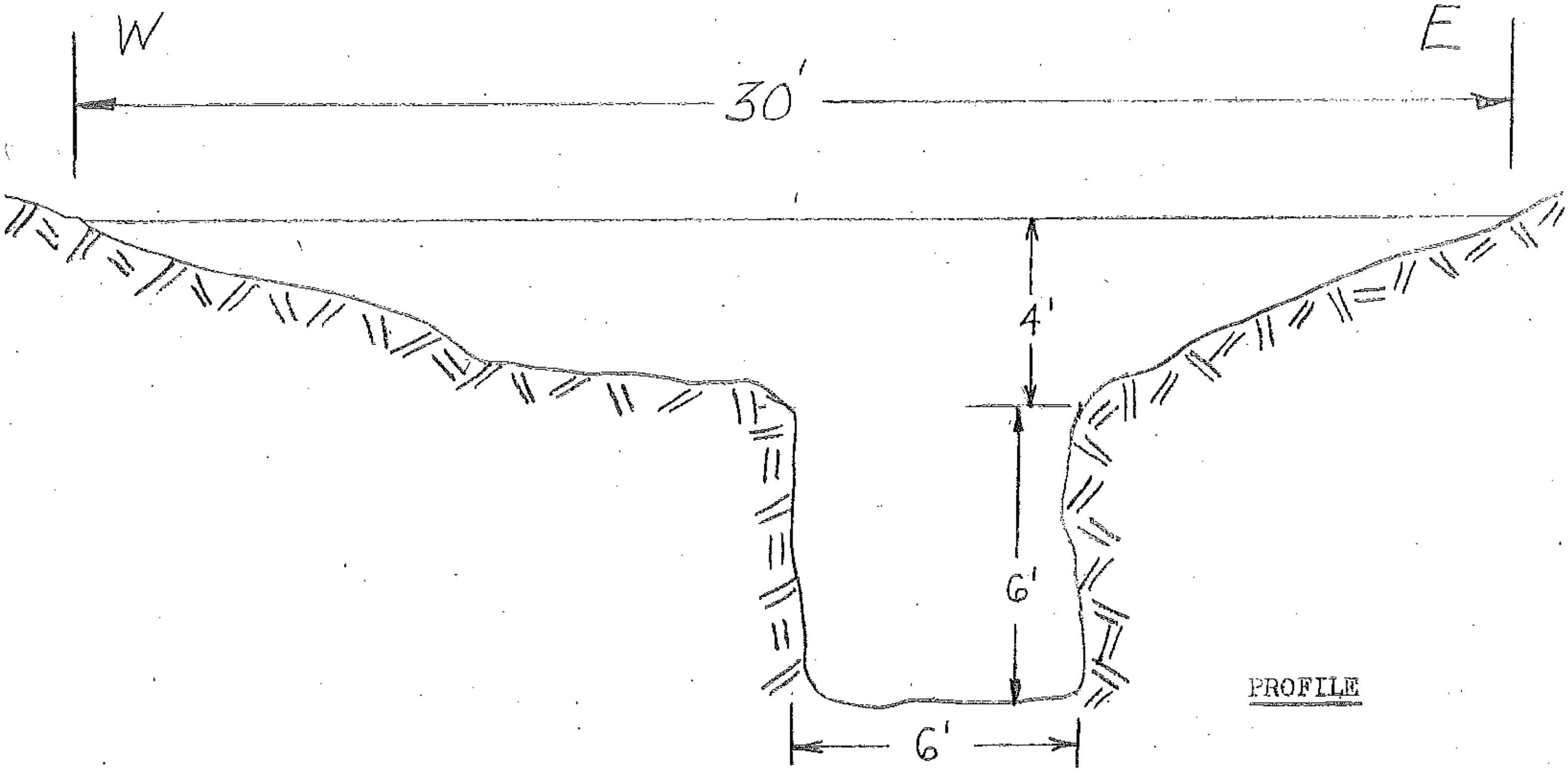
See staked layout in the field.

ZONE I EMERGENCY MEASURES, ITEM 2

Rock-Fill Groin

ASSOCIATES
Street
California

Job No. 260 11/2/62



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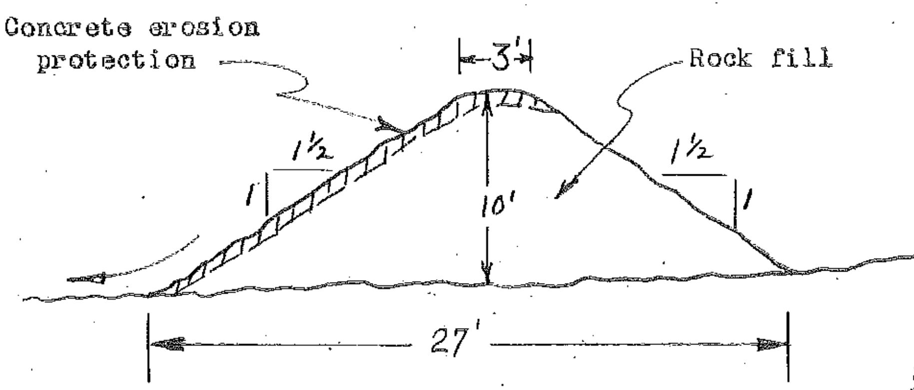


SECTION

Notes and estimated quantities

Rock fill, well graded from 2' size - 50 cy

Concrete erosion protection to equivalent 6" thicknew - 5 cy

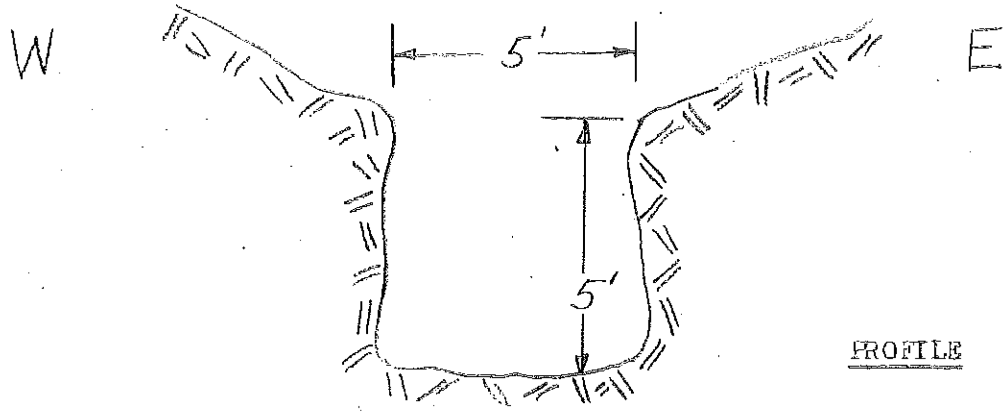
See staked layout in the field.

ZONE I EMERGENCY MEASURES, ITEM 3

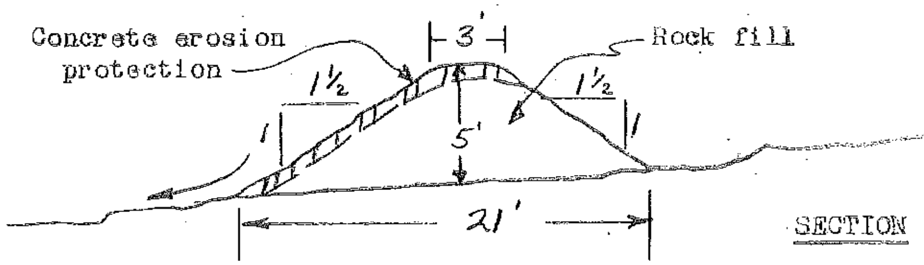
Rock-fill Groin

[illegible] AND ASSOC[illegible]
[illegible] Street
[illegible] 9, California

Job No. 260 11/2/62



PROFILE



SECTION

Notes and estimated quantities

Rock fill, well graded from 2' size - 10 cy

Concrete erosion protection to equivalent 6" thickness - 2 cy

See staked layout in the field.

ZONE I EMERGENCY MEASURES, ITEM 4

Rock-Fill Groin

ZONE I, EMERGENCY MEASURES, CONT.

(5) Repair two existing masonry groins with bagged concrete and/or mortared masonry, as directed in the field by this office.

(6) Cross-fall North Canyon Road from Poultry Building parking area to south side of road at ten (10) percent fall. Use a new section 120 feet in length faired to existing road grades. Create a swale of ten (10) feet bottom width in line with the outfall from Chicken Creek by the Poultry Building and the channel into Strawberry Creek. Grade subgrade to required line-and-grade, place a minimum thickness of six (6) inches of U.R.B. and two (2) inches of P.M.S. Fair base course and surfacing to existing road grades. See Supplemental Sketch, herewith.

(7) Cross-fall the existing dirt road to at least ten (10) percent fall with a swale width of ten (10) feet, fairing to the swale in North Canyon Road and to the channel below.

Excavate a channel down the side slope of Strawberry Creek, of ten foot bottom width, faired to the swale in the dirt road above. Place erosion protection as shown on the Supplemental Sketch.

See the Supplemental Sketch, herewith.

(8) Stockpile sand bags at this location so that in case of extreme emergency conditions in Chicken Creek or at the entrance to the Big Inch storm sewer the flow from Watershed Area C can be diverted into Ten Inch Creek by sand-bagging across this road.

(9) Stockpile sandbags at this location so that in case of extreme emergency conditions in Chicken Creek or at the entrance to the Big Inch storm sewer the flow from Watershed Area B can be diverted into Ten Inch Creek by sand-bagging across this intersection.

(10) Place a sand bag berm or other <u>sound</u> wall along the shoulder of this road as far as may be required to maintain a minimum one (1) foot depth of flow along this road, without spilling over the shoulder into Area A. This will require sand bag heights from zero to about two feet. Place this containment <u>now</u> and leave in-place until a permanent solution of the area drainage problem is obtained.

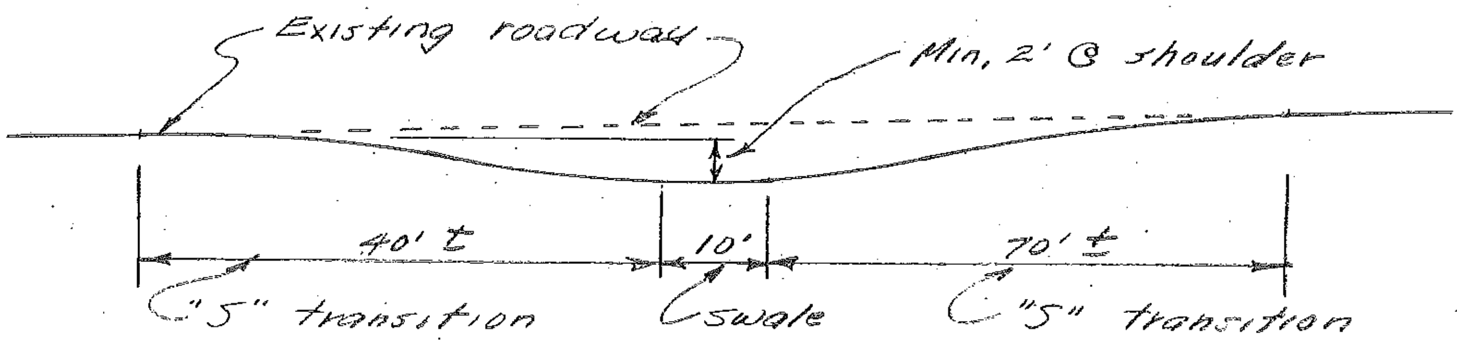
ZONE I, EMERGENCY MEASURES, CONT.

(11) Remove the existing compressor room at the end of the Poultry Building.

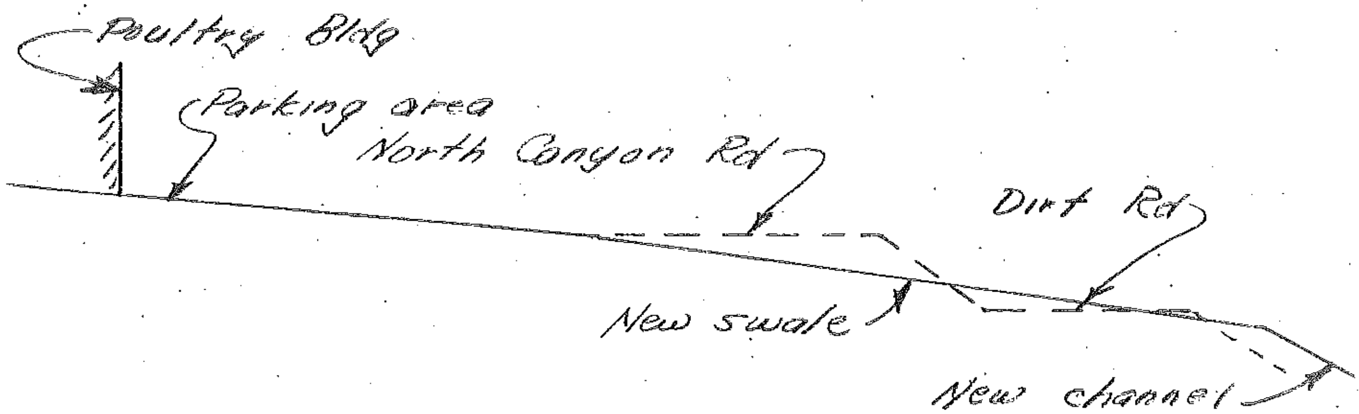
Construct "training walls" with sand bags from the hill slope above the trash-rack at the culvert-inlet at the Poultry Building so as to provide a contained flow channel past the building and to the swale in North Canyon Road. Provide a minimum channel width of five (5) feet and a minimum depth of four (4) feet, with the four feet measured to the top of the trash-rack, culvert headwall or other protuberance into the channel bottom. Remove the trash-rack or other obstructions as required to obtain this flow section.

(12) Extend the two new culverts from Building 77, which extend down the slope of Canyon Road and now "dump" on the slope or in front of the poultry sheds, northerly to the north fork of Chicken Creek. Place a heavy rubble apron for erosion protection at the outfall of the culverts.

Cut a cross-swale in North Canyon Road above the North Fork of Chicken Creek so as to dump flood-flow of the Rad. Lab. area, coming down the road by the South Gate from Areas B and C, over the shoulder of the road and into the creek at this point, rather than letting the high intensity storm flows over-flow at the low-point in the road above the chicken sheds. Restore the road grade with base course and asphaltic surfacing equivalent to the existing section. Obtain a final cross flow channel of at least one foot depth with respect to the inside gutter. See Emergency Remedial Measure #6 for a typical procedure.



SECTION



PROFILE

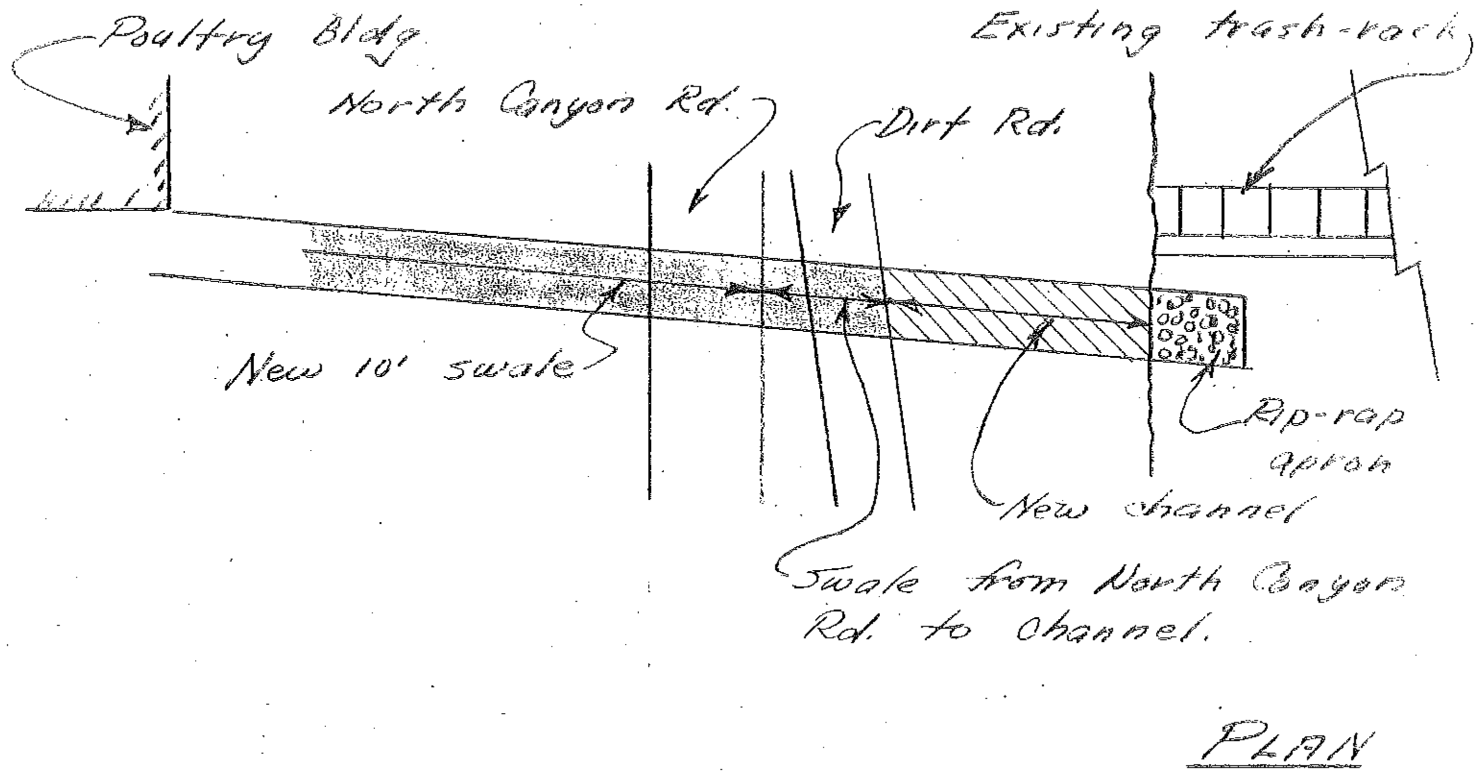
Notes

Vary grades in field to match existing line-and-grade and to protect buried utilities, within the limiting requirements given.

ZONE I EMERGENCY MEASURES

Supplemental Sketch to Item 6

Job No. 260 11/2/62



Notes

See also Item 6.

Pave swale below North Canyon Road with min. 3" P.M.S., over min. 6" U.R.B. as erosion protection.

Place timber flooring or bagged concrete as erosion protection in channel below the end of the paved swale in the Dirt Rd.

Place heavy rock rip-rap (graded from 2' size) in apron area in Strawberry Creek below the channel as protection against scour.

Fair all new construction into existing line-and-grade as found in the field.

ZONE I EMERGENCY MEASURES

Supplemental Sketch to Item 7

UNIVERSITY OF CALIFORNIA AT BERKELEY

STORM DRAINAGE STUDIES

ZONE I - CHICKEN CREEK AREA

LENNERT AND ASSOCIATES
310 Forest Street
Oakland 9, California

Job Number 260 Nov. 2, 1962

LENNERT AND ASSOCIATES
SOILS ENGINEERS

Job Number 260

November 2, 1960

ZONE II -- LOWER STRAWBERRY CREEK

RESUME OF PRELIMINARY OBSERVATIONS

Watershed, storm flow and injected bed and float-load

Strawberry Creek has historically been the drainage outlet for the entire campus watershed area, extending roughly from Oxford Street to Grizzly Peak Boulevard in the east-west direction, and from Vine Street to Dwight Way in the north-south direction. Prior to, say, 1945 the bulk of the area was undeveloped land. heavily covered with trees, brush, grass and humus. Since that time the area has gradually been developed, with the construction of buildings, paved areas, roads, etc., with the relative amount of new development being particularly great in the Rad. Lab. area. These progressive developments have increased the runoff coefficients and decreased the critical accumulation times for the various hydrologic sectors of the watershed area by large factors, thus increasing peak storm runoffs by very considerable amounts.

For purposes of overall hydrologic evaluation of the flow in lower Strawberry Creek the campus area has been divided roughly into three areas, as follows:

Area A. Upper Strawberry Creek. Comprised of the watershed area of upper Strawberry Creek plus the southerly portion of the Rad. Lab. area.

Area B. North Campus. Comprised of the watershed area of the North Fork of Strawberry Creek, the campus area north of University Drive, and the bulk of the Rad. Lab. area.

Area C. South Campus. Comprised of the campus area below the inlet to the Big Inch storm sewer (Haas recreation area and below) and south of University Drive.

Area A consists of about 800 acres, nearly all of which was undeveloped in 1945. At this time roughly ten percent has been developed, and numerous roads now criss-cross the area, providing low accumulation-time drainage to upper Strawberry Creek. All of Area A drains to the entrance to the Big Inch storm sewer, above the Haas recreation area, excepting for occasional diversions at peak storm-flow, which flood down North Canyon Road. The Big Inch pipe then dumps this flow into lower Strawberry Creek at Faculty Glade; and the occasional diversion down North Canyon Road flows southerly along Rimway, thence to Panoramic, and thence to Bancroft Way. As the flow time in the Big Inch pipe is very short, and the pipe capacity is more than adequate to carry all injected flow, the accumulation time of the upper Strawberry Creek watershed at Faculty Glade is about equal to the accumulation time at the entrance to the Big Inch pipe. Reference is made to our report on Zone I (Chicken Creek area) and Zones III and IV (Big Inch Storm Sewer and Upper Strawberry Creek Area, forthcoming) for a discussion of the storm flow into the Big Inch pipe. For this section of this report we summarize by saying that a large peak storm-flow enters the Big Inch pipe from Area A, that the critical accumulation time is about one-half hour, and that this full flood-flow enters lower Strawberry Creek from the Big Inch pipe at Faculty Glade.

Area B consists of about 200 acres, about one-third (the lower one-third) of which was developed in 1945, with the upper area then essentially raw land. At this time, due to extensive development since 1945, especially in the Rad. Lab. area, the area is essentially fully developed with respect to storm drainage. We "best-guess", without substantiating observations, that the peak runoff coefficient of this area is over 75% and the critical accumulation time at the juncture of the north fork with Strawberry Creek is in the range of one-half hour. This area puts a moderately heavy peak storm-flow into Strawberry Creek at the bottom of the campus, near Oxford Street, via the North Fork of Strawberry Creek.

Area C consists of about 200 acres, nearly all of which was developed in 1945. The runoff coefficient has probably increased slightly since that time due to substitution of buildings and paved areas for planted areas, and the average critical accumulation time may have decreased somewhat, but runoff conditions have probably not changed much during this period. Area C drains into lower Strawberry Creek via numerous inlets from streets and storm sewers all along the course of the Creek. It contributes a large amount of very short accumulation time peak storm-flow, and we best guess that the average accumulation time is something less than one-quarter hour.

In summary, it is thus seen that lower Strawberry Creek receives storm runoff from three sources, Area A, which dumps into the creek at Faculty Glade from the Big Inch storm sewer, Area B, which enters near the lower end of the creek and is not important to the matters being considered, and Area C, which enters all along the creek. The flow from Areas A and C will produce peak flows in lower Strawberry Creek at their shortest mutual accumulation time, namely the one-half hour time of Area A. Storms of shorter duration and thus higher intensity will put more water into the creek from Area C, but the peak flow from Area A will not yet have reached the creek. Thus, it is expected that maximum flood conditions will occur in lower Strawberry Creek when the peak flows of Areas A and C merge, with a critical accumulation time and storm duration-intensity of about one-half hour.

One of the important changes which has occurred in the regime of lower Strawberry Creek since 1945, has been in the character of the bed and float-load injected into the creek. Area C has been essentially completely developed for many years, and virtually no coarse material, either rock or vegetal material, comes into the creek from Area C. Area B probably contributes some minor amount of gravel and plant refuse but, due to the high degree of development in the lower portion of the area, and the intervening "drop out" areas between the upper undeveloped area and Strawberry Creek, very little coarse material enters the creek from Area B. Prior to 1945, when Area A was practically undeveloped, and was essentially stable with respect to erosion and stream transport, only moderate amounts of sand and silt, and very little coarse material entered lower Strawberry Creek from Area A. At this time this condition has been completely changed by the post 1945 developments in Area A. As discussed hereafter in this section of the report, during the past storm large quantities of gravel-cobble size material went down the Big Inch storm sewer, and a considerable quantity of boulder size material entered the stilling basin and the pipe. As discussed hereafter, we estimate that between 2000 cy and 10,000 cy of coarse material entered the pipe during the last storm. This material came from erosion in the upper Strawberry Creek watershed, caused by the recent developments in the area, as discussed in the sections of this report covering Zones I, III and IV. Thus lower Strawberry Creek is now receiving large quantities of coarse bed and float-load materials with appreciable amounts of bed-load ranging from gravel to boulder size and extremely large amounts of sand-silt material. In addition, with measures currently taken to prevent the plugging of the inlet of the Big Inch storm sewer, large amounts of leaves, branches and small logs will be delivered to lower Strawberry Creek from Area A.

Considering the changes in storm-flow conditions in lower Strawberry Creek between 1945 and now, and based on the foregoing discussion, the following brief resume is given of runoff conditions affecting lower Strawberry Creek at this time as compared to those obtaining in 1945.

In 1945 lower Strawberry Creek carried the runoff from 200 acres of improved area (Area C) plus 800 acres of unimproved area (Area A). The accumulation time of Area A was then at least two hours at lower Strawberry Creek, and its contribution to peak, flood-flow in the creek was minor. At the present time the creek still carries the flow from Area C, slightly increased; but in addition, it carries the flow from Area A, four times the acreage of Area C, with about ten percent of this area fully developed and an accumulation time of about one-half hour. As a rough best guess we estimate that the maximum peak storm-flow in lower Strawberry Creek, at this time, at maximum intensity of a storm of one-half hour duration, will be in the order of double the maximum flow in 1945. In this regard, it is pointed out that the Big Inch inlet has "plugged" during the past three major floods, with Area A water diverted down the canyon and over the city streets, and this flow has yet to be felt in lower Strawberry Creek in recent years. As the flooding of the areas in and below Strawberry Canyon can no longer be tolerated, and as we are now acting to prevent plugging of the inlet to the Big Inch storm sewer, this peak flow must now be expected in lower Strawberry Creek.

Area C does not contribute any appreciable quantity of bed or float-load to the creek, as it is almost totally developed and little erosion or pick-up of vegetal debris occurs. Prior to its present state of development Area A contributed very little coarse bed-load material, and virtually no large float-load, as the area was reasonably stable with respect to erosion. With the "trash rack" and "grizzly" system previously existing at the entrance to the Big Inch storm sewer no appreciable quantity of coarse material could have been transmitted down the pipe. Thus, until this year, little coarse debris has been injected into the creek. It is probable that large amounts of sand and silt have come down the creek from Area A but this is not important to present flood-flow considerations. At this time, and specifically during the past storm, large amounts of coarse bed-load material, up to boulder size, are being injected into lower Strawberry Creek from the Big Inch Storm Sewer. In addition, large quantities of leaves, branches and small logs are to be expected from this time forth.

Hydraulics and bed-load conditions

Lower Strawberry Creek is a winding, circuitous channel of widely varying depth, width, shape and hydraulic capacity, with its location, width and depth dictated by the encroaching structures and other improvements, and by desired landscape effects. Its present configuration reflects a long period of development, guided principally by area building locations and esthetic considerations, with little consideration of the hydraulic capabilities required of the channel by virtue of its being the outlet for all storm drainage from the campus. As the peak flood-flows in the channel increase, and as the bed-load carried by the channel increases in quantity and coarseness, the hydraulic capabilities of the channel and its ability to transmit coarse bed-load material become increasingly and critically important. We have conducted a very rough and cursory evaluation of these engineering aspects of the creek, keeping in mind the esthetic considerations involved and their very real importance to the campus, and a brief outline of our conclusions is given as follows:

There is ample gradient in the creek to handle present and short-term future demands for flow and bed-load transport if the creek is improved hydraulically by certain modifications. This will basically involve deepening the flow channel, reducing the undesirable effects of some sharp bends, and removing some channel obstructions.

Historically the creek has been much deeper than it now is in many areas, the creek bottom having been raised by the construction of groins across the bottom and by the introduction of sharp bends to avoid improvements. This has resulted in the filling of the creek bottom to the tops of the groins, and in the formation of extensive bars and aggradation of the channel in connection with the sharp bends. This has reduced the maximum flow capacity of the channel at critical points to a fraction of the potential flow capacity, and has greatly reduced its bed-load transport capabilities.

At certain bridge locations over the creek, and especially the bridges at Stephens Union and the Power Plant, the channel height is reduced by the structure to a matter of inches. During heavy storms a transient-bottom condition occurs, wherein the bottom scours out during heavy flows to make a deeper channel, and fills-in immediately as the flow reduces. Without this transient-bottom effect the hydraulic capacity of the channel at the structure is only a fraction of current peak flows. With a sand-silt bed material this phenomena takes care of heavy peak flows, and while it is a somewhat precarious drainage feature, it has apparently worked to date. With the channel bed materials now changing to gravel-cobble-boulder sizes we do not feel that the channel bottom will continue to erode at high flow, but rather that in the immediate future the small opening will plug and force the stream over and/or around the structure. This will result in the bridge acting as a groin, the channel will fill with sediment to the top of the bridge, and the stream will then divert around the bridge and cut a new channel to one side. In the case of the bridge at Stephens Union we estimate that this would result in the deposition of about 1000 to 2000 cy of sediment in the creek above the bridge, and the cutting of a new channel through Faculty Glade. In the case of the bridge at the Power Plant this would result in the filling of the creek channel for hundreds of feet upstream, and the diversion of the creek flow onto the campus area.

There are numerous obstructions in the creek, such as trees, utility lines, stumps, etc., which could act as the nucleus of a jamb, built up by branches, logs, brush, etc., being carried by the stream, which, with the accumulation of bed-load behind the obstruction would dam the creek in a matter of minutes. This would result in the flooding of adjoining improvements with nearly the full flow of the creek, as well as the filling of the creek channel for hundreds of feet upstream. One such particularly bad obstruction is located just below the new Students Union Building, and a jamb at this point would immediately flood this building.

The existing sharp bends constitute an invitation to the creek to fill the existing channel and cut a new, hydraulically more efficient channel. With the sharp increase in coarseness of the bed material which is now taking place, this phenomena becomes quite likely at several locations. At some locations of potential channel shift no major damage would ensue, particularly in the lower campus area, but at several locations it could result in the undermining of existing improvements and serious damage.

In conclusion, we feel that the existing creek is not adequate to carry either the peak storm flow or the accompanying bed and float-loads which will occur during the next heavy storm. In this regard we point out that, due to the unintended diversion of flow at the inlet to the Big Inch storm sewer, the creek has not carried the peak flows since prior to 1958. With improvements now being made in the inlet conditions to the storm sewer, in the next heavy storm the creek will receive this full peak flow. In addition, the creek will receive quantities and sizes of bed and float-loads not experienced in the creek in recent years. We feel that the creek can be made capable of carrying these flows and loads without destroying the esthetic value of the creek, and perhaps considerably improving it, by the execution of selected remedial measures. Our recommendations for immediate, emergency remedial measures to accomplish this end, are given later in this section of this report. These measures basically involve the selective deepening of the channel, the selective removal of the worst obstructions, and the improvement of certain of the worst hydraulically deficient sections of the creek.

Observations during the storm of October 11 through 13

During the above storm, and on detailed examination of lower Strawberry Creek thereafter, the following observations were made:

Peak flow in the creek did not reach impressive proportions. This is probably due to the two following factors:

While the overall four-day rainfall was a new record, the peak-intensity storms which occurred on Friday and Saturday were not unusually severe.

The runoff from Area A diverted down Strawberry canyon at the beginning of peak flows during both heavy rainfall periods, due to inadequacies at the inlet to the Big Inch storm sewer, and thus peak flow rates did not enter the creek from the storm sewer.

The second arch of the bridge at Stephens Union was open to a depth of about three feet at the tail-end of the peak runoff on Friday. It is now silted-up to within a few inches of the top of the arch.

Gravel-cobble bars are now seen in the lower creek area, which were not present prior to the storm. Boulders of up to eight inch size, freshly placed, were found in the bars. Examination of older stream deposits near these bars, incised during the storm, showed only finer materials.

The bed between the outlet of the Big Inch storm sewer and the bridge at Stephens Union is now loaded with gravel and cobbles to six inch size. Examination of older bars showed only silt-sand-gravel materials.

Maximum water height at Stephens Union was just below the deck of the bridge.

Inspection of flow into the City storm sewer at Oxford Street, at the tail-end of the heavy storm on Saturday, showed gravel-cobble sizes moving into the pipe.

We have estimated that at least 2000 cy and up to 10,000 cy of gravel and coarser sized materials entered the Big Inch storm sewer during the past storm.

At the bridges at Stephens Union and the Power Plant the stream channel has been filled to within inches of the top of the flow section. Only a minor opening is left, too small to have carried the flow during the storm by a large factor.

The hydraulic capacity of lower Strawberry Creek, overall, was not taxed by the storm.

General comments and conclusions

Based upon the cursory investigation and analyses discussed above, we submit the following general conclusions and comments regarding the hydraulic conditions of lower Strawberry Creek:

The creek is not adequate to carry the peak flows from any reasonably severe storm, with proper operation of the Big Inch storm sewer and injection of the flow into the creek, which must now be expected.

The creek cannot adequately handle the coarse bed and float-loads to be expected during future severe storms until such time as the upper watershed areas are stabilized.

Immediate measures must be taken on an emergency basis to improve the hydraulic capabilities of the creek or the deposition of large quantities of bed-load materials, severe erosion, and flooding in certain critical areas is to be expected. This is to be expected this winter unless we have another dry winter with no more severe storms.

The present hydraulic inadequacy of the creek is partly due to the increased peak flows and heavy bed and float-loads brought about by the recent developments in the upper watershed areas. The inadequacy of the creek is also due to a continual reduction in its hydraulic capacity by changes made in the creek over many past years, without regard to their effects upon the function of the creek as the only outlet for campus storm drainage.

The hydraulic capability of the creek can be restored and improved sufficiently to handle present and short-term future requirements, by taking carefully selected measures at various locations along the creek. These measures can be taken without impairing the esthetic values of the creek, and in the opinion of this office, may well improve the function of the creek as a relatively undisturbed "natural area".

As long as all campus storm drainage is carried by the creek, the existing choice is whether its hydraulic capabilities will be improved by planned measures or the creek will be allowed to develop an adequate channel by natural hydraulic phenomena. If the creek is allowed to remain hydraulically overloaded it will itself re-establish a stable regime by natural methods, at considerable damage to campus improvements and to the existing "natural setting" of the creek.

LENNERT AND ASSOCIATES
SOILS ENGINEERS

Job Number 260

November 2, 1962

ZONE II -- LOWER STRAWBERRY CREEK

EMERGENCY FLOOD CONTROL MEASURES

(See Resume of Preliminary Observations for Zone II)

Problem

Lower Strawberry Creek is now tobe subjected to greater peak flood-flows, and bed and float-loads of much greater quantity and coarseness, than it has experienced since development of the campus was begun. This produces the following specific problems:

The danger of over-flow and flooding of low areas is now greatly increased.

The potential for deposition of large quantities of bed-load materials in areas where removal would be difficult and expensive is now very great. Note that several thousand cubic yards of material have been removed from the "stilling basin" at the entrance to the Big Inch storm sewer, and from the pipe itself, during the past few weeks, having been deposited during the past storm. With the new inlet conditions at the storm sewer, necessary to prevent flooding of the Haas recreational area again, all of this material would have been dumped into the creek at Faculty Glade.

The danger of hydraulic "accidents", involving blocking of the channel, re-channeling by the creek, etc., with severe flooding and damage in the lower campus area, is greatly increased. For example, plugging of the flow section under the bridge at Stephens Union would probably result in the deposition of thousands of yards of bed-load in the creek and the incisement of a new channel through Faculty Glade. While we cannot predict the occurrence of such "accidents" specifically, we feel that if emergency measures are not taken, and if we have further severe storms this year, such accidents are not only possible but probable.

The basic problem, with respect to this winter and immediate remedial measures is thus to improve the hydraulic capabilities of lower Strawberry Creek such that general flooding will be prevented, large accumulations of bed-load material will be avoided, and the hazard of really dangerous "hydraulic accidents" will be reduced to a minimum.

Specific emergency remedial measures

The basic, long-term solution to the problem of flood-flow in lower Strawberry Creek involves the preparation of a master storm drainage plan for the entire campus and the proper handling of storm runoff in the upper watershed area, coupled with the stabilization of the watershed and the elimination of coarse bed-load material from the creek; together with the preparation of lower Strawberry Creek to carry the known quantities of clean, peak flood flows resulting therefrom. As such measures are not feasible this winter, and as we have recommended emergency measures in the upper watershed area to prevent the repetition of the flooding and damage which occurred during the last storm, which will increase the "load" on lower Strawberry Creek, measures must be taken immediately in the creek to protect the lower campus area during this winter, and future winters, until the overall problem can be solved.

Recommendations for specific measures to be taken immediately have therefore been prepared, with each recommendation having been written and laid-out in the field at the specific location. We have recommended only such measures as we feel are absolutely necessary, so that the minimum of changes will be made in the creek until a full study of the problem can be completed. We have considered the effect of each recommendation on the esthetic qualities of the creek and surrounding area, and have set the remedial measures so as to minimize any possible disturbance of the existing "natural area" conditions. The specific purposes of these recommended measures are given briefly as follows:

To lower the creek bed sufficiently to provide adequate overall hydraulic capacity and to remove the dangerous "transient bed" conditions at a number of locations.

To provide adequate capacity at such critical areas as the new Students Union Building, where creek capacity is poor and flooding would produce severe damage.

To remove points of potential "jamb-up" or other "hydraulic accident" to minimize the danger of "accidental" flooding such as occurred at the Haas recreational area during the past storm.

To provide a stream channel that will transport the expected coarse bed-load materials, without excessive "drop-out" and later expensive removal from developed areas.

On the bases discussed above we have prepared recommendations for seventeen specific remedial measures to be taken in lower Strawberry Creek; and we most strongly recommend that these measures be taken immediately. These recommendations are given as brief descriptive statements, and the location of the proposed measures are shown on an accompanying plan keyed to the number assigned to each specific item. The recommendations given are very brief, and it is our intention to supervise the work as performed so as to assure that the work is done as intended. The specific recommendations and accompanying plan are attached hereto.

General comments

Note that the removal of existing groins, as recommended, will allow the creek bottom to lower by scour during the next heavy storm, thus providing the deeper channel desired. This will produce a neater excavation than could be done with equipment, will avoid damage to trees and surrounding improvements, and will save a large expenditure of money, as degrading the creek bed with equipment would be a very expensive operation. We have provided some "catchment" capacity in the lower creek area to intercept the coarser materials which are scoured from the creek bottom as degradation occurs, to reduce the input of coarse materials into the City system.

We have made arrangements to obtain the locations of utilities passing under the existing creek bed, and will watch the progress of degradation of the creek with regard to these utilities.

The maximum lowering of the creek bed and the location of such lowering, to be accomplished by the recommended measures, has been set up and limited to minimize hazards to adjoining improvements and the stability of the creek embankments. We feel that the measures recommended represent the best overall choices for accomplishing the required hydraulic improvements in the creek with the minimum of change in the existing creek configuration.

LENNERT AND ASSOCIATES
SOILS ENGINEERS

Job Number 260

November 2, 1962

ZONE II EMERGENCY REMEDIAL MEASURES

(1) Remove all groins and other masonry for a distance of 200 feet upstream from entrance to storm sewer. Remodel or remove trash-rack as required to meet new gradient.

Excavate existing sand-gravel-cobble-boulder bed to new gradient (about three feet below existing grade) to reduce input of this material into the storm sewer and make a catchment for material coming in from above. Remove about 500 c.y. of material.

(2) Place bagged concrete to protect footing of northerly pier of C.I. water line crossing creek.

(3) Remove stump and brush.

(4) Remove groin and other masonry to a depth of six feet below the bottom of the bridge stringers.

(5) Remove large stump.

(6) Reduce height of groin at least four (4) feet, or remove in its entirety.

(7) Remove entire groin.

(8) Completely remove four small groins.

(9) Remove entire groin.

(10) Remove center six (6) feet of groin to full depth.

(11) Remove pipes from channel under bridge.

(12) Lower top of groin two (2) feet.

(13) Lower top of groin two (2) feet.

(14) Lower top of groin three (3) feet.

(15) Remove entire groin.

(16) Remove groin and other masonry. Remove willow tree. Remove accumulated debris.

(17) Remove root-bound earth point in channel.

(18) Remove willow tree, pipes and other debris.

(19) Lower top of groin two (2) feet.

(20) Remove entire groin.

(21) Remove all groins and other masonry, and all large rocks, from the flow channel up to the bridge at Stevens Union.

(22) Remove Buckeye and willow trees in channel, and all wood and other debris.

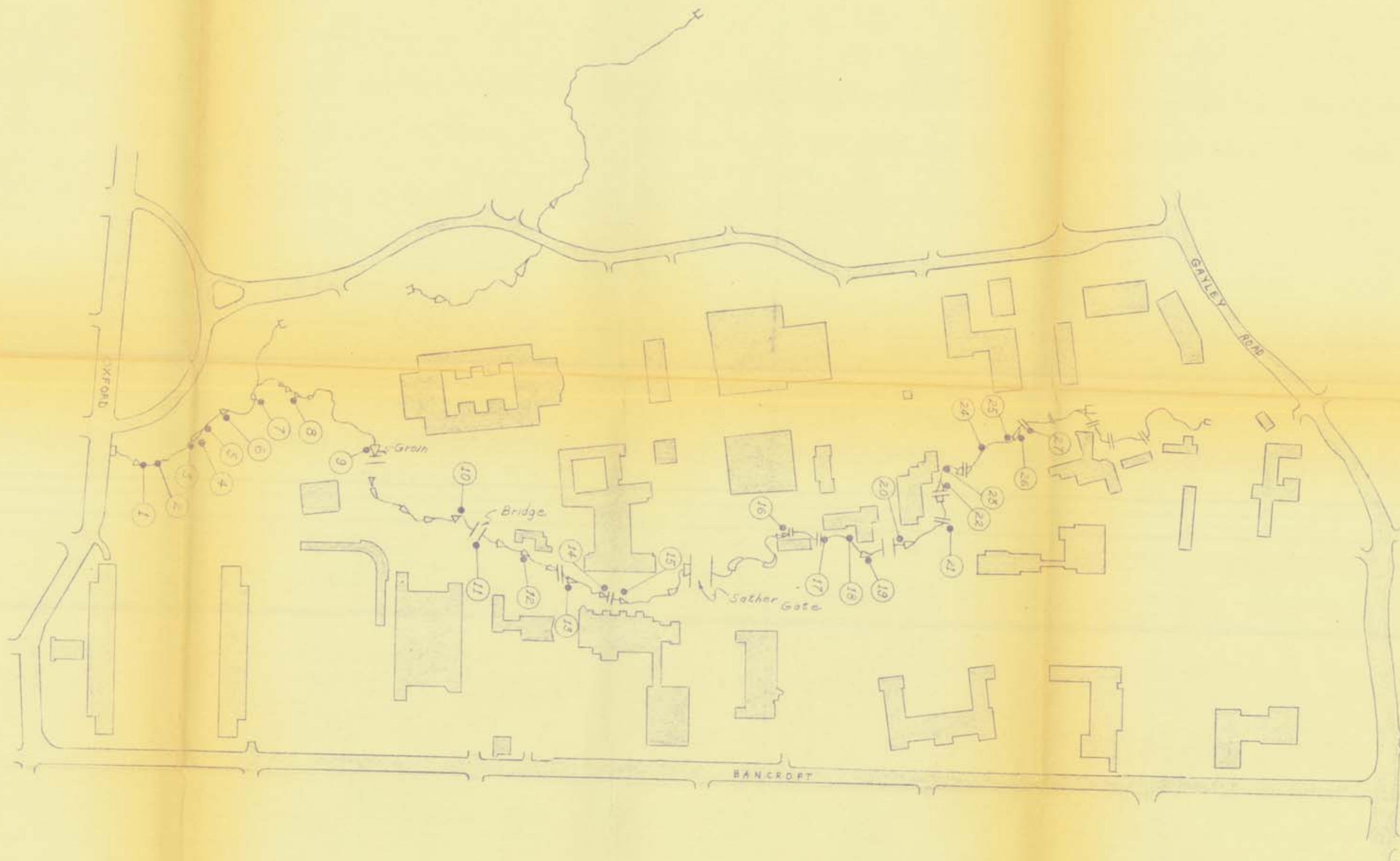
(23) Remove concrete block and one joint of pipe at outfall of concrete pipe drain into creek.

(24) Remove two Toyon trees in channel.

(25) Trim tree in channel to clear channel.

(26) Remove groin under bridge.

(27) Remove tree across channel.



UNIVERSITY OF CALIFORNIA AT BERKELEY

STORM DRAINAGE STUDIES

ZONE II - LOWER STRAWBERRY CREEK

LENNERT AND ASSOCIATES
310 Forest Street
Oakland 9, California

Job Number 260 Nov. 2, 1962

LENNERT AND ASSOCIATES
SOILS ENGINEERS

Job Number 260
December 17, 1962

ZONE III "BIG INCH" STORM SEWER

RESUME OF PRELIMINARY OBSERVATIONS

General Description

The Big Inch storm sewer consists of a circular concrete pipe conduit about 3200 feet in length and varying from 54 to 78 inches in diameter, together with a "trash rack", "settling basin" and inlet structure at the upper end. The inlet structure is located in Strawberry Creek just east of the Haas Recreation Building, and the outlet is located in Strawberry Creek at the northeasterly corner of Faculty Glade; the sewer thus acting to intercept and divert Strawberry Creek between these points. The location of the sewer with respect to the campus is shown on the accompanying plan, titled "Zone III, 'Big Inch' Storm Sewer." The sewer is intended to intercept all flow in Strawberry Creek, effecting a complete diversion of the creek; and the canyon area below the inlet is now occupied by the Haas Recreation Building and associated Strawberry Canyon Recreation Center, Memorial Stadium and further improvements below. This function was originally performed by the "Little Inch" storm sewer, which was built at the time Memorial Stadium was constructed, to permit the construction of the stadium and other facilities within the creek channel area. The inlet of the Little Inch sewer is now in the bottom of the existing "settling basin" and its outlet lies in Strawberry Creek just above the Faculty Club. The system is so operated that the Little Inch sewer carries the normal low-rate flow, in order to provide a permanent flow in the creek at Faculty Glade for esthetic reasons, and the Big Inch sewer is operative and carries flow only during heavy storms and periods of peak runoff, a matter of a few days per year. The sole function of the Big Inch storm sewer thus is to carry the peak storm flow from Strawberry Creek between the inlet and outlet points, by intercepting all flow in Strawberry Creek at the inlet point and injecting this flow back into the creek at the outlet, and it has no other purpose and performs no other function in the campus drainage system. Note that the Little Inch inlet plugs immediately during any appreciable runoff; as it lies at the bottom of the "settling basin", and it is always inoperative during periods of peak flow.

History

In reviewing the history of the diversion of Strawberry Creek by the construction of the Little Inch storm sewer in the early 1920's, through the construction of the Big Inch storm sewer as a bypass to the Little Inch, in 1951, we find a pattern of increasing peak runoff flows as the watershed area has been developed, but no indication of appreciable problems with bed and float loads. This gradually accelerating development of increasing runoff extends to the present time, when overloading of the natural stream channels is producing a severe problem of bed and float load as well as high runoff intensities. From past history it appears that the Little Inch sewer was adequate to carry the storm flow until 1950, and the Big Inch sewer apparently carried peak flows successfully until 1957, including several intense storms between 1951 and 1957. Note that during this period the entrance to the Big Inch sewer was covered with two-inch Cyclone fencing, and that the diversion and flooding in 1957 is reported to have been caused by the plugging of this fencing with fine float load materials. It appears that bed and float loads must have been negligible until 1957, as one-tenth of the material seen in the past storm would have completely plugged the inlet in minutes if it had been covered with two-inch wire mesh. Since the flood in 1957 no major peak runoffs have occurred until the fall of 1962; at which time both peak flows diverted around the inlet to the storm sewer and caused severe flooding and damage below. The first of these two floods took place on October 12, and occurred because the flow from Chicken Canyon was bypassed along the north side of the inlet to the sewer; and the total flood flow, which caused severe flooding and damage, consisted almost solely of flow from Chicken Canyon; the flow in Strawberry Creek being carried by the sewer. During the second period of overflow, on October 13, the flooding was caused by the complete blocking of the "trash rack" and aggradation of the creek bed at the upstream end of the "settling basin", causing a diversion of flow of Strawberry Creek around the south side of the inlet structure. Note that the inlet to the sewer was completely plugged up to the top of the structure at the time of the diversion, and if the float and bed load caught by the "trash rack" had not been so retained it would, without question, have completely plugged the inlet to the sewer and caused as severe or worse flooding and damage downstream as was caused by the diversion.

We thus have a history of increasing runoff and enlarged facilities to the present time, when existing facilities, while potentially adequate hydraulically, are obviously not functioning properly; and the last three storms have produced overflow at the sewer inlet and severe flooding and damage below. If one more period of peak rainfall had occurred during the storm of October 13 the inlet to the sewer would have plugged completely, immediately, and the full flow of Strawberry Creek would have been diverted down the campus, with the most severe flooding and damage resulting below. At nightfall on October 13, only three feet of the inlet structure had been dug-out and was exposed, and several hundred feet of the sewer was filled with cobbles, gravel and sand to within less than two feet of the top of the pipe.

We have thus drawn the following brief general conclusions regarding the historical development of runoff into the sewer system:

Runoff has increased by a large factor since the early 1920's, probably by somewhere between two and four times. The capacity of the sewer has also been increased, probably by a lesser amount than the increasing runoff with respect to pipe flow capacity; but the ability of the system to inject the flow into the pipe is obviously greatly inadequate due to plugging of the inlet system.

It seems that prior to 1957 no appreciable coarse bed load or any appreciable amount of float load arrived at the sewer inlet; as if it had, plugging of the sewer inlet and flooding of the lower canyon would have resulted. The two-inch mesh screen at the inlet to the Big Inch sewer would have plugged almost instantly during the past storm, and a crew of several men failed to keep the widely spaced pipe grizzly clear during both storms. Thus the severe bed and float load condition appears to be a new problem, and is due to the recent intensive development of the watershed area above the sewer, with resulting hydraulic overloading of the natural stream channels. The bed and float load problems are now critical.

The importance of a malfunction of a storm sewer, with resulting flooding below, is dependent upon the costs of damage and cleanup; and if no appreciable loss is incurred the malfunction is not important. The penalty for malfunction of the sewer has increased with time as both the number and value of improvements in the lower canyon area have increased, and as the unit costs for cleanup, repair and replacement have risen sharply with increasing labor costs.

Watershed, storm flow, and bed and float load conditions

Reference is made to the sections of this report covering Zones I and IV for a detailed discussion of the watershed area of the Big Inch storm sewer. The area covered by Zone IV is the watershed area of the sewer, and the area covered by Zone I is presently the most important single "short accumulation time" source of runoff to the sewer. From these two sections of this report the following brief resume of runoff conditions, pertinent to the sewer, has been taken:

The total watershed area is approximately 800 acres, of which about 100 acres are developed with building sites, parking areas and roads, about 300 acres are contingent and slope to existing roads or streams, thus producing relatively fast runoff, and about 400 acres are undeveloped and remote from roads or well developed stream channels.

The average gradient of the watershed area is somewhat greater than 17%, an unusually steep slope with respect to runoff conditions, considering the large area involved; and this steep gradient will produce significant increases in runoff coefficient and reductions in accumulation time, in comparison to normally flatter areas.

Runoff coefficients and accumulations times have been roughly estimated, assuming a peak storm which gradually builds up from an extended, low intensity rainstorm to a peak intensity of one-half hour duration. The values are given for assumed classes of areas, as follows:

Building areas, parking lots, roads and road-slopes:

Runoff coefficient = 100%
Accumulation time = 1/2 hour

Wooded and brush covered areas adjacent to roads and well-developed stream channels:

Runoff coefficient = 70%
Accumulation time = 1/2 hour

Wooded and brush-covered areas removed from roads or well-developed stream channels:

Runoff coefficient = 50%
Accumulation time = 1 hour

Accumulation times given are for the inlet to the sewer, just above the Strawberry Creek Recreation Center. Note that the clayey residual soils, essentially impermeable bedrock, and steep slopes of the hills will produce comparatively high runoff coefficients after saturation by a long storm; and that the steep slopes of roads and streams will produce in-transit times between watershed areas and the entrance to the sewer of relatively small values. Note that the accumulation times given have been doubled over purely surface velocity values to allow time for surface saturation to occur.

Rainfall intensities have been roughly estimated, as follows:

Two-hour intensity = 1"/hour
One-hour intensity = 1-1/2"/hour
One-half hour intensity = 2-1/2"/hour

Considering the "wringer effect" of the Berkeley Hills system, the above values are probably somewhat low, on a 10-year storm basis.

Based upon the above material and the more extensive background given for Zone IV, but still involving meager basic data and many gross approximations, we have made the following rough estimates of peak storm flow accumulation at the inlet to the sewer. Note that three values are given, our "best guess", and maximum and minimum values representing the widest "swing" we can envision by "fudging" all factors and assumptions toward the higher and lower flow figures. Note further that these flow figures are for the present time, with the existing stage of development.

Estimate peak runoff rate	=	1,100 cfs
Estimate maximum swing	=	1,300 cfs
Estimate minimum swing	=	700 cfs

It is estimated, very roughly, that the above flow figures could double at full development as shown by existing campus planning.

The bed and float loads have been evaluated in terms of the past heavy storm during the week of October 11, 1962. Reference is made to the section of this report covering Zone IV, for a description of the bed and float load in the watershed, and to "Observations during the storm of October 11 through 13", hereafter, for the conditions observed at that time. In general, the bed load is derived from severe encisement of the stream channels due to increases in stream flow brought about by recent developments within the watershed, with resulting enlargement and degradation of the channels, aggravated by slide materials contributed by unstable slopes abutting the stream channels. This condition is worsened by the greater transport capability of the higher peak flows in the channels, resulting in the moving of a much coarser and larger bed load than the channels have previously carried. The float load generally results from the contribution of down-wood from the watershed, artificially protected from fires and scavenging, aggravated by the contributions from caving banks and slide bodies absorbed by the streams. The larger flow rates also transmit greater quantities and larger pieces of float load materials. Summarizing with regard to this matter for purposes of this section of this report, we give the following brief outline of our opinions in this regard:

The bed load consists of boulders, cobbles, gravel, sand and suspended fines, up to one foot dimension. The transported quantity is large during peak runoff, having filled the canyon in back of the "trash rack", and the "settling basin" at the entrance to the sewer, in less than an hour during the peak storm on October 13. There is a large amount of very large-sized material, as well as finer sizes.

Float load, as seen during the past storms, consisted of brush, branches and logs grading from fine debris to material over one foot in diameter. Quantities were so great as to completely block the grate at the entrance to the sewer in a matter of minutes, and continual hand-clearing of this unit was performed during both storms, with limited success. During the storm on October 13, complete blocking of the "trash rack" and diversion of the flow into the Recreation Center area occurred in a period of less than one-half hour.

From the above information we have drawn the following general conclusions:

Storm flow into the sewer at this time will be about 1,100 cfs at peak flow for a "ten year" storm, with a potential "swing" due to errors in the estimate of from 700 to 1,300 cfs. It is unlikely that all factors would be in error in the same direction at once, and we feel that a value between 800 and 1,200 cfs is most likely.

Bed load conditions are severe, and will worsen with time in the immediate future; however, with proper preventative work in the next few years the bed load can be reduced to a nominal problem.

Float load conditions are very severe, and will worsen for the foreseeable future. It is unlikely that any effective measures which would greatly reduce the bedload will be feasible from the architectural-esthetics-cost standpoint in the immediate future, as this would entail the removal of large quantities of existing tree and brush cover, both esthetically undesirable and extremely costly. For the foreseeable future upstream interception facilities will have to be employed to screen out the bulk of the float load, coupled with the construction of a non-clogging, self-cleaning inlet structure for the sewer, entailing periodic removal of debris.

Hydraulics of the sewer

The hydraulics of a storm sewer, such as the "Big Inch" are estremely complex, and a detailed analysis thereof is far beyond the scope of our work; however, rough estimates of the potential performance of such a system can be made, and this has been done. The hydraulic capacity of a system such as the Big Inch is limited basically by two factors, (1) the inlet capacity, or the ability of the system to inject flow into the pipe, and (2) the hydraulic capacity of the pipe to carry this flow; keeping in mind that if the inlet structure is plugged with debris and inoperable the capacity of the system is zero, no matter what its hydraulics may be. The inlet of the Big Inch sewer consists of a somewhat encumbered rectangular opening in the sloping sidewall of the "settling basin" and stripped of its cumbersome and hydraulically defeating "trash rack", is approximately a rectangular orifice. We have estimated the inlet capacity of this unit, assuming a water level at the top of the "settling basin", zero approach velocity, orifice geometry, and a free fall outlet because of the steep slope of the initial section of the pipe. We arrive at an inlet capacity of about 1100 cfs, with a maximum value of 1,300 cfs if all factors are "fudged" to meet optimistic limits, and a minimum value of 700 cfs with most conservative assumptions. We feel that for the <u>existing</u> inlet structure the figure of 1,100 cfs is not at all conservative, and, if anything, is too high. Analysis of the pipe itself would be most challenging, as the pipe varies widely in both diameter and gradient, without hydraulically smooth transitions with respect to flow characteristics, but such an analysis is completely beyond the scope of our work. Referring to the table shown on the upper right-hand corner of the accompanying plan, it is seen that pipe diameter varies from 78 to 54 inches, starting at 72 inches, reducing to 54 inches and ending at 78 inches, and that the slope varies from 1-1/2 to 30%. It is noted, however, that approximately the upper one-half of the sewer length is at the flattest grade of 1-1/2%, and is 72 inches in diameter, followed by much steeper sections at 8-1/2, 15-1/2 and 30% gradients. We therefore feel that this upper section will control with respect to pipe hydraulics and have roughly estimated its flow capacity, using the gradient below the lower lip of the inlet opening to allow for inlet losses. On this basis we find the capacity of the pipe to be about 650 cfs, with a minimum of 500 cfs and a maximum of 750 cfs, taking the widest conceivable range of assumptions.

On the basis of the above estimates, we find that the capacity of the system is limited by the very flat upper half of the sewer length, and that a surcharge head of about fifty feet would be required to obtain a flow of 1,100 cfs, equal to the estimated peak runoff and the inlet capacity. This is obviously not possible with the existing system, and the capacity of the upper, flat, portion of the sewer, at about 650 cfs, thus constitutes the hydraulic limit of the system.

<u>Observations during the storm of October 11, through 13, 1962</u>

A brief resume is given hereafter of the most pertinent observations made during the subject storm, particularly during the two periods of peak runoff on Friday night, October 12, and Saturday noon, October 13, and during a later complete inspection of the sewer after the storm.

The inlet system to the Big Inch sewer consists of a wooden upstream "trash rack", followed by a bowl-shaped "settling basin", with a vertical pipe "trash rack" along the upstream edge of the basin; and the inlet is located in the sidewall of the basin at the downstream end, and is "protected" by a pipe "trash rack." The upstream wooden, "trash rack" is about one hundred feet upstream from the basin and consists of widely spaced, sloping timbers blocking the creek in the form of a trestle. The basin is a shallow concrete bowl about one hundred feet long by eighty feet wide, with a maximum depth below the rim of about fifteen feet. There is a "trash rack", consisting of vertical bars at about two foot spacing by four foot height along the upstream end of the basin. The inlet consists of a roughly square nine foot opening in the wall of the bowl, fronted by a vertical pipe "trash rack" of one and one-half foot nominal opening, and covered by a "duck board" platform. The entrance to the "Little Inch" storm sewer consists of a vertical gate with wire mesh screen located near the bottom of the basin. Strawberry Creek flows into the basin over the upstream lip of the basin, and Chicken Creek empties into Strawberry Creek just upstream of the basin and below the wooden "trash rack."

Large quantities of both bed and float load entered the system during the storm. The bed load material graded from suspended silt-clay through sand, gravel and cobbles to boulders of one foot dimension. The float load varied from fine brush to large logs of over one foot diameter. The accumulation of this material was very rapid and large quantities of both bed and float load materials accumulated in and upstream of the basin within minutes during the two peak storm flows.

The action of the system is roughly as follows:

> All coarse bed load materials immediately drop-out in the basin until a steep gradient is established to the inlet. At some gradient scour in the basin becomes equal to input and all further material is washed into the inlet and down the sewer. This appeared to occur at a depth of about five feet of bed load in the basin, if the inlet is <u>not</u> <u>blocked</u> with debris.
>
> As float load material clogs the "trash rack" at the inlet the gradient across the basin decreases and the bottom builds up in back of the clogged section until equilibrium-scour is once more developed. This continues until the "trash rack" is completely clogged, the bed load fills the basin, and the inlet is completely plugged.

The "trash rack" at the upper edge of the basin collects float load material and gradually plugs. As the bars are vertical and footing is precarious, hand cleaning during storms is virtually impossible and nothing effective can be done to prevent this. As the "trash rack" clogs the bed load builds up behind the "trash rack" until the stream channel upstream is filled, and a new scour-equilibrium is reached with the stream bed now sloping to the top of the "trash rack" and the bed and float load going over the top and into the basin.

During the peak flow on the night of Friday, October 12, the following events were observed:

The culvert inlet in Chicken Creek plugged almost immediately; the flow bypassed the culvert, ran through an opening in the fence by the Poultry Building (cut the day before for this purpose), and across South Canyon Road; the flow ran down a dirt road on the north side of the basin, thus bypassing the inlet to the sewer, and ran down the canyon, flooding Haas House and the recreation area and finally diverting around Memorial Stadium on Rimway and thence to Gayley Road.

The "trash rack" at the upper edge of the basin partially plugged, and the canyon area upstream aggraded considerably; but the Strawberry Creek flow all entered the sewer inlet.

The "trash rack" at the inlet plugged to a depth of about three feet below the top of the inlet, and the basin filled with bed-load to this level. The trash rack would have plugged completely, the basin would have filled with bed load materials, and the inlet to the sewer would have been completely plugged, if a crew of men had not been clearing and working the trash rack. This clearing and working consisted of "pulling" coarse float load material and sluicing the bed load between the bars and into the pipe. No removal of bed load material was possible.

If the flow from Chicken Creek had not been diverted around the south side of the basin there is little doubt that the inlet to the sewer would have plugged completely, diverting all flow into the canyon below, with the same or worse flooding and damage as occurred due to the diversion. The unintended diversion "split" the peak flow and may well have resulted in lesser damage than would have taken place had it not occurred.

After the peak flow subsided the "trash rack" was cleared to a depth of about five feet, the sediment in the basin was sluiced into the pipe to form a gradient to the upstream rim of the basin, and the trash rack on the rim of the basin was cleared of debris. The culvert inlet in Chicken Creek was cleared and the sediment laid down in the creek was sluiced through the culvert to clear the channel. Emergency clearing measures were completed about 1:30 A.M. of Saturday morning.

During the peak flow at about noon, Saturday, October 13, the following events were observed:

The culvert inlet at Chicken Creek again plugged immediately and the runoff diverted across South Canyon Road; but as the dirt road had been sloped into Strawberry Creek and sand-bagged the flow went into the creek and did not divert around the inlet to the sewer as it had on the previous evening.

In spite of some attempted clearing, the "trash rack" at the upstream edge of the "settling basin" plugged completely; the creek bottom filled with bed load to the top of the "trash rack"; and the flow then diverted around the south side of the basin, flooded the Haas building and the Strawberry Canyon Recreation Area, and continued down the canyon to Rimway and eventually to Gayley Road.

During the peak flow period a crew of men were attempting to clear the "trash rack" at the inlet to the sewer, by pulling the large float load material and sluicing the bed load through the bars. In spite of attempted clearing the "trash rack" at the entrance to the sewer plugged completely to above the top of the bars, with flow entering the pipe only by flowing over the lower guard rail and through the grating on top of the unit. The basin filled with sediment to the deck level of the unit or somewhat higher. The amount of water entering the sewer at this stage was relatively small due to the diversion along the south side of the basin; and if the flow had not been so diverted to the south of the basin by plugging of the upper "trash rack" and aggrading of the stream channel above, the full flood flow would have completely plugged the inlet structure and the entire creek flow would then have flooded the lower canyon area. It is probable that once again the unintended diversion very appreciably reduced the peak flood conditions lower in the canyon in comparison to those which would have occurred had the inlet to the sewer plugged completely and the entire flow been diverted down the canyon.

Clearing was continued after the peak flow subsided, consisting of pulling the float load debris from the "trash racks" and sluicing the sediment into the basin from above and from the basin into the sewer. No large scale removal of sediment was possible. At nightfall the south side of the basin had been securely sand-bagged against further diversion, about one-half of the upper "trash rack" had been partially cleared, and the inlet to the sewer had been cleared to a depth of about three feet below the deck of the inlet structure. At this point the flow had reduced so much that further large-scale movement of sediment from the basin into the sewer would have completely plugged the sewer, and this office recommended that clearing of the "trash racks" be ceased. Note that clearing of the "trash racks" releases the "dammed up" bed load material into the basin or sewer, as the case may be. This office gave the opinion that further cleaning efforts were futile, and recommended that a guard be posted to cut the fences by the Haas House and associated recreation area, to prevent "damming" and the danger of a severe flood from a quick release of dammed water if the heavy rains continued. We felt that further work at the "trash racks" and inlet structure was ineffective, dangerous to personnel and futile.

No further large storms occurred. If another severe peak runoff, such as the previous two, had occurred, the sewer inlet would have plugged immediately and all flow would have been diverted down the canyon. The flooding and damage occurring therefrom would have been much worse than that produced by the two previous peak runoffs, since the flow was "split" between the sewer and the diversion during both periods of flooding of the lower canyon.

The most pertinent observations made during an inspection of the "Big Inch" sewer from inlet to outlet, after the storm, are given briefly, as follows:

The pipe was "plugged" with a sand-silt-gravel-cobble sediment for a distance of about 300 feet downstream of the inlet, up to less than two feet of the top of the pipe. From this distance the depth of sediment gradually decreased to a nominal depth at a distance of well over 500 feet from the inlet. This material apparently represented a progressive "shoaling" in the pipe, starting with the development of a "downstream bar" of coarse materials. It presumably formed during the period of declining flow, and thus transport capability, of the peak runoff on October 13. Below about Station 20+00 the pipe was essentially clean.

Some severe erosion of the pipe was seen along the bottom of the pipe, at joints with irregular fit. In a few cases the reinforcing steel was exposed. The erosion is minor at this time, but if the pipe continues to carry a heavy bed load, severe erosion of the pipe invert is to be expected.

The sewer appeared to be generally in good condition, and there was no evidence that depth of flow had ever been much in excess of one-half the pipe diameter below Station 20/00.

The bed and float load which had come down the pipe during the storm and been injected into Strawberry Creek at Faculty Glade had moved on down the creek and had not accumulated at the outlet. It appeared that the bed load material had taken the place of finer creek bottom material present prior to the storm, and the creek bed material appeared to be generally much coarser than it was previously.

The two diversions of flow during the two peak run-off periods passed through the Strawberry Canyon Recreation Center, flooding Haas House, the swimming pool, the tennis courts, etc. The flow then diverted southerly along Rimway, past (and through) International House, to Gayley Road where the flow dispersed into the City street system. There was a large drop-out of sand-silt-clay sizes in the recreation area, but the flow contained only suspended fines beyond the tennis courts.

International House was flooded during both peak flow periods. The flooding was caused by the filling of a large and apparently essentially undrained depression on the east side of International House between the building and Rimway. It was apparent that a curb-board along the westerly side of Rimway and at the edge of the depression, had been removed recently; and the flow along Rimway thus pitched off the street and into the depression. The rising water level in this "hole" behind the building then broke through at lower window levels and flooded the building. In regard to the flooding of International House the following brief general comments are given:

At low flows the water passes down Rimway to Gayley Road without topping the edge of the road; but at high flows the high velocity of the water on the steep slope of Rimway causes it to "shoot" over the shoulder at the northeast corner of International House.

The water which flooded International House came from two sources, (1) the flow down Panoramic Way, which drains an extensive area to the east, and (2) the diversion down Strawberry Canyon from the "hydraulic accidents" at the entrance to the Big Inch storm sewer. The proportion of flow derived from each of the two sources cannot even be estimated; but it is our "best guess" opinion that the flow from Panoramic Way was sufficient to have caused the flooding of the building even if no diversion had taken place down Strawberry Canyon.

If the wooden curb (which had been in place previously) had not been removed, the water would not have "overshot" the shoulder of Rimway and the building would not have been flooded.

The solution to the problem of flooding of International House (which has occurred at least three times) is the construction of a masonry curb wall along the shoulder of Rimway. This office considers the existent situation, of an essentially undrained "hole" about thirty feet deep, adjoining the building and lying adjacent to Rimway, without even a standard concrete curb along the street, to be in violation of both common sense and reasonable engineering practice.

The flow from ~~Big~~ 10 Inch and Bull Pen Creeks plugged the culvert inlets and diverted onto North Canyon Road and into the recreation area. As the flow in both of these creeks was relatively small it produced only a minor part of the observed flooding; however the flow from Ten Inch Creek was sufficient to wash gravel-size sediment across the road and into the Haas House patio area. The recreation area, and especially Haas House and the adjoining swimming pool will have to be protected from overflow of these creeks.

A landslide of moderate extent took place in the hillside to the south of the Haas House; blocking the dirt road and crushing the fence which borders the recreation area at this point. This slide represents an overall instability of the hill slope in this area, and can be expected to move again.

General comments and conclusions

Based upon the foregoing material and upon much background information which it is not feasible to include in this report, the following general comments and conclusions are given briefly, as follows:

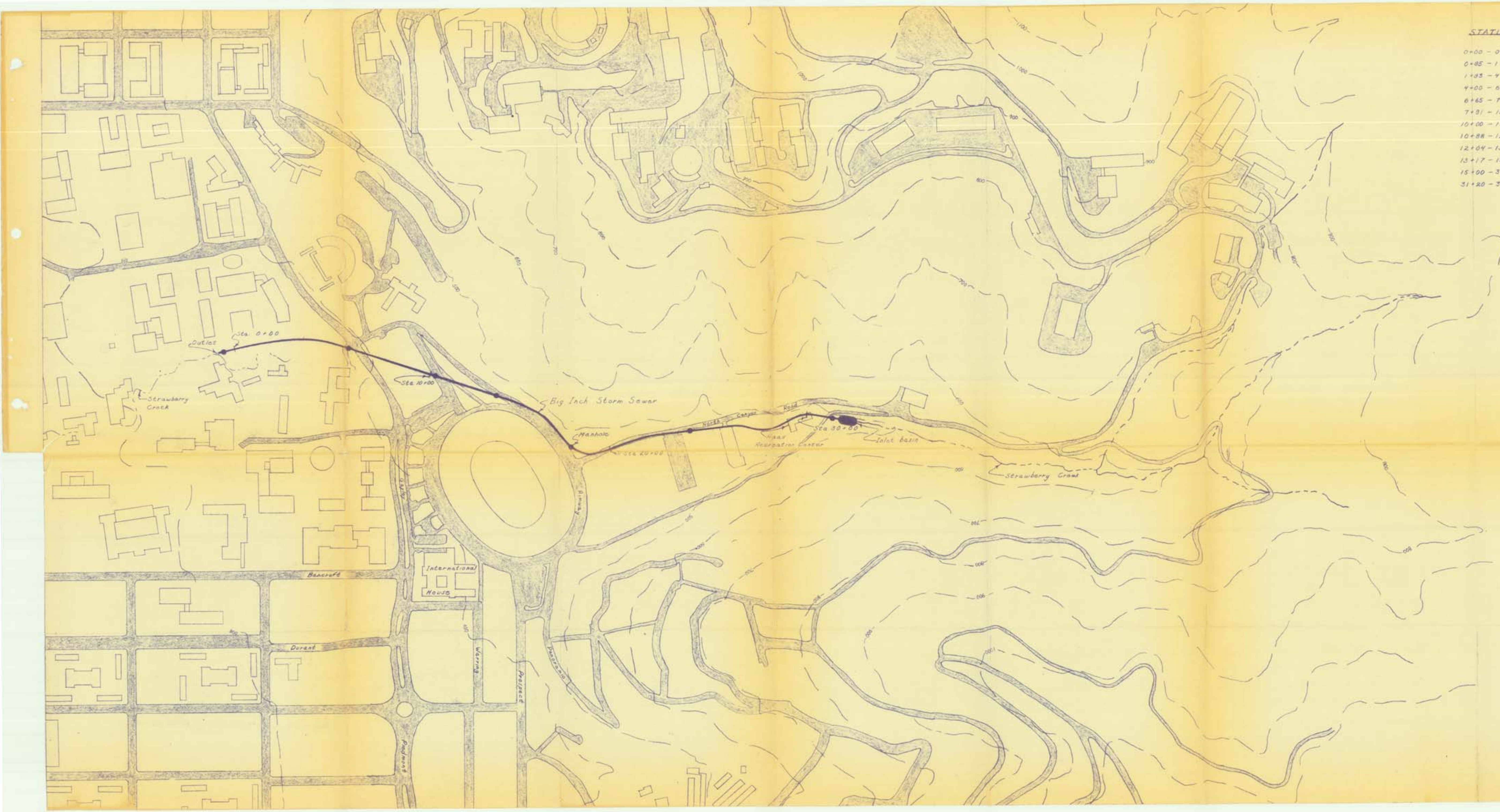
All diversions around the sewer to date, and resulting flooding in lower canyon areas, has apparently been due to malfunction of the inlet system, and not to hydraulic inadequacy of the sewer. Of the three floods since 1957 two have resulted directly from plugging at the inlet from bed and float load accumulation, and one by accidental diversion around the inlet; and if the accidental diversion had not occurred a diversion by plugging of the inlet to the pipe would almost certainly have taken place.

Bed and float load quantities are now very severe, and exceed the present capability of the system to function under these conditions. All bed and float load which reaches the sewer inlet must go on down the sewer. To intercept and accumulate this material at the inlet, as has been done, simply assures plugging of the inlet and flooding of the lower canyon area. The "trash rack" at the entrance to the sewer is dangerous as well as useless. Whatever bed and float load can be intercepted above the "trash rack" at the upstream edge of the basin is successfully held out of the system, even though this catchment method necessitates periodic removal of entrapped material at great expense; but once bed or float load material has entered the basin it must go on down the sewer and be discharged into Strawberry Creek at the outlet of the sewer.

The hydraulic capacity of the sewer as set by inlet capacity is just about equal to present expected peak flows, but is not adequate to expected peak flow with further development in the watershed area above. The hydraulic capacity of the sewer as limited by flow in the upper (flat) half of the pipe is not adequate to presently expected peak flows; and while it is sufficient to carry most of the flow, some remaining peak runoff would be expected to pass down the canyon. As the sewer inlet system has malfunctioned during all recent heavy runoff periods, no in-situ test of the hydraulic capacity of the sewer under current runoff conditions has yet been seen.

The upper (flat) portion of the sewer will "plug" with bed load materials at the "tail end" of a peak runoff period, as lowering quantities of flow reduce the transport capability of the pipe. We do not feel that this will be serious, however, if artificial clearing of the basin at the end of a storm does not inject large quantities of bed load material at this time. We believe that the recent plugging of the pipe, and very costly removal of the material, was due largely to efforts to clear the inlet of the pipe after the peak runoff on October 13; and while this effort was absolutely necessary as a precaution against another peak runoff period during that storm, we doubt that this situation will be repeated.

This office feels that recent events have conclusively proven that the existing inlet system is grossly inadequate to present conditions, and that this inadequacy will worsen with time. We feel that the existing inlet system should be replaced with a system which will solve the problem of plugging during peak flows, will increase the hydraulic capacity of the flat section of the sewer by providing an effective surcharge pressure, and will increase and balance the inlet capacity of the system with the flow capacity of the pipe. Further comments in this regard are given in "Emergency Remedial Measures", hereafter.



STATION	DIAMETER (inches)	GRADIENT (percent)
0+00 – 0+85	78	3%
0+85 – 1+33	72	6%
1+33 – 4+00	66	8%
4+00 – 6+65	66	7%
6+65 – 7+91	78	10%
7+91 – 10+00	66	3%
10+00 – 10+88	66	11%
10+88 – 12+04	54	30%
12+04 – 13+17	66	15%
13+17 – 15+00	72	8%
15+00 – 31+20	72	1%
31+20 – 31+78	Transition – 72" round to rectangular inlet section	12%

UNIVERSITY OF CALIFORNIA
AT BERKELEY
STORM DRAINAGE STUDIES
ZONE III – "BIG INCH" STORM SEWER

Job No 260

12/17/62

LENNERT AND ASSOCIATES
SOILS ENGINEERS

Job Number 260
December 17, 1962

ZONE III - "BIG INCH" STORM SEWER

EMERGENCY REMEDIAL MEASURES

(See Resume of Preliminary Observations and accompanying plan)

Problem

There are many deficiencies in the existing system which are beyond solution on an emergency basis this winter. Recommendations are given herein for remedial measures for items which we feel can be dealt with at this time on an emergency basis and which will be effective in improving the performance of the system this winter and in reducing the hazard of further flooding of the lower canyon area. A very brief outline of the problems dealt with in our recommended emergency remedial measures is given as follows:

Prevent plugging of the entrance to the Big Inch sewer. Assure that all bed and float load materials which enter the inlet basin go on down the sewer.

Prevent diversion of flow around the inlet to the sewer on either the north or south sides of the inlet basin.

Prevent plugging of the Little Inch sewer pipe, and thus forcing abandonment of the pipe.

Provide as large a catchment volume above the inlet basin, for bed load materials, as is feasible within the creek geometry and cost considerations.

Increase the hydraulic capacity of the system as much as quick, inexpensive measures will allow.

Repair and remedy the damage and plugging resulting from the past storm to an extent consistent with performance of the system and probable overall modifications to be made next summer.

Minimize damage from flooding in the canyon below if another peak runoff does by-pass the sewer.

Specific emergency remedial measures

The remedial measures recommended hereafter were actually begun during the storm of October 11 through 13, 1962; since they were most necessary and urgent to prevent further flooding in lower Strawberry Canyon. These measures were thus worked out on the spot with members of the University staff, and many of the most valuable suggestions were contributed by these people. Most of the measures recommended below are already completed, and checked and approved by this office, with the work being handled by the Department of Grounds and Buildings under the engineering direction and supervision of the Office of Architects and Engineers. This office has been consulted during the course of the work, and work now completed has been approved by this office. In the recommendations given hereafter work now completed is denoted by an asterisk (*) following the item number.

In context with the section of this report entitled "Zone III, 'Big Inch' Storm Sewer, Resume of Preliminary Observations" we make (or have made) the following specific recommendations, for emergency remedial measures in the Zone III area. These recommendations are described in the briefest terms to shorten the length of this report, but have been worked out in detail in the field, and inspected, by this office as done; or will be when performed. Our recommendations are thus given on an item-by-item basis, as follows:

(1) Remove all of the front (easterly) bars from the "trash rack" at the entrance to the sewer. Do not remove the side bars, deck, or railing. (This has been done, excepting that one bar on each side of the opening is yet to be removed.)

(2)* Remove the sediment "plug" in the sewer down to at least the mid-height of the sewer.

(3)* Remove all sediment and debris from the basin, and the creek area upstream of the basin between the basin and the wooden "trestle" trash rack, to as great a depth as embankment configuration will allow.

(4)* Cross-fall the dirt road on the north side of the basin so that it slopes into the basin. Fill as required to raise the road above the rim of the basin. (This has been done, and the road paved.)

(5)* Fill along the south side of the basin so as to cross-fall the side area into the basin with a fall of at least 10 percent.

(6)* Grade the dirt road south of the recreation area, so as to fall to the basin from the "high point", cross-falling the road into the hill so as to prevent the flow of storm runoff into the recreation area.

(7)* Fill around the west end of the basin, and "tie" the fill for Items 4, 5 and 6 together, so that the entire north-west-south peripheral area around the basin slopes into the low section of the basin wall. Raise the west side of the fill as high as feasible to "surcharge" the inlet. (This has been done, and paved.)

(8)* Repair the "wooden pole" trestle-trash rack above the basin if and as feasible, especially including repair of the northerly abutment, which has yielded. If not feasible to repair this unit, remove same. (Unit was repaired.)

(9)* Stockpile sandbags in the area for use in diverting flow along North Canyon Road in an emergency.

(10)* Regrade North Canyon Road along Haas House and the swimming pool area, so as to pitch the road into the bank and contain flow along the road. Place a berm, wall, or sandbags along the shoulder of the road as required to prevent flow over the shoulder and into the recreation area. Take special note of the outflow points of Ten Inch and Bull Pen Creeks.

(11) Close the gate at the entrance to the Little Inch storm sewer at the start of rainstorms, to prevent the plugging of the Little Inch pipe by the coarse bed load materials. Since this conduit is presumably in very poor condition at this time; if it is plugged with coarse debris it might have to be abandoned. This would force reconstruction of the drainage system in Memorial Stadium and "dry up" the portion of Strawberry Creek above the Big Inch sewer.

(12) Place a curb-wall along Rimway at International House to prevent "overshooting" of the shoulder of the road (or urge the Owners to do so). (A concrete wall has been built at this point, and appears to be adequate in design, excepting that we feel that it should be extended in length at both ends.)

(13) Organize stand-by measures for cutting the fences across the canyon in the recreation area, to prevent "damming" and later "flash flooding", in case the sewer again malfunctions.

General comments

Compliance with the above recommendations will, we believe, prevent further flooding this winter unless a very severe storm occurs. These measures do not, however, provide a permanent solution to the storm drainage problems in Zone III. With the present value of improvements in and below the lower canyon area, and with the severe costs of cleanup and repair work as well as the severe liability exposure; as a final solution absolute assurance must be had that Strawberry Creek will not produce an uncontrolled diversion down the canyon again under any reasonably conceivable circumstances.

We feel that a permanent solution to the problems in Zone III will entail four major measures, as follows:

Build a new inlet structure to the sewer, moving the structure upstream so as to obtain a more favorable location for the inlet and to develop enough elevation to apply a surcharge to the pipe, to increase the capacity of the flat portion of the sewer. Provide positive protection of the inlet from bed and float load by a properly designed grizzly system and the development of upstream retention.

Regrade North Canyon Road so as to provide protection from overflow of Ten Inch and Bull Pen Canyons, and to provide an emergency diversion channel for the storm sewer.

Place new inlet structures with adequate culverts in Chicken, Ten Inch, and Bull Pen Canyons, connecting the culverts directly to the storm sewer. Design these systems to take peak flow from these canyons at full development of the watershed area.

Institute a serious, long-range program for control of bed and float load in the watershed area.

We feel that the new inlet structure can take the form of a "self-cleaning" grizzly with a transition flow section into the sewer; or of a small dam with a retained lake, inlet structure and by-pass. Of the two choices we feel that the low dam would provide the best solution, offering a good surcharge head for the sewer, a hydraulically efficient inlet structure, positive control of bed and float load, and storage for "clipping the peaks" off peak storm runoff, thus reducing the required sewer capability. The emergency by-pass level could be raised so as to divert down North Canyon Road, thus offering positive protection to the facilities in the canyon. The canyon area just above Chicken Canyon would be an ideal location for such a unit, and due to the favorable geometry and soils conditions the dam could be made "hell for stout" at very moderate cost, assuring the safety of the facility. Note that such dams are now being planned and used in canyon areas all over the Bay Area, specifically in Richmond and in Belmont to name two areas of which this office is aware. The lake could be used for recreational purposes at little to no extra cost.

We feel that the traffic load from devêlopment of the upper hill area will soon necessitate the improvement of North Canyon Road. At that time the road could be designed as an emergency by-pass to the storm sewer, for rare storm peak runoff, thus making the sewer adequate for final development in the watershed and saving many hundreds of thousands of dollars, and providing positive protection to the lower canyon area. If this is done the road might carry storm flow, say, once every ten years.

The development of North Canyon Road as suggested above would also offer complete protection against overflow of Chicken, Ten Inch and Bull Pen Creek, along the north side of the road; and would allow a much "tighter" design of the inlet structures and culverts for these creeks, with a very appreciable savings in construction costs.

It is pointed out that storm drainage systems are designed for peak flows, and only operate at full capacity every ten to fifty years or so if properly designed. If a system is designed for a "ten year storm", it will presumably overflow every ten years. The size and cost of a system varies radically depending upon whether it is designed for a 10, 20, 30 or 50, etc., year storm. If infrequent and moderate overflow of the system can be tolerated the cost of the system is much less than if any overflow will result in disastrous flooding and damage. Thus, in an area where all valuable facilities are on high ground the storm sewers are designed for lower peak flows, and infrequent area flooding is accepted; however, where many valuable facilities are actually "down in holes" and subject to flooding, as at the campus, this approach will result in disastrous flooding and heavy dollar losses every ten years or so. We feel that for the Strawberry Canyon storm sewer diversion system, realistic considerations of a combination of construction cost and potential flood damage will eventually dictate a modification of the existing system to a realistic "ten year storm" basis for final development of the watershed, absolutely and clearly coupled with a well designed, safe, infrequent peak diversion down North Canyon Road.

Job Number 260

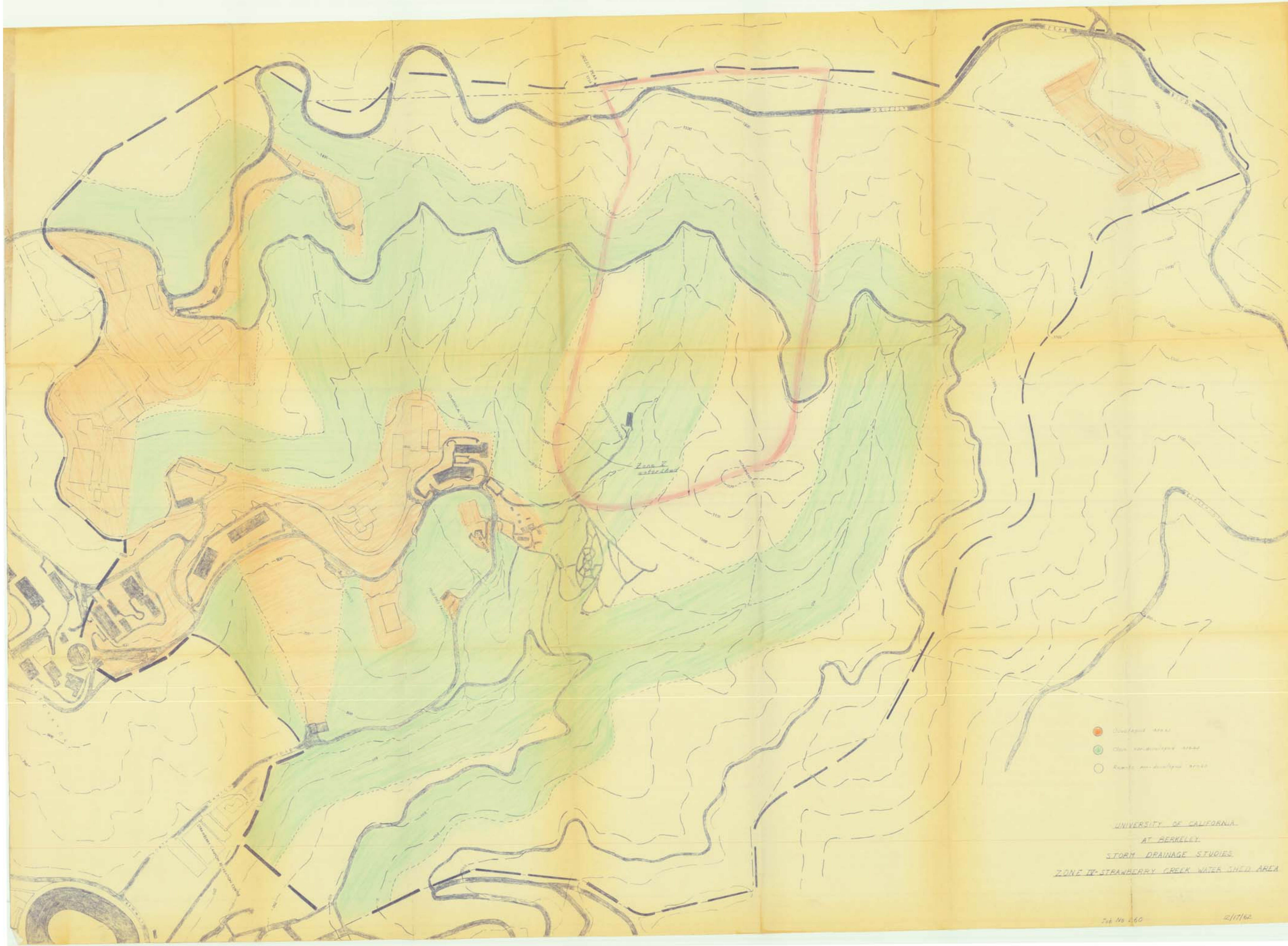
December 17, 1962

ZONE IV - UPPER STRAWBERRY CREEK WATERSHED

EMERGENCY REMEDIAL MEASURES

No recommendations for emergency remedial measures are made for Zone IV as we do not feel that "emergency" measures are justified at this time. This is not to imply that the Zone IV area does not require extensive improvements with respect to storm drainage at this time, as it most certainly does; but we do not feel that any measures can be taken this winter which would be justified in consideration of the costs and risks involved. Remedial measures in the Zone IV area must be based upon a campus master drainage plan and closely correlated with the upgrading of storm drainage capabilities in Zones II and III.

On a long-term basis we feel that storm drainage measures in Zone IV will basically involve the solution of bed and float problems, the artificial maturation of storm runoff channels in correlation with development of the watershed, the proper distribution of runoff in the various available channels, and the minimizing of peak runoff rates in the lower campus area by the wise use of all potential storage in the upper watershed and the maximizing of accumulation times with respect to the lower campus area. This problem is so complex, and its proper solution is so important with respect to final costs of storm drainage facilities for the campus, that we do not wish to comment further on this matter in this report, even though we have developed many ideas in the matter during the course of our work. The final solution of storm drainage problems in and resulting from Zone IV is intimately related to the final solutions for the entire campus, and can only be based upon a thorough, integrated solution to the storm drainage problems of the entire campus.


Developed areas
Open non-developed areas
Remote non-developed areas
UNIVERSITY OF CALIFORNIA
AT BERKELEY
STORM DRAINAGE STUDIES
ZONE IV-STRAWBERRY CREEK WATER SHED AREA
Job No 260
2/17/62

ZONE IV - UPPER STRAWBERRY CREEK WATERSHED

RESUME OF PRELIMINARY OBSERVATIONS

General description

The campus can be divided on a geographical-geological basis into two separate areas of greatly differing characteristics: one the flatter alluvial fan area in which most of the campus development now lies; and two, the steeper bedrock hillslope area which is only recently undergoing intensive development. The two areas are completely different in ground configuration and slope, in subsoil conditions, in the geological processes of their development and their current position within these continuing geologic processes, in rainfall and storm runoff conditions, and in their potential for development and thus the way in which they are developed.

The lower campus area lies mainly in an alluvial fan, the subsoil consists of clastic stream sediments grading from clayey silts to cobbles and boulders, and the area is nearly tabular with a gentle slope to the west. The upper campus area lies in the much steeper hill slopes rising above the alluvial fan, the bedrock is shallow and ranges from the Franciscan Formation of Jurassic age to the late Pliocene Orinda Formation. The contact between the two areas lies roughly along the Hayward Rift Zone, which has "sheared off" the westerly slope of the hills, the Rift Zone passing through Memorial Stadium and striking roughly northwest-southeast. The "break" between the two areas can be seen on a topographic map of the campus as a sudden "spreading" of contour lines, indicating an abrupt change in slope. For a more detailed discussion of the geology and geologic genesis of the area the reader is referred to a report by this office entitled "Soils Design Report, University of California Residence Hall Number Three, Berkeley, California", dated July 21, 1961.

When considering storm drainage on the campus it is thus necessary to think in terms of two very dissimilar areas; the upper area with local runoff and soil-stability problems indigenous to the area, and the lower area also having its own local drainage aspects plus the additional problem of having to carry the runoff from the area above. The problems in the upper area are mainly local, involving erosion, landslides, very local "spot flooding" and localized diversion; while in the lower area local storm drainage problems have generally been solved long ago, and the major problem lies in handling the runoff from the upper area and prevention of damage therefrom, especially where artificial developments or diversions in the upper area have changed the drainage patterns or increased the flows to particular areas below.

Because of the configuration of the hill area and due somewhat to recent artificial diversion, the bulk of the upper campus area drains into the Big Inch storm sewer, and thus forms the watershed for the sewer; the inlet to the sewer lying some five hundred yards up Strawberry Canyon from (easterly of) the "break line" between the flatter and steeper areas. The remainder of the upper, steeper portion of the campus drains to the north campus area and to Blackberry Canyon in a devious and complex pattern that has been much altered by the development of building sites and roads in and to the "Rad Lab area" above.

The area that we have taken as Zone IV in this report comprises the watershed area of Strawberry Creek as we believe it will be at the time of final development of the campus. The existing watershed is somewhat smaller than this, and less highly developed, but has been evaluated for present-time estimates in terms of percentages of final development. We feel that this approach permits a better balanced evaluation of the watershed area of the Big Inch storm sewer, as it permits the inclusion of the final development condition in present evaluation of current problems with the system. The Zone IV area is shown on the accompanying plan entitled "Zone IV, Upper Strawberry Creek Area", herewith. Note that the storm runoff from the entire zone, comprising approximately 1/3 of the total campus area, accumulates at the entrance to the Big Inch storm sewer and is thus diverted into Strawberry Creek at Faculty Glade if the storm sewer functions properly.

Analysis of the watershed

The watershed area of upper Strawberry Creek, as it enters the Big Inch storm sewer, is outlined on the accompanying plan by a heavy dashed line. This line represents the "break line" of the watershed, and encloses the area draining into the creek. Note that the break line is "controlled" to the northwest by the "Rad Lab" area and the proposed new road connecting North Canyon Road with Grizzly Peak Boulevard, as we have assumed that this road will divert peak flow (it will, whether intended or not, if it is designed like existing roads). To the south and east the break line is controlled by Claremont Ridge and to the northeast by the Grizzly Peak ridge system and Grizzly Peak Boulevard. To the west the control is provided by the cross-ridges which fall to Strawberry Creek and the location of the inlet to the storm sewer. The area thus encompassed by the heavy dashed line, which forms the watershed to the inlet to the storm sewer, consists of some 700 acres, varying from paved parking and road areas to forested areas densely covered with trees, brush, grass and humus.

For evaluation of an area with respect to storm runoff, the following factors are the basic considerations which pertain:

Size of area receiving rainfall.

The slope of the area receiving rainfall, and the slope and condition of the channel which carries the water to the inlet point being considered.

The surface condition of the area, i.e., paved, buildings, grass, brush, timber, humus, etc.

The permeability of the soil.

The capacity of the creeks, roads, gulleys, etc., to transport the runoff, and the resulting accumulation time to the entrance to the sewer of the various areas.

Considering these factors for Zone IV the following comments and discussion are given:

The watershed is normally broken down into sub-areas of relatively similar properties,for analysis of runoff. This has been done on a very rough basis for this analysis.

The average slope of the total watershed is about 17%. Local hill slopes to creeks generally average steeper than this, lying mainly between 30 to 60%.

Area surface cover varies from roofs and pavement to dense timber and brush with deep humus. This has been roughly accounted for in our analysis.

The bedrock is essentially impermeable, and all surface soils are clayey and of low permeability.

Due to their steep slopes, the roads and mature creeks within the site provide very high velocities and short in-transit times for runoff water. The upper immature (grassy, brushy, "clogged" ravines) creeks will provide much slower delivery of runoff to the lower areas, and higher channel storage. This has been roughly taken into account in our analysis.

The basic factors affecting peak storm runoff are thus generally conducive to very high peak runoffs in this watershed. The only major limiting (and thus helpful) condition, has been the heavy ground cover and poor channel capacity, and this is rapidly being changed by development of the area and erosion of the presently immature ravines into clean, high-velocity creek channels.

In a storm runoff study the watershed is normally broken down into sub-areas in which the variation in pertinent factors is not large, and similar areas are then grouped for consideration in the study. For our purposes of arriving at a rough "best guess" evaluation of the zone, we have broken it down into three basic area types, as follows:

Developed areas. Building areas, paved areas, roads and adjoining bare cut slopes, essentially clear surfaces in building areas, etc.

Close nondeveloped areas. Wooded areas adjoining high-capacity creek channels or roads feeding directly to Strawberry Creek; whose maximum in-transit flow time to the entrance to the storm sewer is estimated at 1/4 hour or less.

Remote nondeveloped areas. Wooded areas remote from high-capacity creek channels, whose maximum in-transit flow time to the entrance to the storm sewer is estimated at 1/2 hour or less.

The developed areas at full campus development have been approximated from the "University of California at Berkeley, Long Range Development Plan", dated June 1962, as shown on the accompanying drawing, and comprise about 110 acres of the total 700 acres. These areas are drained by roads and/or steeply sloping creeks, and we have assumed an average in-transit velocity to the inlet to the storm sewer of 10 feet per second, giving a maximum in-transit accumulation time of about 1/4 hour. Assuming a period of 1/4 hour to achieve full ground and channel storage, this gives an effective critical accumulation time of 1/2 hour with respect to storm intensity. For the 1/2 hour accumulation time as described above we have assumed an effective runoff coefficient of 1.0.

The non-developed portion of the watershed has been divided into two separate areas, to very roughly account for in-transit travel time and short-term ground storage effects, and the breakdown has been arbitrarily set up as follows:

All areas on either side of mature stream channels, and sloping steeply to the channels, to a distance on either side of 300 feet from the center of the channel, have been set up as low transit-time and low ground-storage areas, resulting in a short accumulation time and high runoff coefficient.

All nondeveloped areas more than 300 feet from mature stream channels have been deemed to be "remote", with a longer in-transit time and much greater ground storage, resulting in a longer effective accumulation time and lower effective runoff coefficient.

The "close" nondeveloped watershed area as defined above has been found to consist of about 300 acres, as shown on the accompanying drawing. These areas have rapid access to the storm sewer inlet via roads and mature creeks, and we have assumed an average in-transit velocity of 10 feet per second and a maximum in-transit flow time of 1/4 hour. Assuming a period of 1/2 hour to develop full ground and channel storage, there results a critical accumulation time of 3/4 hour with respect to storm intensity, to develop full runoff. Taking the 1/2 hour effective accumulation time of the developed areas as approximately the critical time for peak flow for the storm sewer (a gross approximation, of course) we have assumed an effective runoff coefficient of 70% for this shorter accumulation time.

The "remote" nondeveloped watershed area was found to be about 290 acres, as shown on the accompanying plan. These areas are more than 300 feet, measured downhill, from a road or mature stream channel capable of offering fast transit to the storm sewer. We have assumed an average in-transit velocity to the storm sewer of 5 feet per second, giving a maximum in-transit time of about 1/2 hour. Assuming a period of 1/2 hour to achieve surface and bank storage, this gives a critical accumulation time of 1 hour, with respect to storm intensity, for the area to develop full runoff. For the assumed critical accumulation time at the entrance to the storm sewer of 1/2 hour we have assumed an effective runoff coefficient of 0.50.

The zone has thus been divided into three types of areas for purposes of evaluating storm runoff conditions, as described above. While the methods used are the roughest of gross approximations, a study of greater refinement is far beyond the scope of our work, and we feel that the results are reasonably correct. The analysis shown has been performed on the basis of "full development" as shown on "University of California at Berkeley, Long Range Development Plan", dated June, 1962. For intermediate stages of development the relative amount of developed and close nondeveloped areas can be estimated, and the total acreage adjusted to equal 700 acres.

Runoff

The runoff from a given storm drainage area varies widely with the intensity and duration of precipitation, and with the sequence in which a series of peak rainfall intensities may occur during one storm. If a storm gradually builds in intensity over, say, 2 hours ending with a severe 1/2 hour deluge, it will, in a watershed such as Zone IV, produce a peak runoff of extreme magnitude. This is due to the overlapping of peak runoffs from areas of decreasing accumulation times, ending with the final introduction of a severe peak from the areas of short accumulation time which correspond to the last 1/2 hour peak intensity of the storm, and producing a runoff coefficient of nearly unity for all areas. At the other extreme, if a storm of 1/2 hour duration is not preceded by a "cascading" buildup in intensity, the runoff coefficient will be unity only for the low accumulation-time areas, and all other areas will show only fractional runoff coefficients, resulting in a greatly reduced peak runoff. The intensity-duration pattern of most real storms lies somewhere between these extremes.

Properly designed and effective storm drainage systems are not designed for daily flow, or by similar concepts, but are designed for a peak storm runoff lasting only a fraction of an hour, which will occur only once in 10, 20 or 30 years; as it is these infrequent storms which cause severe flooding and damage, and must be contained. If overflow and flooding does not result in serious loss the engineer will design for, say, a 10 year storm, and let all storms of greater intensity (and less often occurrence) flood the area. Where such flooding will result in great damage this approach is not desirable, and one normally designs, say, the pipe system for a 20 year storm and the street system to take all other peak flow to, say a 50 year storm, without serious damage. Where the street system dumps the flow into expensive improvements with great damage resulting, the engineer normally modifies this aspect of the street system or faces a severe economic problem in designing the system. Very few storm drainage systems are designed to handle a 50 year storm in the pipe system; due to the extreme cost of such a system.

In consequence of the above considerations the intensity-duration pattern of precipitation <u>within the watershed being considered</u> is of great concern. Rainfall intensity-duration patterns vary widely over the Bay Area, and from year to year, and we have no reliable data for the Zone IV area; however, the following general observations are made for the area, and are the basis of our "best guesses" regarding the ten year storm intensity-duration relationships which pertain.

> The Berkeley Hills produce a "wringer" effect, and precipitation on the hill slopes is greater than in the flat valley area below.
>
> The 10, 20, 30, etc., year peak storms are probably intensified by the "wringer" effect, especially at lesser duration values. Thus we would expect, say, double the intensity in the hills for a 15 minute storm as compared to the flat area below.
>
> Bursts of rainfall of high intensity and short duration probably occur more often in the hill areas than in the flat areas below, and thus the shape of the intensity-frequency curve is probably altered in the hill area to the extent of being generally higher and flatter than in the lower areas.

For purposes of this report we have set up the following intensity-duration relationships for the Zone IV area, as the best cursory evaluation which we can make within the scope of our work:

Duration	Intensity
Hours	Inches per hour
1/2	2-1/2
1	1-1/2
2	1

These values have been used for our runoff calculations for the watershed.

Using the watershed data given in the foregoing portion of this report, and the above rainfall intensity values, we arrive at the following rough estimate of peak flow at the inlet to the Big Inch storm sewer, based on a 10 year storm:

Developed areas:

Area = 110 acres

Intensity = 2-1/2 inches per hour

Runoff coefficient = 1.0

Peak flow = 275 cfs

Close nondeveloped areas:

Area = 300 acres

Intensity = 2-1/2 inches per hour

Runoff coefficient = 0.70

Peak flow = 525 cfs

Remote nondeveloped areas:

Area = 290

Intensity = 2-1/2 inches per hour

Runoff coefficient = 0.50

Peak flow = 360 cfs

Total peak flow = 1150 cfs

Note that we could assume a "cascading" storm intensity, use runoff coefficients of 1.0 for all areas, and use rainfall intensities of 2-1/2, 2-1/2 and 1-1/2 inches per hour, respectively; and this would result in a peak flow figure of 1460 cfs. In the same way, many other combinations of assumptions are possible. "Fudging" all factors either in the direction of producing greatest or least flow we feel that the maximum probable range of error of the peak runoff figure given is as follows:

Minimum peak flow = 700 cfs

Maximum peak flow = 1,500 cfs

We believe that an exhaustive analysis of the watershed would give a peak flow value between the two figures given above.

The above figure is for total development of the watershed, as previously defined. For the presently existing conditions we estimate the peak flow as about 900 cfs, with a possible range between 1,100 cfs and 700 cfs. Note that these values are somewhat less than those given in the section of this report covering Zone III; as these figures are based upon a later and more extensive analysis and are thus somewhat "sharper". Note further that the proposed final development as shown on the reference plan is seen to affect the calculated peak runoff value only moderately; since the proposed final development adds only moderately to the existing road system and developed areas, which are largely graded and existing in semi-developed form at this time. Looking back in time to the period just after World War II, when the area was largely undeveloped, if we assume an accumulation time of 2 hours and runoff coefficient of 0.5, we calculate a peak storm flow of about 350 cfs. It thus appears that the greater part of the increase in peak runoff has now occurred, <u>if the proposed final development plan is followed</u>. If the upper campus area were to be developed to the degree that the lower area is now, the peak runoff value would increase by a large factor, to say something in the range of 1,700 cfs.

It is pointed out that the above flow figures are for 10 year incidence, i.e., they will be seen only once in ten years. In addition, these flow rates will last for only, say, 1/4 to 1/2 hour. Thus a system built to handle such flows will have great over-capacity in nine years out of ten. It is the losses during the tenth year which force the design of a storm drainage system for such flow rates; losses which are of recent recollection in the case of the recent storm during October 1962.

<u>Bed and float load conditions</u>

Flooding and damage in the Strawberry Creek area to date has resulted more from the problem of severe bed and float loads than from the peak runoff quantities. This has been and is now true due to certain conditions in the watershed, and a resume of these conditions is given briefly as follows:

The area "bedrock" consists mainly of geologically young Orinda Formation sediments of poor induration and mechanical soils properties, lying nonconformably on Franciscan Formation sediments of great age and induration, and reasonably good properties. The Orinda sediments generally show poor soils properties, erode easily, and are unstable and slide at slopes in the range of those found in this watershed. Thus incisement of stream channels occurs easily with increasing stream flow; and such incisement often leads to major landslides moving into the stream channel. This results in the erosion of large quantities of material and produces a large bed load. The creeks thus experience great difficulties in some areas in developing "mature" beds, that is, channels which suffer no net erosion and are stable under peak flows; and in some areas erosion of large quantities of material will take place until artificial intervention occurs (an example of this is the large slide in Chicken Canyon just upstream of the Poultry Building and on the westerly side of the creek).

The recent development of the watershed area has resulted in greatly increased peak runoff, incisement of previously immature stream channels, and general overloading of the existing drainage system. We thus now see a drainage area in which degradation of stream channels, progressive instability of embankments, and heavy erosion and large bed loads are the rule. Chicken Canyon is a good example of this situation.

In consequence of the above situation the bed load, that is, the boulder-cobble-gravel-sand-silt load carried by the drainage system, is very heavy. This will continue without improvement, and, in fact, will worsen with time, until artificial stabilization of the creek channels is effected. Chicken Creek is now a prime example of this problem, due to the recent diversion of high peak runoffs from the "Rad Lab" area into the creek, but other presently immature canyons will also undergo this phenomena as upper areas are developed.

Strawberry Creek is now relatively mature, and shows only moderate erosion and degradation; the worst conditions of encisement and erosion being now confined to secondary canyons. As the development of the area increases, however, Strawberry Creek will also show progressively greater instability; and this problem should be controlled before many years have passed, or a truly serious condition could arise.

The float load (i.e., floating debris, logs, branches, brush, grass, etc.) problem in Strawberry Creek is now severe, as witness the difficulties encountered from this source in the recent storm. The float load materials are derived almost solely from down-wood normal to the watershed, plus trees, branches, and brush derived from the landslide debris and caving embankments. Since the watershed is now artificially protected from forest fires, which would limit the accumulation of these materials under "natural" conditions, we see no end to this problem in the foreseeable future. It is expected that the problem will have to be solved by the construction of suitable control facilities ahead of the inlet to the storm sewer, with yearly removal of the accumulated debris. It is pointed out that the float load is harmful only as it clogs the storm drainage system and prevents the proper function thereof; and much of the past difficulties caused by excessive quantities of float load materials can be eliminated by proper design of the storm drainage system. If this is done, only the larger floating debris need be intercepted, and this can be done with reasonable effort and expense.

As a result of the foregoing conditions, large quantities of bed and float load materials move down the creek channel during heavy runoff; and it was estimated that during the storm of October 11 through 13, 1962 many thousands of yards of bed load material moved down the creek and into the inlet system of the storm sewer during each of the two peak runoff periods. During the second peak runoff period the quantity of float load was sufficient to completely "plug" the "trash rack" at the upper edge of the inlet basin in a few minutes, causing the second flood diversion down Strawberry Canyon which occurred during that storm. The bed load during the second peak runoff period filled the creek channel upstream of the settling basin, up to the top of the "trash rack", shunting flow around the basin, in a matter of a few minutes, and later filled the settling basin to the top of the inlet structure. A matter of several thousand yards of material was involved, being moved into the area in, say, 1/4 hour, and this quantity is additional to the material which passed on down the sewer. At the "tail end" of the second peak runoff period the sewer was nearly filled with bed load material to a distance of several hundred feet below the inlet to the sewer.

We have thus drawn the following conclusions in regard to bed and flood load conditions in the watershed:

At low runoff rates little material moves; at intermediate flow rates the bed load quantity begins to become appreciable; and at high flow rates the bed load volume lies in the range of many thousands of cubic yards per hour and the float load rate in the range of many tons per hour.

The bed load problem will be remedied only by artificial stabilization of the stream channels.

The float load problem can be dealt with only in terms of designing the storm runoff system so as to avoid serious effects from the float load. No practical way of eliminating the float load on a permanent basis is apparent.

Observations during the storm of October 11 through 13, 1962

Reference is made to the sections of this report covering Zones I and III for the observations recorded therein. As this material covers the bulk of the available information, only a few additional comments will be made in this section of this report, as follows:

During both peak periods the quantity of runoff did not seem to be phenomenal; and this comment was made by many observers. This would indicate that the peak runoff seen did not represent the magnitude of a true "ten year storm".

Strawberry Creek itself showed little net encisement and degradation; however, it easily carried all bed load contributed to it from tributary channels. Severe erosion and the production of large quantities of bed load material appeared to be confined to secondary canyons such as Chicken Creek. There was no evidence that Strawberry Creek was hydraulically overloaded, and the depth of flow in the creek did not reach unusual proportions. All serious problems of erosion and hydraulic capacity appeared to be confined to secondary canyons, only.

All three culverts in the North, Center and South Forks of upper Strawberry Creek, where a dirt fire road crosses the creek branches, were found to be inadequate during the storm, and did not remain open or carry the peak runoff. No serious problems resulted, but improvement of these facilities will be required at some future date.

General comments and conclusions

Based upon the foregoing material, the following general conclusions are given in an attempt to very briefly summarize our view of the existing runoff conditions pertaining to the upper Strawberry Creek watershed:

The Zone IV watershed has flooded the lower canyon area during every heavy runoff since 1955. This is three times in seven years. It seems obvious that all three of these peak runoffs could not have been "ten year storms", and in fact there is no assurance that any of these peak flow periods had a "ten year storm" intensity and runoff rate. It is open to conjecture as to what the effects of a true "ten year storm" would be with existing watershed conditions, considering what has happened during the past three periods of heavy runoff. It is our opinion that the two peak runoff periods which occurred during the storm in October 1962 were not of "ten year" intensity, even though the overall rainy period set a record for precipitation over a period of several days and in fact, may not have been at all unusual with respect to peak runoff. It seems most probable that we have yet to see the effects of a true "ten year storm" on the Strawberry Creek watershed under existing conditions.

Due to the "plugging" of the inlet to the storm sewer and diversion of peak flow, peak quantities and sizes of bed load materials have not yet been dumped into lower Strawberry Creek at the storm sewer outlet in Faculty Glade. In consequence of this, the effects of the current watershed bed load in lower Strawberry Creek are yet to be seen. We speculate that the large quantities of coarse bed load materials will tend to force lower Strawberry Creek to alter its existing regime. This will probably entail the elimination of bends by the cutting of straighter channels, the erosion of "soft" banks on the "throw" sides of the creek, etc. A typical location where an existing stream meander might well be eliminated by this action is the sharp bend at Stephens Union Building in Faculty Glade.

The effects of peak runoff from the watershed have not yet been seen in lower Strawberry Creek due to the inadvertent diversions of the creek, as discussed previously, and had the peak flow of the last three major runoffs passed through lower Strawberry Creek rather than being diverted at the inlet to the storm sewer, the resulting flooding and damage might well have been more severe and costly than that which occurred by reason of the unintended diversion. We believe that if the peak runoff of a "ten year" storm were to be dumped into lower Strawberry Creek at this time, with existing watershed and creek conditions, that the creek would overflow at certain points due to inadequate channel capacity, as well as to the "shoaling" effects of the new coarse bed load materials. This assumes that recommended emergency remedial measures have been taken in Zone II; and without these measures the result of a true "ten year" storm would probably be quite spectacular.

Peak runoff rates and bed and float load sizes and quantities have been increasing continuously for many years, with particularly abrupt increases in, say, the past ten years. At the same time the capacity of the disposal system to handle the flow and bed and float loads has not been increased at all, excepting for construction of the "Big Inch" storm sewer; and the hydraulic and transport capacity of many portions of the disposal system, except the storm sewer, have probably been reduced during this period, expecially in lower Strawberry Creek (Zone II).

There has been a considerable diversion of highly developed watershed in the "Rad. Lab." area, from the Blackberry Creek watershed to Strawberry Creek, and further such diversion is expected as the upper area is progressively developed. This has had the effect of "taking pressure off" the Blackberry Creek area and worsening runoff conditions in Strawberry Creek. A good example of this is seen and discussed in Zone I, Chicken Creek, but this type of diversion is not confined to Zone I.

ZONE V - BOTANICAL GARDENS

The Botanical Gardens have been set up as a separate zone because of the damage which occurred there during the storm of October, 1962. This "zone" consists of the watershed area of the middle fork of Strawberry Creek, which flows through the Botanical Gardens, within the total Strawberry Creek watershed, which is Zone IV; and this area is shown on the plan of Zone IV given previously in this report.

Referring to the above plan it is seen that the watershed is quite extensive, totaling some ninety acres, of which some forty acres are of "Close Non-developed" classification, and fifty acres are "Remote Non-developed" area. With calculations as explained for Zone IV, the estimated peak "ten year" storm flow is 150 cfs.

The flow in the creek above the Gardens enters a culvert just above the Japanese pool, and the culvert discharges back into the creek bed some distance below the pool. The culvert is a twenty-four inch diameter concrete pipe, and the entrance to the culvert is low in the creek bed; thus the culvert is vulnerable to "plugging" at even moderate bed or float load conditions.

During the heavy storm in October 1962 the culvert plugged, the stream diverted around the culvert and into the Japanese pool area, and thence on down the creek channel. The flood flow carried a heavy load of boulders, cobbles, gravel and sand through the pool area, destroyed much of the Japanese garden and pool facilities, and filled the pool with sand, gravel and boulders.

This office carefully checked the watershed and creek area, and arrived at the following findings with respect to watershed conditions and the cause of the damage to the Gardens:

The watershed has changed very little in recent years, and there has been no appreciable change or increase in runoff, float or bed load conditions in, say, the last twenty years.

A heavy flow of water passed down the creek during the flood but the peak flow was probably not spectacular.

A very unusual quantity of bed and float load materials passed down the creek, including large logs and boulders of greater than one foot dimension.

A rock-masonry groin just upstream from the Gardens had been badly end-cut; and a new erosion channel and deep incisement of the creek bed was found extending upstream from the incisement at the groin for a distance of several hundred feet. It appeared that this incisement of the creek and its embankments had resulted in the removal of a very large quantity of bed load materials, including much materials to large boulder size which had previously been trapped in the creek bed by the groin. It appeared that nearly all of this incisement and transport had occurred during a very short time at the peaks of the two heavy runoffs during the storm of October, 1962.

A wedge of dumped rock fill was found on the canyon slope below the Seismology Station, apparently representing excess cut dumped onto the canyon slope during excavation of the tunnel. A small part of this material was carried down the creek and into the Garden during the storm, but the amount was minor; however, it is probable that as this material slides down the canyon slope in the future it will become bed load material in the middle fork of Strawberry Creek.

The only visible sources of the bed load material were the moderate quantities of rock dumped into the creek from the excavation for the Seismology Station tunnel, and heavy incisement of the creek bed due to end-cutting of the old stone-masonry groin just upstream from the Gardens. From examination of the area and the apparent action of the creek, and from examination of the debris deposited in the Garden, we feel that the bulk of the transported material came from end-cutting of the groin and resulting upstream incisement of the bed and side slopes of the creek.

It is our opinion that the bulk of the damage to the Garden resulted from failure of the groin and resulting incisement of the stream channel above, which produced the unusual quantity and large sizes of transported materials. We believe that if the groin had not failed, the culvert might have plugged and a large flow of essentially clear water would then have passed through the Gardens, but that very little bed or float load would have come down the creek, and very little damage to the Garden would have resulted. It must be remembered that while groins in creeks will raise the creek bed, trap coarse bed load material, and stabilize the bed at a higher level; failure of the groin during peak runoff will result in rapid incisement of the entrapped materials, as well as of embankments thus rendered unstable, releasing the entrapped material downstream in large quantities. We feel that this did happen at the Botanical Gardens and that this was the basic cause of most of the observed damage. Note that where we have recently removed or lowered groins in lower Strawberry Creek, to improve the channel hydraulics, that the creek bed immediately incised to the new stable bed configuration during the first periods of moderate runoff, releasing large quantities of previously entrapped bed load materials.

In consequence of the above considerations this office has recommended that the masonry groin be repaired and further strengthened so as to repair the damaged end, to maintain flow in the mid-channel area, to prevent undercutting at the toe, and thus to stop current incisement of the creek channel and prevent a future repetition of the recent failure. With this being done, it is the opinion of this office that, while the culvert may again plug and divert flow through the Garden, this flow will be essentially clear water and little damage will result.

For a permanent final solution to the problem we feel that a new hydraulically efficient culvert inlet should be constructed; and that a peak-flow diversion path should be provided around the Gardens, possibly by modification of the existing road system, so as to handle the true peak storm flows which obviously will be in excess of the culvert capacity.

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LENNERT AND ASSOCIATES
SOILS ENGINEERS

Job Number 260

February 22, 1963

ZONE VI - NORTH CAMPUS AND NORTH RADIATION LABORATORY AREA

As far as this office is aware there have been no serious flooding problems in the Zone VI area, nor along Blackberry Creek, during this year, and we do not feel that any severe "emergency" problems requiring immediate "emergency remedial measures" are present in this area. We have set up this zone, and have investigated it, because it represents a natural unit of the campus storm drainage regime and should be discussed in order to provide a complete overall picture, and because certain potential problems and proposed construction this year require that storm drainage studies and remedial measures be accomplished before the winter of 1963-64. In addition, we feel that certain construction scheduled for this year should be designed taking account of the matters discussed hereafter. Our treatment of Zone VI will, therefore, be somewhat cursory, and confined mainly to describing the zone, its basic conditions, and certain drainage problems, without attempting to go into the details of its hydrology or hydraulics as we have for some other zones where we have felt that immediate dangers and "emergency" conditions existed.

The area set up as Zone VI is that watershed area, which, without artificial diversions, would be tributary to Blackberry Creek (the north fork of lower Strawberry Creek within the lower campus area) at the point of outlet of the City storm sewer which intercepts the creek at Highland Court above. This accumulation point lies within the campus, near North Gate, just south of Hearst Avenue and just west of Euclid Avenue. This area is shown on an accompanying plan entitled "Zone VI Watershed Area", and upon "Storm Drainage Studies, General Site Plan", included with this report. Note that the area abuts Zone IV (the watershed area of Strawberry Creek) to the south, and is controlled by the watershed "break-lines" on all borders except the lower end, where the boundary was arbitrarily taken at the point of resumption of open flow in Blackberry Creek. Note that at its contact with Zone IV the watershed area is shown bounded by a proposed road, not yet constructed, for reasons discussed in more detail hereafter.

The Zone VI area is only approximately defined, due to a lack of suitable topographic data; and in addition, it has been severely altered by artificial diversion of runoff in both the campus and City areas. The area shown on the plan covers some 160 acres, approximately 90 acres lying within the campus and 70 acres within the incorporated area of the City of Berkeley. It is pointed out that the above area is the watershed area of the accumulation point described, without consideration of present artificial diversions, and including a proposed future diversion at a new road not yet constructed. We do not know the actual watershed area closely, and the determination of the true area, with present diversions, is far beyond the scope of our current work.

Narrative comments, describing this area, some of its more important storm-runoff aspects, and matters pertaining thereto which we feel are of immediate importance, are given on an item-by-item basis, as follows:

Storm drainage

Using the assumptions and procedures as discussed for Zone IV, we have estimated the peak runoff from this area, as follows:

Assume that at this time half of the area is fully developed and half is steep and has rapid access to mature flow-channels (developed and close-nondeveloped areas, as per Zone IV).

Assume a maximum accumulation flow-time of 15 minutes, and a ground saturation-channel storage time of 15 minutes, giving a total effective accumulation time for peak runoff of 1/2 hour. This figure is probably high, and thus gives a lower runoff value.

Assume a peak storm intensity of 2-1/2 inches per hour for a ten-year storm of 1/2 hour duration.

Assume a runoff coefficient at 1/2 hour accumulation time of 1.0 for the developed area, and 0.70 for the "close, nondeveloped" area.

Peak runoff is thus calculated as 340 cfs. Since the 1/2 hour critical storm intensity time is probably too low, this runoff figure is also probably low. If the total effective critical accumulation time is reduced to 15 minutes during a "cascading" storm, then the 2-1/2 inches per hour rainfall intensity would be a low assumption.

Estimating "original" storm runoff conditions in this watershed prior to development, in the same manner as discussed in Zone IV, we arrive at a peak, "ten year" storm flow rate of 80 cfs at the outlet of the storm sewer at North Gate, and 60 cfs at the inlet to the sewer at Highland Court. These flow values are in the range of the capacity of the existing storm sewer system, showing the existing system to be adequate for the nondeveloped condition; while it is completely inadequate for the present level of development, without the existing artificial diversions.

Looking forward to the time when the Lawrence Hall of Science and the adjoining new road are constructed, when the area will be essentially totally developed, we arrive at a peak runoff rate of 400 cfs, based upon the assumptions given above. This figure, again, is probably the minimum peak ten year flow estimate for full development of the area.

Due to a "splitting" of the runoff by diversion along Cyclotron Road and over the City streets, the peak runoff does not now enter the system, and has not for many years. We estimate that not more than half of the total peak runoff now reaches the accumulation point at the outlet of the City sewer at North Gate, part being diverted through the campus via the erosion gully just south of Stern Hall and Gayley Road, and part over the City streets.

The inlet to the storm sewer at Highland Court is above a portion of the subject area, and total flow of 340 cfs would thus not apply at this inlet. We estimate that an equivalent flow at the Highland Court inlet, without artificial diversion, would be about 250 cfs. The existing storm sewer from Highland Court to North Gate is obviously inadequate to carry anything like 250 cfs, with respect to either pipe or inlet capacity.

The City storm sewer from Highland Court to North Gate consists of a reinforced concrete pipe of 48 inches diameter. The inlet is below existing creek bed, "buried in a hole" from aggradation of the creek channel (probably due to ponding in front of the inadequate inlet), with a grossly improper "wooden grizzly". The stream channel shows recent incisement to depths of several feet, and a large cobble-boulder bedload is seen in the creek. It is our belief that the existing City sewer is now highly vulnerable, and at some presently conceivable period of heavy runoff it will completely plug and the flow will be diverted through the residential area below. The action would be quite similar to recent diversions at the inlet to the Big Inch storm sewer.

Existing diversions

A considerable part of the northerly Rad. Lab. area runoff, from areas which originally drained to Blackberry Creek, is now diverted to the northerly campus area during periods of peak runoff. An exceptionally large diversion occurs down Cyclotron Road, with the flow "jumping" the road above Stern Hall and passing down a swale area just south of Stern Hall; the flow having cut a large erosion-gully at this point. This is discussed in detail in our letter dated February 19, 1963 concerning the erosion-gully just south of Stern Hall, and reference is made thereto for a more detailed discussion of this matter. This flow then continues down Gayley Road to Cowell Hospital, where it "jumps the curb" and eventually drains to Strawberry Creek at or below Faculty Glade; and it is this diverted flow which is largely responsible for the recurring flooding of Cowell Hospital.

It appears that during periods of peak runoff an appreciable portion of the runoff from the "City" area of the zone does not enter the sewer system, and instead flows down the street system, eventually reaching the corner of Hearst Avenue and Oxford Street.

We thus do not know the total effective existing watershed area tributary to the accumulation point described, at peak storm flow, excepting to state that it is obviously less than the area shown, apparently by a considerable percentage; and a closer determination of this matter is far beyond the scope of our work at this time. The important point to our present studies is that whatever the diversion of runoff from Zone VI to the campus area below may be, it must be returned to the Blackberry Creek system; for if this is not done the recent flooding of Cowell Hospital and erosion south of Stern Hall will progressively worsen until the problem is corrected. In addition, it must be assumed that the City will eventually return all runoff from the area to the storm sewer and thus into the lower creek system.

The diversion of peak storm flow along Cyclotron Road can be remedied by simply "pitching" the road at key points so as to divert the flow down secondary canyons back to Blackberry Creek. If this is not properly done, however, the erosion produced in these newly hydraulically overloaded secondary canyons will in itself become a serious problem; and in addition, facilities lower in these canyons must, of course be protected. It may be found to be more desirable to redivert the flow in the Rad. Lab. area above the road; or possibly to "hold" the flow in the road and return it to Blackberry Creek via Hearst Avenue. In the actual solution of the problem a combination of the above methods will probably be used: diverting part of the flow at the Rad. Lab. area above: diverting part of the flow into the secondary canyons on the way down Cyclotron Road, controlling the amounts of diversion in each canyon by proper sizing of the inlets: "holding" part of the flow in Cyclotron Road and outletting it onto Hearst Avenue: and possibly even permitting some carefully limited diversion south of Stern Hall. The most desirable and least expensive means of solution of the problem must be carefully worked out in context with area conditions, final development of the area above, and potential improvement of Cyclotron Road.

Proposed new road

A new road is to be constructed between North Canyon Road, just south of Building 77, and Grizzly Peak Boulevard, passing north and west of, and below, the proposed site for the Lawrence Hall of Science. The road passes along the southerly boundary of Zone VI at its contact with Zone IV, crosses the Chicken Creek watershed (Zone I), cutting off about the upper 40% of this area, and joins North Canyon Road at a point such that flow in the new road can be carried down North Canyon Road to Strawberry Creek. The location of the road is shown approximately on the accompanying plan.

Whether desired or not, this road will become a major factor in the storm runoff system in the upper campus-Rad. Lab. area. If properly designed this road can limit and/or partially alleviate present and future storm flow problems in Zone VI; and it can reduce peak runoff in Chicken Canyon (Zone I) by about 40%, thus going a long way toward solving the present very serious runoff-erosion problem in Chicken Canyon. In addition, the road can supply a channel for peak runoff which will eliminate the need, in the very near future, for a storm sewer system to carry peak runoff from the Rad. Lab. area, costing hundreds of thousands of dollars.

If constructed without regard for its effects upon peak storm flow, as other roads in the area appear to have been, the new road could worsen the already critical storm flow conditions in Chicken Canyon, and greatly increase peak runoff problems in Zone VI. In addition, a low-point in the new road which allowed the "dumping" of peak flows, would produce flooding problems in the highly developed Rad. Lab. area, due to peak runoff from the watershed above, somewhat similar to the problems now found in the lower campus due to development of the Rad. Lab. area. Specifically, a low-point in the road at upper Blackberry Canyon would probably "dump" a large part of the runoff from the Lawrence Hall of Science site, and the new road, into the area around the Bevatron, below, which lies in Blackberry Canyon and below the proposed Lawrence Hall of Science site. The cost of a culvert-inlet system which would actually handle this flow and protect the Bevatron area during even a "20 year" storm, would be in the "$100,000 range"; and the dumping of this flow into Blackberry Creek would probably force the construction of a new storm sewer through the City area below, at a costin the range of several hundred thousand dollars.

Chicken Canyon is a good example of unintended diversion by a road system, with the bulk of the current excessive peak flow in Chicken Canyon coming from diversion of flow from historically non-tributary areas by existing roads in the Rad. Lab. area, the water "dumping" into Chicken Canyon due to a wholly unnecessary "sag" in North Canyon Road at Chicken Canyon. With some forethought the road could just as easily have been graded so as to carry the peak runoff to Strawberry Creek, eliminating the current very serious problem in Chicken Canyon.

It is pointed out that a storm sewer designed for, say, a "30 year" storm, operates at capacity for only a fraction of an hour, once every thirty years; and represents a gross waste of capital at all other times. Thus, storm sewers are normally designed for, say, a 3, 5 or 10 year storm; and all greater flows are taken in the street system. However, this can only be done when severe flooding and costly damage will not result.

The new road thus represents an opportunity to not only partially or wholly solve many existing or future storm drainage problems; but italso offers a chance to save many hundreds of thousands of dollars which will otherwise have to be spent on mammoth storm sewer systems. This can be done by putting the peak, say, "3 year" flow into the secondary canyons, taking all greater flows down the road, and thus avoiding the construction of any new storm sewers at all or reducing the size of the required sewer system by a large fraction.

We cannot overemphasize our recommendation that the new road be designed in context with a master drainage program for the entire campus, and that it be designed as a unit of the storm drainage system. We categorically state that the design of the road to handle peak storm-flows will not raise the cost of the road by over 10%, at most, and possibly not at all; that the road can be designed to handle these flows; and that the transmission of peak flows down the road at infrequent intervals (once a year or less) will not damage the road if it is properly designed and constructed.

City storm sewer

Since part of the length of Blackberry Creek lies within the City of Berkeley, with most of this length now filled and bypassed by the existing, inadequate storm sewer between Highland Court and North Gate, and since the most serious potential for flooding and very costly damage lies in the residential area below the inlet to the existing storm sewer at Highland Court, the solution of storm drainage problems in Zone VI must involve some degree of cooperation with the City of Berkeley. Since the City is apparently preparing plans for alteration of the existing storm sewer, a prompt communication with the City might be desirable.

Zone VI thus represents a natural watershed area, the runoff from which has been greatly altered by the "improvements" in the watershed, with a large net diversion out of the flow channel below. On the basis of the foregoing calculations and the fact that the City storm sewer is apparently still handling runoff to the inlet, we "best guess" that this diversion is probably about equal in amount to the increased peak runoff caused by development of the area, and flooding below has thus been avoided We feel that if this runoff were returned to its historic channel at this time, without proper preparation below, severe flooding in the residential area in the canyon below the Highland Court inlet would result in the next normally heavy rainfall, without a "ten year storm" being required. At this time the only "serious harm" occurring to the campus by diversion of peak storm runoff from Zone VI, is the erosion just south of Stern Hall and the flooding at Cowell Hospital. Our comments regarding the erosion gully at Stern Hall are given in our letter of February 19, 1963, and will not be repeated herein. Our comments and recommendations regarding the flooding at Cowell Hospital are given in the section of this report covering Zone VII, General Campus.

It seems obvious that the existing diversions of flow from Zone VI to the north campus area must be eliminated, and the runoff returned to its historic channel in Blackberry Creek; as this is the only economical means of remedying the problems now being caused by this diversion, and the only solution which is hydraulically acceptable with respect to handling peak flows in Strawberry Creek and other campus areas.

It is even more obvious that no rediversion of flow into Blackberry Creek can be contemplated without first determining the effects of such an increase in flow upon the Blackberry Creek area, and taking all measures necessary to properly handle this flow before the rediversion is made. Failure to do this would virtually assure severe flooding and costly damage in the City area below, with attendant problems of liability for contributing to the cause or causes of such flooding and damage.

The development of the proposed Lawrence Hall of Science, and of the proposed new road from the Rad. Lab. Corporation Yard, past the Lawrence Hall of Science site, to Grizzly Peak Boulevard, will add a large increment of peak storm runoff to the existing situation in Zone VI. If this is put into the Blackberry Creek system under existing conditions, it will probably cause disastrous flooding and damage in the City area described above and/or greatly worsen the erosion south of Stern Hall and the flooding of Cowell Hospital. This office has verbally given most strong recommendations that the new road be designed as an "interceptor", to divert and transport all runoff from the area south of the road to the Strawberry Creek system. Note that in setting up the areas of Zones IV and VI we have assumed that this would be done, and have set the zone boundaries at this proposed road. At the present time the Zone VI watershed break-line actually lies south of the line shown, inside Zone IV, adding a small area of nondeveloped area to Zone VI at the expense of Zone IV. When this area is developed in the near future, the disposition of storm runoff from the area south of the new road will be a matter of serious concern in both the Rad. Lab. area and in the Blackberry Creek area below.

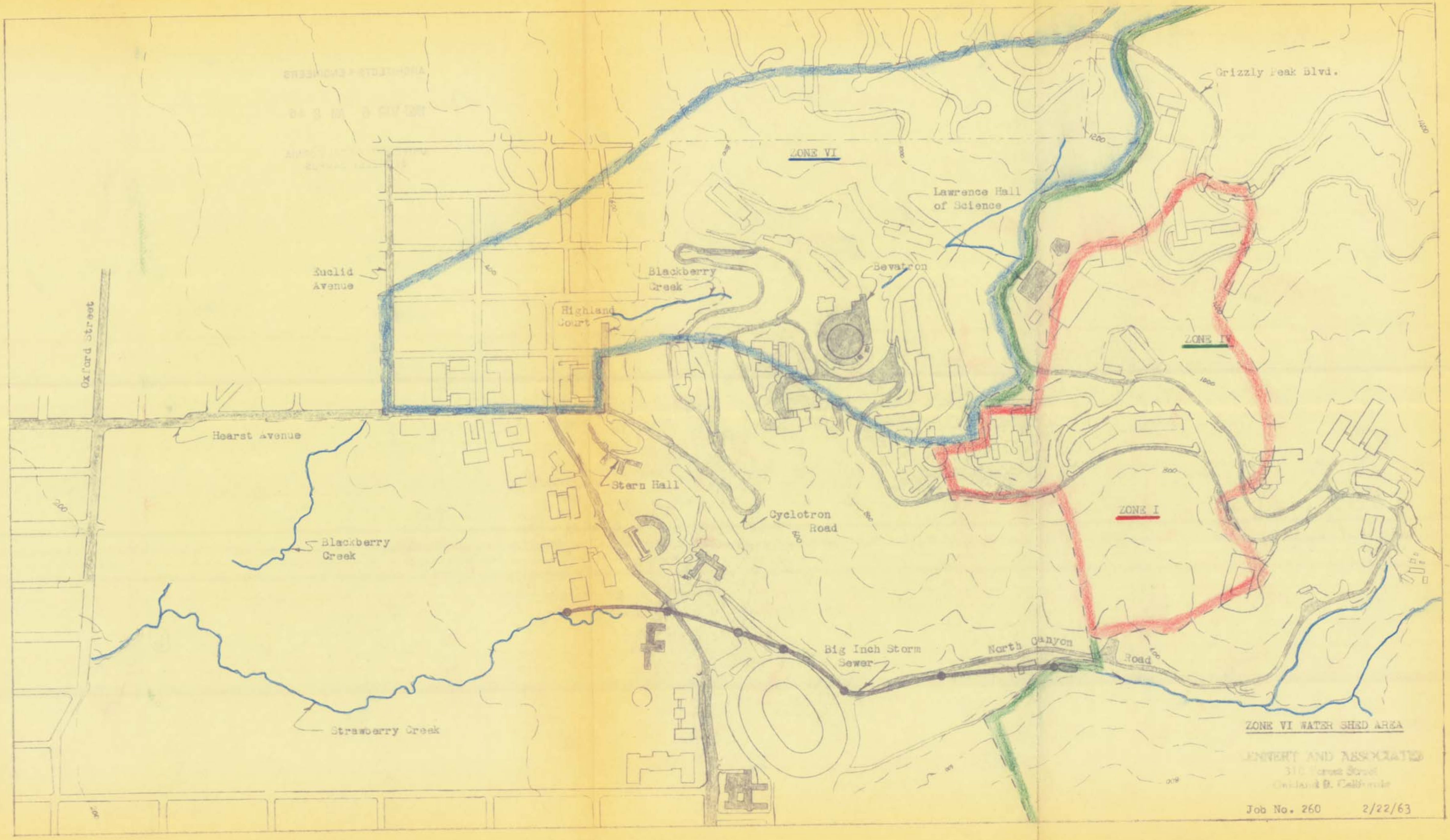
In summation of our report covering Zone VI, we submit the following resume in the form of comments and recommendations:

> The Blackberry Creek area has not shown severe flooding in recent years because of artificial diversions of peak storm runoff in the Rad. Lab. area, even though development of the watershed has progressed from zero to nearly full development in the past, say, twenty years.
>
> The only severe problems resulting from runoff from Zone VI at this time are the erosion south of Stern Hall and the flooding at Cowell Hospital. Neither of these problems are so severe as to warrant large scale "emergency remedial measures"; but they must be remedied before the winter of 1963 or truly severe flooding and costly damage can easily result.
>
> The runoff from the original watershed area of Blackberry Creek must now be rediverted to the creek, and the existing diversions therefrom eliminated. Before this is done the capacity of the Blackberry Creek system must be increased so that it can handle the increased peak flow quantities; and this will involve a thorough engineering study and the preparation of proper designs for both control of the runoff pattern and transmission of the peak flow so obtained and controlled. This will possibly require a large increase in the capacity of the City sewer between Highland Court and North Gate, as well as design and construction of a suitable inlet system.
>
> The new road from North Canyon Road to Grizzly Peak Boulevard must be designed to intercept and carry all flow from the area to the south, including the Lawrence Hall of Science site, southerly to Strawberry Creek; or if this is not done, then both the Blackberry Creek system <u>and the developed Rad. Lab. area below the road</u>, must be prepared to carry this new component of peak storm runoff. The new road should <u>not</u> be designed and built until this matter is resolved. If this road is built with disregard for its effects upon storm runoff in the area, as some other roads in the area apparently have been, a severe storm runoff

problem will be created which will be very serious in both required remedial construction and the cost of resulting flood damage; and later remedy of the problem will probably involve extensive reworking of the new road or a very expensive storm sewer system.

The new road from the south side of Building 77, in the Rad. Lab. area, to Grizzly Peak Boulevard, represents a chance to begin to develop rational control of storm runoff in the entire upper campus area. By proper design it will resolve a good part of the existing problem in Chicken Canyon and areas southerly therefrom; it will help in the Zone VI area; and it will protect the highly developed Rad. Lab. area below, which will be in danger of flooding by flow from upstream watershed areas, just as the lower campus now is from Strawberry Creek. This use of the new road for handling of peak storm flows can be accomplished at little to no extra cost in construction of the road; all that is required is intelligent design of the road for storm drainage conditions and purposes. We cannot overemphasize the absolute necessity of grasping this opportunity to accomplish a very valuable positive effect on campus storm drainage conditions at virtually no cost; and that this new road must not be allowed to produce another unintended, uncontrolled, diversion of storm runoff.

To conclude, while we have not recommended any "emergency remedial measures" for Zone VI, we do most strongly recommend that the basic problems described herein be resolved before the winter of 1963-64. This will have to be done as part of a master drainage plan for the entire campus, in cooperation with the City of Berkeley with respect to the City storm sewer between Highland Court and North Gate; and the new road to be constructed along the southerly side of Zone VI must be included in storm runoff plans for the area.


Grizzly Peak Blvd.
ZONE VI
Lawrence Hall
of Science
Bevatron
Blackberry
Creek
Euclid
Avenue
Highland
Court
ZONE IV
Oxford Street
Hearst Avenue
Stern Hall
Cyclotron
Road
ZONE I
Blackberry
Creek
Big Inch Storm
Sewer
North Canyon
Road
Strawberry Creek
ZONE VI WATER SHED AREA
Job No. 260
2/22/63

ZONE VII - GENERAL CAMPUS

This "zone" has been set up to provide a sub-section of this report wherein certain items could be covered which did not logically fit into the other hydrologically defined zones. As each of the matters covered in this report is essentially a separate item, they have been divided into separate sub-reports and transmitted as completed during the course of our work.

The items covered under Zone VII of our report are as follows:

A. Gayley Road Area

B. Local Flooding of Buildings

C. Cowell Hospital

D. Berkeley City Storm Sewer

Reference is made to the "General Site Plan", accompanying this report, for location information pertinent to the items listed above. The sub-reports covering these items are given hereafter.

VII-A. Gayley Road Area

Gayley Road, and the natural watershed above and to the east, forms a special area within the overall storm drainage regime at the campus due to its location with respect to the upper watershed areas. The area considered has a shape roughly approximating a truncated isosceles triangle, with the base formed by Gayley Road between Hearst Avenue and Bancroft Way, with the northerly side being formed by the ridge on which Cyclotron Road is located, above Hearst Avenue, and with the south side formed by the ridge which falls from the Cyclotron to Memorial Stadium. The truncated top of the triangle originally lay at the juncture of the two ridges described above; but the drainage area is now distorted and obscured by developments in the Rad. Lab. area, as described hereafter. This area is shown on the "General Site Plan", accompanying this report.

The above area is set apart in that it consists of the southerly face of the north-south trending ridge which separates the Strawberry Creek and Blackberry Creek watersheds. Storm drainage from this ridge falls either easterly to Strawberry Creek or westerly to Blackberry Creek, and only the water which impinges directly upon the southerly "nose" of the ridge naturally flows through this area. The swales found in this area are normally broad, shallow and immature, bottomed in soft soils and grass covered, as there has never been an appreciable flow of natural runoff to develop deep, mature canyons. The soil cover is thick in this area, and deep erosion occurs readily upon even moderate concentrations of runoff.

The entire area covers only some sixty acres of partially developed land, with runoff "split" into three poorly defined swale areas; and thus under normal conditions this area, and Gayley Road which intercepts runoff from the area, would not be subjected to high flow rates from indigenous rainfall. Since there is no upper area naturally tributary to this area, extraneous flow will not naturally pass through this area, causing flooding and erosion problems.

Gayley Road shows a gently undulating grade between Channing Way and Hearst Avenue, rising from Channing Way to Bancroft Way, and then rising irregularly to a high point at the northerly side of Memorial Stadium. The street then falls to a low area between Cowell Hospital and Lewis Hall, and thence rises to a high point at Hearst Avenue. The main surface outlets from the low area (not considering storm sewer inlets which plug and are inoperative during peak runoff) are the ambulance entrance driveway to Cowell Hospital to the south and

University Drive to the north. Of these two potential flood-flow outlets, the ambulance entrance to Cowell Hospital is lowest, lying in an original swale area, and takes the bulk of the peak flood flow reaching this part of Gayley Avenue. All streets falling westerly from Gayley Road will potentially carry runoff, but maximum peak flows actually concentrate in those outlets which combine low elevation and location below the peak flow runoff channels from the upper watershed areas.

The Gayley Road area thus consists in the natural condition of avery restricted watershed area, with the drainage intercepted and diverted at Gayley Road. It is unique in that without artificial diversion the area would be essentially free of any serious problems of flooding or erosion, since all heavy runoff from the major upper campus watersheds would pass north of Hearst Avenue or south of Memorial Stadium. In actuality, severe erosion and flooding has occurred within this area, due to artificial diversions of runoff both into and out of the area, as discussed hereafter.

An artificial diversion of runoff has occurred in the Rad. Lab. area, and it appears that runoff from a large part of the Bevatron-Cyclotron area is now diverted into the triangle. It further appears that a large part of the peak flow from this diversion passes down the ridge and swale area occupied by Cyclotron Road, enters the swale just south of Stern Hall, flowing thence to Gayley Road, and thence to the ambulance entrance driveway at Cowell Hospital. Other diversions of lesser magnitude appear to take place down the swales above Kleeberger Field during periods of peak runoff. This input of extraneous runoff apparently derives from a relatively large developed acreage in the Rad. Lab. area, is of large magnitude at periods of peak runoff, has cut a deep erosion gully south of Stern Hall, and forms a large part of the total flow cuasing flooding at Cowell Hospital. The peak runoff from this area, occurring during short-duration storms of high intensity, is probably several times as large as the runoff from the natural watershed. Reference is made to a letter from this office dated February 19, 1963, covering this diversion as it affects the erosion-gully south of Stern Hall, and the detailed comments given in this letter are not repeated herein. Note however, that present diversions from the Rad. Lab. area into the swales below the Bevatron and Cyclotron and the intervening area, flow to Gayley Road and thence to the Cowell Hospital ambulance driveway; and these flows pass by the Greek Theatre, Bowles Hall and Kleeberger Field, as well as Stern Hall.

It is pointed out that, due to the grades of the intersection of North Canyon Road and the road around Memorial Stadium, the flow down North Canyon Road diverts southerly around Memorial Stadium and does not reach Gayley Road within the

"Gayley Road Area"; and that Hearst Avenue forms a cutoff at the northerly side of the area. We thus find, that all extraneous runoff now reaching this area comes from diversions in the Rad. Lab. area, as described above. It must also be pointed out, however, that all new peak flow from the Rad. Lab. area is not an "artificial diversion" in the pure sense, since a part of the southwesterly side of this area originally lay in the natural watershed of Gayley Road. This area has been changed, however, from undeveloped grass-land to full development, thus increasing peak flows by a large factor, and it is our belief that this "originally tributary" area constitutes only a small part of that area from which runoff is now diverted to Gayley Road, as described.

In general conclusion in this matter, we give the following resume of the pertinent factors pertaining:

The "Gayley Road Area" has been transformed from one naturally free of appreciable runoff problems to one with severe problems of runoff and erosion, by diversion of peak flows from the highly developed Rad. Lab. area above.

The severe erosion at Stern Hall is due solely to the diversion of flow from the Rad. Lab. area, and to the concentration of this flow in the swale south of Stern Hall by grading in the Cyclotron Road area.

Removal of this excess peak flow by re-diversion to Blackberry Creek, including diversion of the fully developed areas originally a part of the natural Gayley Road watershed, would solve the problem of erosion at Stern Hall, and of minor flooding in the Greek Theatre-Bowles Hall area. In addition, the problem of flooding at Cowell Hospital would be greatly reduced.

The problem of flooding at Cowell Hospital can be solved assuredly and permanently only by reconstruction of the intersection at the ambulance entrance driveway. This is discussed in detail in the portion of this section of this report entitled "Cowell Hospital".

It is our thinking at this time that a final solution to the Strawberry Creek runoff problem will involve the use of North Canyon Road north of Memorial Stadium, Gayley Road, and the upper end of University Drive, as an emergency, peak flow, bypass to the Big Inch storm sewer. This would require minor re-grading of North Campus Road, Gayley Road and the upper end of University Drive; and this re-grading would also solve the problem of flooding at Cowell Hospital due to flow down the ambulance entrance driveway. This matter is discussed briefly in the letter of transmittal and summary of this report.

The bulk of the extraneous flood flow appears to pass down the swale south of Stern Hall; but during the heavy rains of October 1962, large flows were seen coming down North Canyon Road north of Memorial Stadium. It would thus appear that at peak runoff appreciable diversions from the Rad. Lab. Cyclotron area come down the swales above Kleeberger Field.

The "Gayley Road Area" should be freed of all extraneous runoff, excepting for the carefully engineered use of the road as an emergency flow bypass, as discussed above, as the area cannot suitably transmit any appreciable quantities of extraneous runoff without severe erosion and flooding, as has already occurred. This will apparently entail the re-diversion of a considerable quantity of peak flow from the Bevatron-Cyclotron area, either down Cyclotron Road to Blackberry Creek or into a major new storm sewer system.

The above material covers our preliminary evaluation of the subject area. Reference is also made to our letter of February 19, 1963, and to Zone VI and the letter of summary and transmittal of this report. We have not recommended "emergency remedial measures" for this area as we have not felt that the existent problems were sufficiently dangerous and severe to warrant such measures within our interpretation of the purpose and scope of our present work. The question of whether "emergency" measures should be taken to prevent the flow of runoff down the ambulance entrance driveway at Cowell Hospital, and toprevent further enlargement of the erosion-gully at Stern Hall, will depend in large part upon the timing of completion of measures necessary to the permanent overall solution to the campus storm drainage problems.

VII-B. Local Flooding

Numerous buildings within the campus are subjected to local flooding during even moderate rainstorms, due to the configuration of the area around the buildings, with no connection to the overall storm drainage problems of the campus. While not a part of the overall storm runoff problem, we feel that the damage and inconvenience resulting from this situation warrants a brief discussion in this report.

Since the campus area slopes westerly at an appreciable gradient, it has apparently been customary to make a cut to the east and a fill to the west at many building sites, in order to obtain a flat building area. In many cases the cut areas to the east have been "blocked off" by the building, forming a catchment area, with little or no effective drainage. The typical situation can be seen at the upper (easterly) sides of Stern Hall, International House, Cowell Hospital, Haviland Hall, etc., where the drainage into these relatively large depressed areas is blocked by the building. Of these examples, International House and Cowell Hospital probably show the worst situation, while Haviland Hall is more typical of lower campus sites with a much less serious problem. At International House and Cowell Hospital the basic problem of near-site geometry is greatly worsened by the encroachment of large quantities of "foreign" flood flow during peak runoff, while the problem at Haviland Hall results almost solely from undesirable local geometry, with only minor amounts of extraneous runoff from the rear, uphill area.

Haviland Hall has thus been taken as an example of the problem under consideration, and the situation at this building site is described briefly, as follows:

The long axis of the building is oriented in the north-south direction, extending for about 175 feet roughly parallel to the area contours.

The easterly side of the building area lies in cut, with a low cut embankment of about 10 foot maximum height lying easterly of the building. This area is occupied by an asphalt-surfaced driveway of about twenty foot width, which rises toward North Gate to the north and to a parking area to the south.

The low-point in the driveway occurs at the northerly doorway to the building. The driveway at the north end of the building is about two inches above the footjamb of the doorway, and at the south end is about level with this jamb. The driveway is thus essentially level and at building entrance grade for the 175 foot length of the building. The southerly entrance to the building is essentially level with respect to the driveway grade.

There is a drainage inlet at the northeasterly building corner and another at the southeasterly corner, consisting of small grate-inlets, which apparently have "plugged" almost immediately during recent severe rainstorms.

The alternate flow paths for surface drainage accumulating in the pocket easterly of the building, other than the two small grate-inlets, is around the southeast corner of the building or into the two main doorways and thus into the building. Steps lead downward from the main lobby floor elevation, providing a natural flow path into the lower floor of the building.

This building was nearly flooded during the small storm in January, 1963, with water up to the footjamb at the entrance, and has reputedly been flooded many times in the past. This flooding is due solely to the lack of suitable storm drainage capacity in the driveway area at the easterly side of the building, as there is plenty of "fall" available locally, and a minor change in driveway elevations during initial construction would have avoided this problem.

The situation at Haviland Hall is typical of many on the campus. We have discussed it as an example of the general condition, rather than for the specific problem at this site, and we offer the following general comments which we feel apply to the general aspects of this problem, as follows:

Low areas which can impound runoff behind a building, and are drained only by a sewer-type outlet, are potential causes of flooding of the building. Where the low area is subject to flooding by large quantities of extraneous flood water (such as at International House or Cowell Hospital) the hazard is severe. The recent flooding of International House, twice this fall, is a good example of this problem. Where only limited amounts of extraneous flood water can encroach (such as at Haviland Hall) the magnitude of the problem is reduced, but flooding from local rainfall can still be inconvenient and costly.

With the amount of natural ground slope available in the campus such local flooding is in nearly all cases completely unnecessary, and results only from lack of provisions for storm water disposal by the proper shaping of the surrounding area. In most cases little or no extra initial construction cost would have been involved, and the change in configuration of the surrounding area from that now producing flooding problems would be so minor as to be indistinguishable architecturally or esthetically.

Floor drains, grate inlets and other sewer-type means of draining such embayments usually do not "work" when they are most needed; i.e., during a period of heavy rainfall and high runoff rate, unless they are carefully and intelligently designed for this condition. Most such inlets are conceived of as simply "wash-water" drains, and are totally inadequate to carry the runoff from heavy rainfall from even a small area. In addition, since heavy rainfall and runoff normally produces transport of large quantities of accumulated trash and debris, only a specially designed inlet system will resist plugging and almost immediate stoppage. No inlet capable of handling the potential trash-debris load has been seen on the campus in association with a building-embayment area.

The most certain and inexpensive means of preventing the problems described is to provide a surface flow channel which will carry the heavy runoff from the infrequent severe storms. Such flow channels can consist of roads, driveways, sidewalks, walkways, planted areas, etc., the only requirement being that flow area and gradient be provided sufficient to handle peak runoff flow for a period of a few minutes, once a year or so. Such usage will not harm a road, driveway, sidewalk or patio area in any way, and will not harm pathways or planted areas if they are developed with a reasonable amount of foresight. Lawn areas can take such flow conditions with no detrimental effects whatsoever. As an example, at Haviland Hall, if the driveway on the easterly side of the building were to be given a cross-fall to the east of about six inches, with the flow then carried southerly in the side-swale thus developed at about one percent fall to the steeply sloping walkway to the southwest, the problem of flooding at Haviland Hall would be solved. This could have been done in the original construction at no extra cost or change in architectural appearance, and it could be done now for, say, about $1500, including regrading and the replacement of the existing deteriorated driveway with a new, high quality base course-surfacing section.

There are many building areas on the campus suffering from various aspects of the problem described above; and while an analyses of these areas is not within the scope of our work, we feel, on the basis of our brief review of the problem, that most or all of these conditions could be cured at small to moderate cost. While these areas are not hydraulically a part of the basic campus storm drainage picture, they are a serious problem and deserve equal attention with the more spectacular aspects of the overall problem of campus storm drainage.

VII-C. Cowell Hospital

Flooding has reputedly occurred repeatedly at Cowell Hospital in recent years, due to the flow of storm runoff down the ambulance entrance driveway and into the "bowl" at the easterly side of the hospital. As discussed in sub-section VII-A of this report, a large part of the peak flow causing this flooding comes from the Rad. Lab. area above, reaching Gayley Road via several routes, and flowing thence to the ambulance entrance driveway to the hospital.

The courtyard and driveway area east of the hospital lies in a "bowl", enclosed to the east by a steep slope falling from Gayley Road and to the west by the hospital buildings. To the north the ambulance entrance driveway falls steeply to the courtyard area, and to the south any potential peak flow outlet is encumbered by a maze of improvements. The "bowl" thus formed apparently is, however, sufficiently well drained by surface outlets to the south and/or sewer inlets in the courtyard, such that the area floods only during periods of heavy runoff, when the input flow rate exceeds the outlet capacity of the area, causing water to pond in the courtyard and flood the building.

We thus feel that the following somewhat preliminary conclusions can be drawn regarding the flooding at Cowell Hospital:

> If flood flow was not entering the "bowl" via Gayley Road and the ambulance entrance driveway outlet capacity would apparently exceed input capacity and no flooding would be occurring.
>
> Without the extraneous flow from the Rad. Lab. area it is quite likely that the available outlet capacity from the "bowl" would be adequate to handle peak input flow; and thus while the overall geometry is not desirable, severe flooding would probably not result without this extra "foreign" runoff.
>
> It thus appears that the recently observed flooding can probably be eliminated by removing the "foreign" peak flood flow from Gayley Road, and can assuredly be eliminated by ending the diversion of flow down the ambulance entrance driveway from Gayley Road. In any case, both the encroachment of "foreign" runoff onto Gayley Road and the unfortunate geometry at the ambulance entrance driveway should be eliminated in final campus storm drainage plans, as both conditions are undesirable and unnecessary.

It has been the feeling of this office that the flooding at Cowell Hospital is a matter of relatively long standing, and is of limited severity comparable to that seen at other campus locations, and thus did not warrant "emergency" measures this year. This seemed to be particularly true since certain overall measures planned for 1963 will eliminate this problem. If these overall measures, as briefly discussed elsewhere in this report, are not to be taken this year, then "emergency remedial measures" should be taken to prevent further flooding at Cowell Hospital. Since we do not know what final course of action will be taken, our recommendations for such "emergency remedial measures" are given as follows:

Remove a twenty foot section of curb and associated earth berm from the westerly side of the ambulance driveway directly across from the opening onto Gayley Road.

Place a hot plant mix berm across the driveway from the southerly side of the driveway "return" to Gayley Road, to the southerly side of the above opening in the curb. Make this berm of such vertical height that a minimum flow depth in the resulting flat "vee" flow section above (northerly of) this berm is at least eight inches deep.

"Fair" the above geometry in the field so as to obtain the best possible "high velocity" flow path for the input flow from Gayley Road across the driveway to the opening in the curb. In doing this it will probably be best to "curve" the berm and flow path downhill somewhat so as to "fit" the fall of the driveway, depending upon the actual elevations of the area as "shot" when "blue topping" for the work.

Carefully clean and prime the existing driveway surface so as to obtain the best possible bond between the old and new asphalt, thus minimizing the danger of separation at peak flow.

The above procedure will "dump" this flow onto the slope above Girton Hall, a small, wooden, structure just south of the hospital. We doubt that this building would be structurally damaged by such a diversion, but some erosion of the slope must be expected. This would however, presumably be acceptable in lieu of further flooding at the hospital.

The diverted flow will then reach upper College Avenue, and either "jump" the south side of College Avenue and enter Strawberry Creek and/or flow by diffuse routes to the lower campus area.

Place a large sign reading "SLOW-BUMP", at the ambulance entrance driveway, to warn drivers of the bump in the driveway.

The above "emergency remedial measure" is far from a "good solution", due to the possible inadequacy of this measure to divert all flow at the driveway, to the certain erosion of the slope below the driveway, and to the uncertain path once the flow reaches College Avenue. A far better solution would be obtained by the regrading of the intersection of Gayley Road, South Drive, lower North Canyon Road and the ambulance entrance driveway, as discussed elsewhere in this report; as this procedure would assuredly reroute all flow at the intersection down South Drive to Strawberry Creek at the Faculty Glade. We would prefer to see execution of the latter, permanent solution, rather than the "emergency remedial measure", but if the permanent solution is not completed before the winter of 1963, then the emergency measure should be taken.

VII-D. City Storm Sewer

On October 20, 1962 the principal of this office inspected the City storm sewer which intercepts storm drainage from the campus at Oxford Street, by traversing the sewer, and sections of open creek channel, from Oxford Street to San Pablo Avenue. The inspection was terminated under San Pablo Avenue because the sewer became a "combined" sewer at this point, the air was very foul, it appeared that the sewer terminated in a submerged tidal outlet, and it appeared to be very dangerous to continue further without greater knowledge of what lay ahead. The purpose of this inspection was to determine the effects of the heavy flow and bed and float loads which entered the sewer from the campus on October 11-13, 1962, and to obtain the data necessary to evaluation of the effects of forthcoming "emergency remedial measures" on the campus upon the City system below.

The overall layout and facilities of the sewer were found to be as follows:

From Oxford Street to just below Sacramento Street the sewer consists of round or arch sections of varying age, type and materials. The older portions were the old fashioned "horseshoe" shaped section, and newer portions were round concrete pipe or C.M.P. semi-arches. The equivalent-round size varied, but was generally in the range of six feet.

From just west of Sacramento Street to about one block east of San Pablo Avenue the sewer alternated between closed conduit and open channel. The conduit sections were similar to those above; and the open sections were generally "raw", unimproved creek channel, irregular, meandering and hydraulically deficient.

One block east of San Pablo Avenue the sewer changed from open channel to closed conduit, and it appeared that this conduit extended to a "tidal outlet" in the Bay. This section began as an old fashioned "horseshoe" arch, and then changed to an old "egg shaped" brick section; such as was used many years ago for sanitary or combined sewers. The "horseshoe" section of the sewer was the hydraulic equivalent of say a five foot round pipe, while the "egg" section was hydraulically inferior to this section. The entrance to the conduit was a plain flat opening, hydraulically inefficient and opening onto an open channel of poor hydraulic properties.

The structural-stability conditions of the system were found to be as follows:

The section between Oxford and Sacramento Streets was reasonably sound excepting for large holes in the base of some of the old "horseshoe" sections. These holes consisted of areas where the masonry of the floor (and sometimes of the lower wall) was completely missing, where the bottom had scoured, leaving holes of up to three foot depth and twenty foot length and extending as much as three feet outside of the sewer wall. In some of these areas the sewer appeared to be nearing a condition where structural collapse would be imminent. The newer sections seemed to be in good condition, with no signs of overt structural distress. Erosion of the invert was generally moderate to severe in the older sections of the pipe, and moderate to negligible in the new sections.

The open channel sections consisted generally of unimproved creek channel, with a highly variable section, a meandering course, and with much obstruction from abutting improvements, plant growth and accumulated debris. Side-slope instability was not severe, but incisement of the stream bed and slope erosion was seen in some places. Partial blockage by logs, old masonry, debris, etc., was seen in some areas.

The intermittent closed conduit sections showed no overt structural distress or severe erosion, but some minor undercutting and distress was noted at inlet-exit points where special problems occurred.

The closed conduit leading to the Bay was generally sound structurally, with only moderate deterioration in some areas, but was very old and appeared to be of pre-World War II construction. Moderate to appreciable erosion was seen in the invert section.

Because of the generally good gradient obtaining from Oxford Street to the Bay, averaging roughly 1.8 percent, the hydraulic capacity of the system is probably somewhat greater than would be normal for such an installation, considering the very poor hydraulic conditions in many areas, especially the open-channel sections and the lowest section of conduit. The overall hydraulic aspects of the sewer, as inferred from our observations, are briefly reviewed as follows:

The inlet at Oxford Street is hydraulically inefficient at peak flows, and probably does not match the pipe capacity. The inlet capacity could be improved by removal of the hydraulically undesirable existing wooden "grizzly", and the execution of certain other measures, but we do not feel that it is safe to take these steps until the peak flow rate, bed and float load problems are better understood, as discussed hereafter.

The conduit from Oxford to Sacramento Streets is apparently reasonably efficient hydraulically, excepting for local head losses due to structural deterioration and changes in section. The gradient of this section of the sewer averages some 2.1 percent, and for an equivalent six foot diameter round section we "best guess" its peak flow capacity to be roughly 650 cfs. This is less than the estimated peak "ten year" runoff from the campus, not counting the flow into the pipe from the City area below Oxford Street. Note that during the storm in October 1962, this sewer failed to "take" the peak flow, and Strawberry Creek flooded over Oxford Street and thus bypassed into the City street system. Note that this occurred even though the inlet to the Big Inch storm sewer had malfunctioned and diverted much of the Zone IV peak flow from the immediate creek system. Thus unless some blockage occurred at the inlet, and we are not aware of this happening if it did, it is at least indicated that the City sewer proved inadequate during this storm. Since the sewer inlet is hydraulically deficient an indisputable deduction as to the pipe performance cannot be made; but we feel that the flooding onto Oxford Street is significant.

From the outlet of the conduit west of Sacramento Street to the inlet to the final section of conduit east of San Pablo Avenue the average flow gradient is some 1.8 percent, appreciably less than for the section between Oxford and Sacramento Streets. While an estimate of the flow capacity of this section of the system with its alternate open and closed sections, transitions, meanders, etc., is far beyond the scope of our work, we draw the obvious conclusion that it is considerably less than that of the upper section, and thus inadequate for present peak flows. In addition, a large acreage of City area drains to the system between Oxford and Sacramento Streets, increasing the peak flows at this point.

The average gradient from the inlet of the final section of sewer conduit just east of San Pablo Avenue to the Bay is something less than 1.3 percent, flatter than the two sections above, and the inlet is hydraulically inefficient. In addition, it was noted that the sewer showed a relatively flat gradient from the inlet to San Pablo Avenue, and then dropped quite steeply, thus giving an even flatter gradient in the upper section of the pipe. These conditions will have the effect of reducing peak flow capacity by a large factor, and combined with smaller equivalent size and lesser gradient, make the basic hydraulic capabilities of this section of the sewer much poorer than the upper section of conduit. In addition, the City area draining to the sewer at this point has now increased to a large acreage of completely developed watershed, and the overall peak flow capacity of this section of the system is thus obviously inadequate to carry the peak runoff from the area served.

It is pointed out that the sewer malfunctioned at or below the inlet east of San Pablo Avenue during the storm of October 1962, and a large surrounding area was flooded and appreciable damage occurred. This inadequacy of the lowest section of the sewer, and resulting flooding and damage, could be due solely to the hydraulic deficiency of this section of the system, without artificial stoppage or other hydraulic "accident"; however, we do not have any positive proof of the true cause of the overflow and flooding which did occur.

We have thus come to the preliminary conclusion that the City system is currently hydraulically overloaded during periods of peak runoff; and that when the system reaches capacity all additional runoff simply follows alternate surface routes in lieu of flowing through the sewer system. It appears that this "natural redistribution" of flow takes place by the following mechanisms:

Diversion of flow down the City streets at the Oxford Street inlet when the upper pipe section reaches capacity.

Diversion of sewer flow to surface flow at the various open channel sections below Sacramento Street.

Inadequacy of the curb inlets to the sewer to handle peak runoff, together with surcharging of the pipe at peak runoff, results in limiting the input of flow from the City area into the sewer during peak runoff periods, thus diverting this flow down the City streets.

Diversion of channel flow to surface flow at the inlet to the last section of conduit just east of San Pablo Avenue, when this section of the sewer reaches capacity.

Such "natural redistribution" of flow obviously took place during the storm of October 1962, and has apparently been doing so during all severe storms in at least the past five or ten years. The determination of whether or not such diversions are acceptable, and if so in what areas and to what extent, is beyond the scope of our present work.

We conclude that the City storm sewer system below Oxford Street is now inadequate to carry peak flows within the system, requiring "natural redistribution" to surface flow during peak runoff. The manner and extent to which peak runoff from the campus interacts with and affects the City system and contributes or does not contribute to flooding and damage is not clear at this time; but our best present opinions, used as a guide in setting up the "emergency remedial measures" on the campus, are given in the conclusions at the end of this report.

One of the important aspects of the City storm sewer from the standpoint of storm drainage on the campus is whether the City sewer system can handle the bed and float load injected at Oxford Street without "shoaling", excessive invert erosion, stoppage or other undesirable result. During our visual inspection of the system the following conditions pertinent to this consideration were noted:

The conduit from Oxford to Sacramento Streets was essentially clean, with only sparse large rocks, representing dropout during falling flow rate, being seen in the pipe down to Sacramento Street.

A few hundred feet above the outlet of the pipe (starting at about Sacramento Street) a deposit of sand, gravel and cobbles was encountered, grading in depth from nothing at about Sacramento Street to about half the pipe diameter at the outlet. This deposit was continuous with the bed of the section of open creek channel below the end of the pipe, and appeared to represent progressive shoaling in the pipe as the creek bed aggraded from dropout of coarse bedload materials. We suspect that this shoaling is a "transient" condition, representing dropout during the "tailing off" of peak flow, and will probably move on down the system and not be present during a period of peak flow. In addition, if this material is not replaced by a new supply of coarse bedload material coming down the system during future peak flows the material will probably be removed naturally and not replaced.

The open channel sections below Sacramento Street locally showed both aggradation and incisement, depending upon conditions at a given location. We feel that on balance the situation was one of net aggradation from deposition of coarse bedload materials; however, we also feel that this may well be a "transient" condition, as described above, which will not seriously hinder future peak flows and will be naturally remedied if the injection of coarse bedload materials from above is terminated.

The conduit sections below Sacramento Street were generally nearly clean, showing coarse deposits in the invert only where "tied" to shoaling of an adjoining open channel section.

The conduit from the inlet east of San Pablo Avenue was clean, and showed no signs of any appreciable deposition to the point explored. From the conduit geometry it appeared that any material entering the pipe would pass on through, unless there were an artificial blockage of the pipe or other "hydraulic accident".

Based upon the above information and inspection, the following very preliminary "best guess" opinions are given regarding the bed and float load situation in the City system:

It appears that a considerable quantity of bed and float load materials passed down the system during the storm in October 1962. These materials probably contained a relatively small percentage of cobble-boulder sizes, and were mainly in the gravel and smaller size range.

The only dropout and shoaling from these materials appeared to occur in the open channel sections, where poor hydraulic conditions produce "back-up" of flow, greater flow area and reduced velocities, and hence lessened transport power. This dropout and shoaling appears to be "transient" at this time, but could be the cause of overt stoppage of the system if conditions worsen, similar to the phenomena discussed with regard to Strawberry Creek at Stephens Union in Zone II. If bedload sizes and quantities are kept at the October 1962 level in comparison to peak flow rates and thus transport power of the flow, the system appears to be relatively safe from disastrous results from this cause at this time. It does appear, however, that the injection of large quantities of cobble-boulder sizes might produce serious shoaling in the system, especially in the open creek sections.

The only appreciable source of coarse bedload materials appears to lie in the campus, as all other tributary areas are highly developed and no other source of such materials was seen. A few new fills along open creek sections were eroded appreciably, and coarse rubbish and debris is evidently dumped into the creek, but these sources are probably minor.

A large tributary area drains to the pipe below Oxford Street, greatly increasing flow and thus transport power, without adding bed or float load. It thus seems most likely that any reasonable bed or float loads injected into the system at Oxford Street will be carried out to the Bay, excepting for gross hydraulic deficiencies in the system or for "dropout" during "tailing off" of peak flows.

We thus draw the "best guess" conclusions that injected bed and float loads from the campus were probably not seriously harmful during the storm of October 1962, and will not be this year if held to comparative load-transport relationships. It would not be wise, however, to inject larger or coarser loads into the system without much further study. Our recommendations for remedial measures in Zone II were made with serious attention to this consideration; and we required the excavation of a "coarse bedload catchment basin" above Oxford Street, and left the existing hydraulically undesirable "trash rack" in place at the inlet, for this reason.

On the basis of the foregoing information, we thus draw the following very preliminary, "best guess" conclusions regarding the conditions and capabilities of the City storm sewer system between the campus and the Bay, and the most important aspects of this system in relation to the campus storm drainage regime existent at this time.

The City storm sewer is apparently inadequate to carry a "five year" peak flow from the campus area, not considering the large tributary City area below, if all campus storm drainage facilities function properly. Resulting overloading of the City sewer has apparently been lessened to date by the hydraulic deficiencies within the campus, which have acted to "clip the peaks" off flood flows entering the City system from the campus. This includes the present inlet deficiencies at both the Big Inch storm sewer and the inlet to the City sewer at Oxford Street. As remedial work is performed on the campus, solving campus drainage problems and "expediting" the flow of peak runoff rates to the City system, the "pressure" on the City system will increase.

Since neither the gross area in the "City" watershed of the sewer nor the basic runoff conditions within have changed appreciably for many years, the bulk of change in storm runoff conditions will be the result of development of the campus area and the improvement of the storm drainage facilities within the campus, and the more efficient injection of City area peak runoff into the system by the various secondary storm sewer "improvements" which the City constructs and connects to the system from time to time.

Since we know that the inlet to the City system at Oxford Street has failed to carry peak storm runoff on several occasions during the past five to ten years, with flow bypassing to the City street system, we can conclude that the injection of campus runoff <u>into the pipe</u> has been limited by inlet and/or pipe capacity, and will continue to be so limited as long as we do not appreciably change the <u>peak</u> flow inlet conditions. Thus any present excess peak flow will divert to the City street system at Oxford Street as long as we do not change the existing inlet conditions, as will future increases in peak campus runoff due to further development of the upper campus area or to improvements in the campus storm drainage system. We can thus be reasonably assured that future campus runoff will not be more harmful to the <u>lower</u> sewer system than it has been for five or ten years, <u>but</u> that local flooding in the City street system will worsen as the peak campus runoff rate increases. We do not now know of any severe flooding problems or damage due to this local flooding of the street system at and below Oxford Street, and we <u>may</u> be quite safe in this regard at this time. If local flooding is found now to be, or in the future becomes, a serious problem, consideration would have to be given to increasing the flow in the conduit by improvement of the inlet system, to lessen the share of peak runoff rate being bypassed to the street system. By the same basic logic, the City might be well advised to seriously weigh the effects on the system before they connect any new "storm drainage improvements" into the existing sewer complex, or otherwise increase the peak flow rate load on the system. This matter can be intelligently resolved only after much more extensive studies are completed than have been possible under the scope of our present work.

We feel that the City storm sewer system has been "getting by" with only the relatively limited flooding damage and other troubles experienced to date in much the same fashion seen on the campus; namely that there are numerous limited diversions which "clip the peaks" off peak runoff rates during severe storms, with some local flooding and damage, but thereby avoiding much worse, cumulative flooding lower in the system. In the City system we believe that a combination of diversions on the campus, diversion at Oxford Street, limited diversions and flooding all along the open channel sections, and inadequacy of the street inlets to handle peak flow in the City area, thus diverting flow toward the Bay along the street system, has kept the situation from becoming critically dangerous to date. The point of worst flooding and damage to date has apparently been at the inlet just east of San Pablo Avenue, where gross hydraulic inadequacy of the last section of the system causes overflow onto the City streets and appreciable flooding and damage.

With the good westerly gradients obtaining it may be completely acceptable to allow diversion down the City streets at peak runoff periods. If no severe flooding or damage results there is nothing wrong with this condition. We do not know what conditions pertain at this time regarding surface flow between the campus and the Bay.

It is not clear at this time whether the "peak" flow rate from the campus coincides with the peak flow rate from the City area below. If the effective accumulation times for various points along the storm sewer are greatly different for the City area and the campus, then the peak rate runoff from the campus will not be directly additive to the City peak and the effects of campus drainage upon flooding in the City area may be minor. At this time we do not have an answer to this important question; however, it may be confidently concluded that any remedial measures on the campus will have the overall effect of reducing the effective accumulation times to points below, and will worsen the present situation, whatever it may be.

As discussed more extensively above, it appears that the present injection of bed and float load materials into the system has not been seriously harmful. "Emergency remedial measures" taken in lower Strawberry Creek have been set up so as to limit the future injection of coarse material into the sewer to the same or lesser load-transport relationship as existed during the storm of October 1962.

To render a brief general conclusion, we feel that conditions are such that increases in peak campus runoff rate have long since ceased to cause an increase in the peak runoff rate in the lower City sewer system, and that such increases now appear as added surface flow in the street system at and below Oxford Street. We know that the City sewer system is not adequately handling the peak runoff rate in the system; but we do not know of any serious problems due to surface flow in the street system due to diversion of peak flow from the campus. We thus conclude that we are reasonably safe at this time, as far as the effects of peak campus runoff on the City system is concerned, as long as we do not greatly alter the "balance" between flow injected into the sewer system and that diverting to surface flow. In any event, even if we are not so "safe" at this time, we certainly do not want to worsen the already severe flooding problems known to exist in the lower sewer system by injecting surface flow which is not now known to be doing any appreciable harm. From the standpoint of bed and float load, we feel that the indications are that any reasonable quantity of fine material will not be seriously detrimental at this time; and as long as the coarse fraction is limited in load-transport relationship to that which was injected during the storm of October 1962, or less, it appears that no seriously harmful effects will result below.

The above conclusions have been carefully considered in our recommendations for "emergency remedial measures" on the campus. We have kept the inlet conditions at the entrance to the City sewer at Oxford Street essentially unchanged at peak flow, leaving the wooden "grizzly" in place; and we have provided a catchment area for coarse bed load materials above this inlet, removing the groins in lower Strawberry Creek in stages so as to limit the injection of coarse bed load materials into the catchment area. As far up the system as the inlet to the Big Inch storm sewer, we have been cautious in raising inlet and pipe capacities, in consideration of potential downstream effects of resulting increased peak runoff rates; and even though these precautions were designed mainly to protect lower Strawberry Creek, they do also help to protect the City system below.

Considering the long-term aspects of the campus storm drainage regime and its effect upon the City area and sewer system below, we feel that a period of severe and costly overloading and flooding is approaching; and at this time the first serious effects are becoming apparent. We feel that within the next few years the problem will have to be seriously studied, and permanent, long-term solutions set up, or really spectacular and costly flooding and damage is going to occur during a peak intensity storm. It appears that the University's portion of such studies should be doneas part of an overall, campus master drainage plan, discussed elsewhere in this report; and that the findings from this study should be used as a basis of informing and cooperating with the City in working out a final, area-wide approach which will resolve the existing problems and prevent the occurrence of further difficulties in the future.

LENNERT AND ASSOCIATES

SOILS ENGINEERS

310 FOREST STREET, OAKLAND 18, CALIFORNIA

TELEPHONE: OLYMPIC 3-6223

Job Number 260
November 9, 1962

Mr. George H. Kimball
Principal Engineer
Office of Architects and Engineers
University of California at Berkeley
Berkeley 4, California

Re: Storn drainage investigations and emergency remedial measures at the Berkeley Campus.

Dear Sir:

Transmitted herewith is a portion of the results of our investigations, observations and recommendations regarding storm drainage conditions and emergency remedial measures for the Berkeley Campus. For purposes of this work we have divided the campus into the following zones:

Zone I	Chicken Creek area
Zone II	Lower Strawberry Creek
Zone III	"Big Inch" storm sewer
Zone IV	Upper Strawberry Creek area
Zone V	Botanical Gardens
Zone VI	North Radiation Laboratory area and North Campus
Zone VII	General campus

These studies cover a very cursory evaluation of runoff and storm-flow conditions, observations during the last storm, and recommendations for emergency remedial measures. Each zone has been evaluated and is reported as a unit, to simplify the work and reports, and to allow the most critical zones to be evaluated and reported as rapidly as possible.

Our reports on Zones I and II are transmitted herewith. They cover the two most critical areas, flood-wise, and contain our recommendations for emergency remedial measures. The sections on Zones III and IV will be issued this week, and the other zones will be reported as soon as possible.

In order to make some of our conclusions more understandable, we point out the following physical factors applying to the campus drainage problems. These brief statements cover matters of complex technology and are thus somewhat oversimplified, but we believe that they are essentially correct and very pertinent to the matters at hand:

A storm sewer system is limited in capacity by pipe diameter and fall, and by the capacity of the inlet systems to admit water to the pipe. With the gradients obtaining on the Campus, inlet capacity will control in most cases. In addition, adequate inlet capacity must be maintained by self-cleaning during heavy runoff, when heavy bed and float-loads occur, as manual cleaning during heavy storm-flow simply does not work.

Most storm drainage systems of feasible cost employ both storm-sewer capacity for moderate flow, and the use of flow down streets and open creeks during peak flows of short duration. If the entire area layout is properly designed this can be done with little or no inconvenience, at a great savings in cost of the storm drainage system. If the entire area layout is not set up with this consideration in mind severe flooding at critical points, often with heavy damage and cost, will usually result.

The existing peak-intensity runoff pattern on the campus bears little resemblance to the low-flow pattern, due to the inadequacy of the sewer-culvert-inlet systems and the immediate plugging of most inlet units. The peak-flow drainage pattern is dependent upon street and ground configuration not set with storm-flow in mind. Hence, the peak-flow drainage pattern on the campus does not follow a rational-design pattern, but is determined by chance of original topography and artificial improvements. Thus while the low-intensity flow pattern, as set by the storm sewer-culvert-inlet system, protects the campus improvements at low flows; at peak intensity flows the flooding of key areas such as the Haas Recreation Center, Cowell Hospital, International House, and probably the new Students Union Building in the future, is virtually assured by the existing peak intensity runoff system which involves streets, creeks, and sheet-flow rather than the "storm drainage system".

Whenever runoff coefficients are increased and accumulation times decreased, such as in the development of an area and by the installation of storm drainage systems, the peak runoff rates which must be handled in systems lower down the drainage pattern are increased by startling factors. Thus, whenever one improves the storm drainage capacity of an area, he must take into account the effect that this will have in exceeding the capacity of the system below. On the campus, the flow capacity of Lower Strawberry Creek, and possible of the City system below, is apparently close to being exceeded by current peak runoff rates, and thus any improvement in the storm drainage system in the upper areas should be done in such a manner as to minimize the increase in peak flow in the system below. This can best be done by the maintenance of the original dendritic drainage system, the maximum use of the original creek systems, and the minimal use of new pipe systems. The unwise installation of rapid runoff facilities in the upper campus area could easily result in the necessity of building a completely new storm drainage system below, at a cost of many millions of dollars.

In order that the seriousness, scope, and degree of urgency with which these recommendations have been made shall not be misunderstood, this office gives the following opinions and comments:

Unless the recommended emergency remedial measures are followed immediately the re-occurrence of flooding and damage as bad or worse than that experienced in the last storm must be expected this winter. This is not a chance or gamble, but a virtual certainty, if heavy rains occur.

Unless permanent remedial measures, which will be briefly outlined in our final report, are taken next year, flooding and damage will become progressively worse each year until suitable measures are taken.

The campus area is now at a point of development where a master drainage plan must be prepared or heavy costs in storm damage and avoidable duplication and/or reconstruction of new work now being designed and built will be incurred. For example, the flood damage and cleanup costs incurred due to the past storm would have been almost completely eliminated if the emergency remedial measures recommended herein had been taken this past summer. Some of the existing roads and streets will have to be re-graded to eliminate existing flooding problems, and could have been properly graded as-built if an overall campus drainage plan had been available. The new improvements now being designed should be evaluated with regard to their effects upon the campus storm-drainage system and their danger of being flooded; and this can only be done with a master drainage plan covering present and all future development.

This report covers only a small fraction of the information obtained in this work, as a complete review of the subject matter would easily run to several hundred pages. We will be happy to discuss this matter with you and to pursue verbally any aspects or details not covered in this report, as you may request.

Respectfully submitted,

B. J. Lennert
Registered Civil Engineer
State of California #9232

BJL:cz

LENNERT AND ASSOCIATES
SOILS ENGINEERS
310 FOREST STREET, OAKLAND 18, CALIFORNIA
TELEPHONE: OLYMPIC 3-6223

Proj. Arch.
Proj. Engr.
Dukleth

Job Number 260

December 26, 1962

Mr. George H. Kimball, Principal Engineer
Office of Architects and Engineers
University of California
Berkeley 4, California

GHK

Re: Emergency storm drainage measures in lower Strawberry Creek.

Dear Sir:

On this date Mr. Lowell Dukleth and the undersigned inspected the lower Strawberry Creek area to review the performance and results of emergency storm drainage measures as recommended for Zone II in our report dated November 9, 1962. The execution of the recommended remedial measures to date is suitable to and approved by this office, and the effects of these measures, as seen in the recent light rainstorms, is most gratifying.

During the course of the remedial work, and of subsequent degradation of the stream bed during the recent minor rainstorms, the creek bottom elevation has been lowered by one or two feet, and more groins and other obstructions have been revealed. This has necessitated a somewhat more extensive removal of obstructing items than was delineated in our original recommendations. In addition, the change in stream bed conditions revealed by the recent minor runoff and consequent erosion, makes certain further work necessary. We therefore make the following recommendations for immediate emergency remedial measures, supplemental to our recommendations of November 9, 1962 and keyed to the plan and numbering system used in that report, as follows:

Item 11. Original recommendation. Remove pipes from channel under bridge. This has not yet been done and should be done immediately.

12.1 Groin at Item 12 in original recommendations should be observed as the stream bed degrades and lowered in successive 2-foot increments as required to conform to new creek bottom configuration.

12.2 Erosion of the south bank of the creek near the new Students Center, severe in the past, is now worsening. This erosion will destroy the small trees and bushes along this bank if not remedied. We recommend the removal of the old, large Willow tree and associated brush and root clusters on the north side of the creek about 25 feet east of Item 12 of the original recommendations, to widen the creek to the north and retard erosion of the south bank. Brush and root-bound soil should be removed so as to provide a bottom channel width of at least 10 feet.

13.1 Remove root-bound soil point on the north side of the creek at the location of Item 13 of the original recommendations, in order to widen the channel and reduce erosion of the south bank.

19.1 Remove the entire groin referred to in Item ~~15~~ 19 of the original recommendations.

20.1 Remove large pieces of rubble and rock from the stream channel at the location of Item 20 of the original recommendations.

We believe that execution of the above recommendations should complete the <u>emergency</u> remedial measures in Zone II.

Respectfully submitted,

B. J. Lennert
Registered Civil Engineer
State of California #9232

BJL:cz

LENNERT AND ASSOCIATES

SOILS ENGINEERS

310 FOREST STREET, OAKLAND 18, CALIFORNIA

TELEPHONE: OLYMPIC 3-6223

Job Number 260

February 19, 1963

Office of Architects and Engineers
University of California at Berkeley
Berkeley 4, California

Attn: Mr. Lowell Dukleth

Re: Erosion between Stern Hall and the Greek Theatre

Gentlemen:

This letter is written in confirmation of opinions given by the Principal of this office on this date in telephone conversation with Mr. Dukleth regarding the existing large erosion-gully just south of Stern Hall.

The physical aspects of this problem, as we see them, are as follows:

The subject erosion-gully lies in a general drainage area with a shape roughly approximating a truncated isosceles triangle, the base being formed by Gayley Road between Hearst Avenue and Bancroft Way, with the north side running down the ridge on which Cyclotron Road is located, above Hearst Avenue, and with the south side formed by the ridge falling to Memorial Stadium. This area is shown on the rough sketch map attached, along with certain other pertinent features, as follows:

The above area is outlined in a brown pencil line.

Cyclotron Road is colored red.

The boundary of Zone VI is shaded in blue, Zone IV in green, and Zone II in brown.

Blackberry and Strawberry Creeks are shown as blue lines.

The erosion-gully is shown by a red mark.

Note the location of the area with respect to the Rad. Lab. area, and especially to Cyclotron Road.

This "drainage area" has been drawn because it has certain common characteristics, described as follows:

The area lies on the westerly facing "nose" of the overall ridge which separates Strawberry and Blackberry Creeks. The bulk of the ridge drains either to the south or north, to Strawberry and Blackberry Creeks, respectively, and the only drainage which naturally falls to this area is that of the area itself. The area thus has no tributary watershed except its own area, excepting for artificial diversions brought about by improvements in the Rad. Lab. area above.

The area is essentially unimproved and of small extent, and thus will show low to negligible peak storm runoff flows, excepting for artificial diversions into the area.

All swales in the area are immature and the soil zone is thick; thus any high runoff flows in these swales will cause severe erosion.

The construction of the Rad. Lab. area above, and especially Cyclotron Road, has caused a large diversion of runoff from Zone VI (see our preliminary report on storm drainage conditions at the campus) into this area, the diversion amounting to ten's of acres of completely developed Rad. Lab. area above.

The bulk of the excess storm drainage comes down Cyclotron Road in a devious pattern, "jumps" the road above Stern Hall and the Greek Theatre, and flows down the swale just south of Stern Hall.

Peak storm flows in this water course have been very large, the recent small storm causing severe erosion in the swale area.

The swale is eroding badly, with an erosion-gully having started some years ago. This erosion gully is now at the point of development where it erodes very rapidly, and the "scarp" of the gully now moves uphill by, say, five to ten feet during each normal, not peak, rainstorm.

Erosion-gullys such as this one move very rapidly once they reach a certain point of development, sometimes cutting back as much as fifty feet or more in a severe storm. This gully is approaching this stage of development.

The erosion seen is due solely to diversion of "foreign" runoff from the Rad. Lab. area above. Without this diversion the gully would not have formed and no erosion would now be taking place. Note that except for this diversion, the runoff conditions in these swales are essentially unchanged from say, 50 years ago, and the swales did not erode at all, and were stable, prior to construction in the upper campus area. Without this artificial change each of the small swales drains only a small area, incapable of producing sufficient flow to cause severe erosion.

In our preliminary work on the campus storm drainage problems, overall, we have not considered the above erosion to be an "emergency" situation, and have made no recommendations for "emergency remedial measures" therefor, for the following reasons:

The subject erosion is not now causing any costly damage, and <u>in comparison to other areas</u> where really dangerous conditions were found, it is not presently a matter of great concern.

The problem will be completely solved upon return of the upper campus runoff to the original runoff pattern, where it belongs. At that time the erosion-gully can be filled in and planted, and the matter forgotten.

Remedy of the observed erosion, other than removal of the artificial diversion of runoff, would be extremely costly, involving building a culvert from Stern Hall to the Big Inch storm sewer. Since this facility would be unneeded and useless after solution of the problem in the Rad. Lab. area, we cannot concur with the construction of such a unit.

It is our opinion that the solution of this problem does not lie in constructing a new, expensive, storm drainage facility in the Stern Hall-Greek Theatre-Bowles Hall area, but in correcting the defective runoff condition produced by construction in the Rad. Lab. area, and most especially Cyclotron Road.

We do not believe that the runoff coming down Cyclotron Road should be diverted back into Blackberry Creek at this time, as an "emergency measure", because of the dangerous effects that this might produce in the lower Blackberry Creek area. Note that the "north campus" area has not flooded badly in recent years, and this is almost undoubtedly due in large part to the diversion discussed above. To suddenly put this runoff back into Blackberry Creek would, in our opinion, be very risky. One has but to look at the depressed, inadequate entrance to the City storm sewer intercepting Blackberry Creek, at the recent incisement of several feet and the large cobbles and boulders in the creek bed, and at the residence resting in the canyon just below the inlet like a cork in a bottle, to feel quite cautious about changing the runoff of Blackberry Creek without adequate study. We believe that the runoff should be returned to Blackberry Creek before the winter of 1963, but only after adequate studies are made, proper warning is given to the City, and the results of this action have been evaluated. This is discussed in more detail under Zone VI of our preliminary report on campus storm drainage problems.

To conclude, we do not feel that "emergency remedial measures" are indicated for the subject erosion-gully and thus we have not and do not recommend that emergency measures be taken at this time.

With respect to present surface conditions, and action which might be properly taken at this time to lessen the nuisance created by the gully, we make the following suggestions and comments:

If the gully is now a hazard to pedestrians we have suggested that it be "barricaded" with a guard rail, and that the adjoining trail be closed.

Diversion of the flow from the gully by ditching could be accomplished by "bull dozing" a rather deep temporary drainage ditch along the dirt road above the area, so as to take the water around the Greek Theatre and to the parking lot between Bowles Hall and the Greek Theatre. This would require quite an extensive ditch, deep and hazardous to pedestrians, and the ditch would erode badly during all appreciable rainstorms. As the Greek Theatre has been built into a sort of "depression" the diversion of the water to the Theatre area would probably cause severe flooding of the Theatre. We do <u>not</u> recommend such diversion, but have described the conditions pertaining to give a more complete picture.

Erosion in the gully could be greatly reduced or halted by the placement of sand-bag "wing dams" of two or three bag height across the slope above the gully, thus diverting the flow to a small swale some 50 to 100 feet south of the existing gully. This swale is similar to the original condition of the one in which the gully has been eroded. The existing ditch and flow channel along the pathway should be blocked with sand bags as part of this work. Such action would halt further heavy erosion in the existing gulley, and initiate gullying in the swale to the south; but since such erosion-gullys develop slowly at first, it would "buy" a year or two of time in which to solve the basic problem.

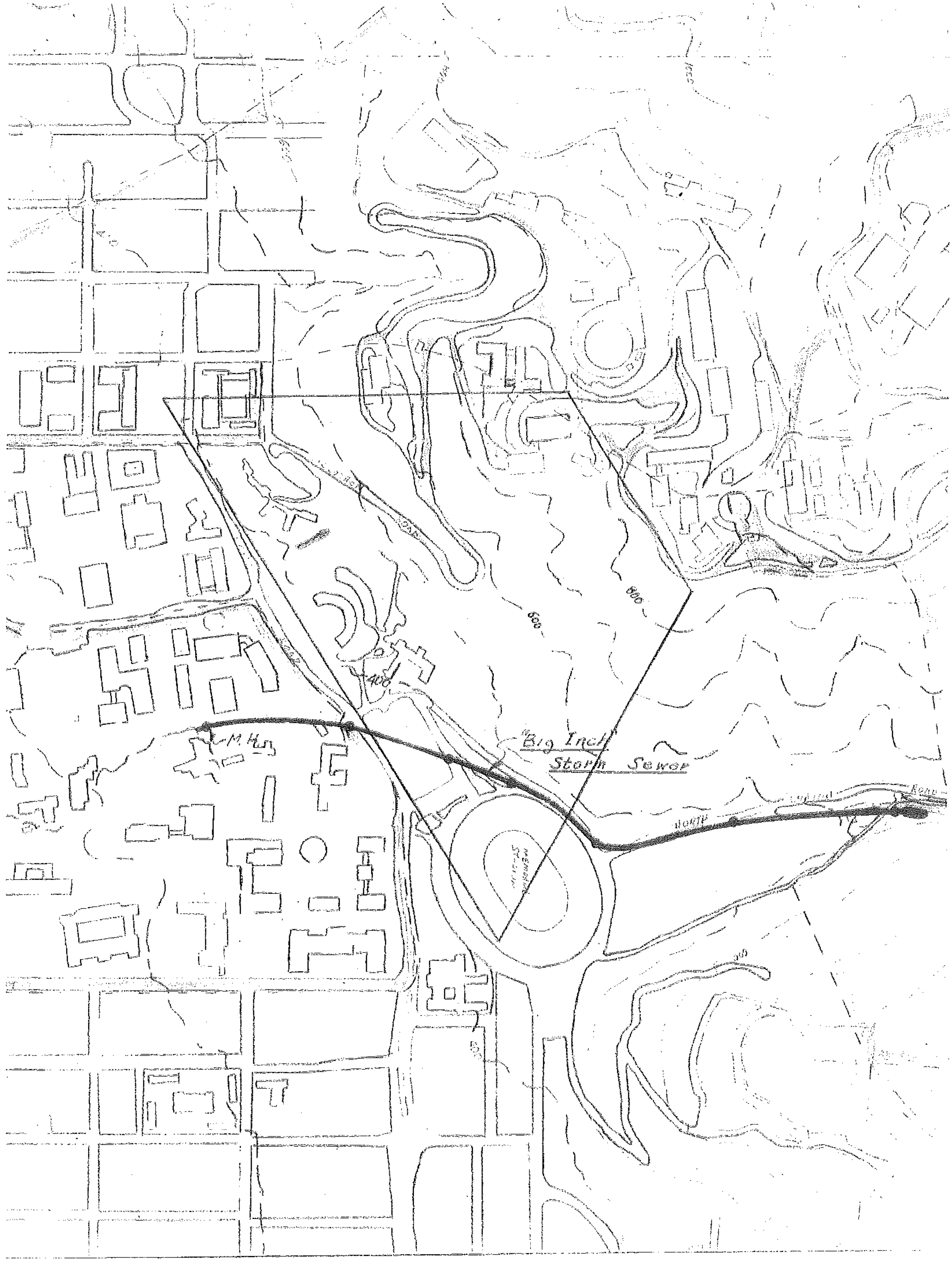
In conclusion, this office recommends that if you feel that the gully is a nuisance and that some measures must be taken at this time, that you place barricades around the gully, and divert the flow to the swale to the south with sand-bag "wing-dams" as described above. You should not fill the gully now as planting for erosion-protection would not "take hold" in time to prevent severe erosion of the new fill during further possible rainstorms this winter. On the long-term basis we recommend that the problem be solved by restoration of the original runoff conditions within the "triangle", and not by construction of a large expensive culvert system, which might not "work" during a severe storm when it was really needed, anyway.

We will be happy to lay out the suggested sand bag "wing-dams" in the field if you so request.

Respectfully submitted,

B. J. Lennert
Registered Civil Engineer
State of California #9232

BJL:cz


"Big Inch"
Storm Sewer
M.H.
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LENNERT AND ASSOCIATES
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310 FOREST STREET, OAKLAND 18, CALIFORNIA
TELEPHONE: OLYMPIC 3-6223

Job Number 260

March 25, 1963

Office of Architects and Engineers
University of California at Berkeley
Berkeley 4, California

Attn: Mr. Lowell Dukleth

Re: Chicken Canyon rock groin system.

Gentlemen:

On this date Messrs. Dukleth and Parish, of the University Staff, and the undersigned inspected the lower rock groin area in Chicken Canyon. This letter will confirm the opinions and recommendations given by the undersigned at this meeting:

The slope of the new rubble groin should be flattened and the toe extended by the addition of more rubble in the lower portion of the groin. The area below the groin should be "armor coated" with one layer of larger rip-rap pieces for a distance of five feet out from the new toe-of-slope.

It is not necessary for you to concrete-slurry the face of this groin at this time. This involves some risk of erosion; but we feel that the hazard is small and the cost of placing this concrete at this time would be prohibitive. Some time this summer, during the course of overall remedial work in the Canyon and after the area in back of the berm has been filled and stabilized, the face of the groin should be concreted for permanent protection; and this can be done at that time at much less cost than now.

It was recommended that the groin immediately below the one described above be extended to the west to protect it from impending end-cutting, and that an existing "hole" in the groin be filled in with coarse rubble.

The existing old groin above the newest groin should be protected from further erosion at its toe by the dumping of rubble in the existing hole, and placing one layer of large pieces of rubble as erosion protection for a distance of five feet beyond the toe of the groin.

It was recommended that two more groins be built above the highest existing groin in the lower creek area, using rubble from campus demolition as it becomes available. The locations of these groins were discussed and "spotted" in the field, and Mr. Dukleth is to flag these locations. The flow-channel of the creek is to be shifted easterly, away from the slide in the westerly slope, by putting the low-point flow channel in the groins to the east of the existing creek channel. The groins are to extend to the westerly slope to prevent end-cutting.

This office recommended that coarse rock, rubble and/or pieces of asphaltic concrete obtained in your general work in the campus be dumped into the stream channel just above the highest groin in the lower section of the creek. This will provide coarse bed material necessary to form an erosion-resistant creek bed. As the slide material being eroded contains little coarse, hard rock this source of erosion-resistant material will hasten the formation of a stable stream bed; and in addition, this procedure will avoid the necessity of hauling this material to the "dump", at a considerable savings to the University.

We approve your dumping excess soil from campus excavations above the existing highest groin, to fill-in the creek channel to the new groin height. As soon as the creek channel is raised to the intended top of the new groin, a rock facing should be placed on the fill slope to form the new groin, as described above. Coarse material is preferable for this dumped soil, but ordinary "dirt" is acceptable for filling behind the groins. The exposed "dirt" surface should be covered with waste rubble as much as supply and practicability will permit. In taking this action we are taking some risk of losing this material to erosion; however, it is the opinion of this office that no coarse material will move down the creek, as it will be stopped behind the groins and act to "harden" the bed, and transported fines reaching the road below will pass on down the system as many thousands of yards of slide material have already done this winter. This action therefore saves the University the cost of hauling this excess soil to the "dump", and hastens the filling behind the groins and resulting stabilization of the slide to the west.

It was noted that the large slide which forms the westerly side of the lower creek channel is still active and "squeezing" the channel. The filling of the "hole" in back of the newest groin by the recent small rain is indicative of the amount of slide debris moving in the creek. The performance of the groins now built has been very gratifying to date, and the raise in channel grade now achieved is beginning to stabilize the slide by surcharging the toe of the slope. The continuing construction of groins with campus-derived rubble, and the filling in back of these groins with campus-derived waste soil, will be both beneficial to the program of stabilizing the slide and stream channel, and save money on normal campus costs as well.

Respectfully submitted,

B. J. Lennert
Registered Civil Engineer
State of California #9232

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