PB
523
H75
#2

Municipal Reference & Records Center
MUNICIPAL REFERENCE LIBRARY
CITY AND COUNTY OF HONOLULU

KALIHI TUNNEL REPORT

Honolulu. Dept. of Public Works. Bureau of Plans.

HE380
U53
H658
Copy 3

Letter of Transmittal

September, 1952

The Mayor and Board of Supervisors
City and County of Honolulu, Hawaii

Gentlemen:

The following report presents preliminary plans for a vehicular tunnel project from Kalihi Valley through the Koolau Mountain Range. It outlines briefly the considerations which led to the planning for a tunnel through the Koolau Range, and presents a description of the tunnel project itself.

It is to be noted that the report encompasses the Kalihi Tunnel Project in its entirety and sets forth the three stages in which it will be accomplished. It describes the processes and machinery for starting the first of these stages immediately in order to provide for an orderly progression of the work.

In addition, the report presents certain recommendations for action.

Respectfully submitted,

Karl Sinclair
Acting Chief Engineer
City and County of Honolulu

Municipal Reference & Records Center
MUNICIPAL REFERENCE LIBRARY
CITY AND COUNTY OF HONOLULU

KALIHI TUNNEL REPORT

For The

CITY AND COUNTY OF HONOLULU
HAWAII

John H. Wilson - MAYOR

BOARD OF SUPERVISORS:

John M. Asing
Dr. Sam K. Apoliona, Jr.
Samuel K. Ichinose
Noble K. Kauhane
Nicholas T. Teves
James K. Trask
Sakae Amano

Karl A. Sinclair
Acting Chief Engineer

Prepared in Collaboration With

BUREAU OF PLANS

Harold Butzine - Engineer
Samuel Hirota - Civil Engineer

and

LAW & WILSON

Architects and Engineers

September 1952

Recognition should be given to the following
for their efforts and interest in the
Kalihi Tunnel Project

The Honorable Mayor of the City and County of Honolulu, John H. Wilson, for his untiring efforts in finding ways and means of bringing this project to a realization;

Karl A. Sinclair, Acting Chief Engineer of the City and County of Honolulu, for his leadership as head of this project;

Members of the City Planning Commission of the City and County of Honolulu: Alex Gignoux, Chairman, A. A. Wilson, Kenneth W. Roehrig, Thomas B. Vance, David Bent, Henry Chun Hoon, Robert Murakami, Lester Petrie, and William Loper. George K. Houghtailing, Director of the City Planning Commission of the City and County of Honolulu, for his work in presenting facts and figures to the legislature and to the public;

Joseph Kunesh, former Chief Engineer of the City and County of Honolulu, for his effort and support during the early planning stages.

Sadaichi Dodo, Engineer in charge of the Kalihi Tunnel Section of the Bureau of Plans, for preliminary engineering and economic studies and establishing the location for the entire project;

Max H. Carson, District Engineer and George Hirashima, Office Engineer, of the U. S. Geological Survey Surface Water Branch, for data on rainfall and runoff;

Dan A. Davis, District Geologist and Kiyoshi Takasaki, Geologist of the U. S. Geological Survey Ground Waters Branch, for description and interpretation of core borings by Samson and Smock;

Leslie J. Watson, Civil Engineer in charge of Water Resources Division of the Board of Water Supply of the City and County of Honolulu, for rainfall data;

Ralph G. Wadsworth, Chief Engineer of the City of San Francisco, for plans and specifications of the Broadway Tunnel in San Francisco;

The Department of Highways of the State of Pennsylvania for plans and specifications of the Squirrel Hill Tunnel in Pittsburgh, Pa.

INDEX

		Page
I	INTRODUCTION	1
II	THE TUNNEL PROJECT	
	A. Description of the Tunnel Project	4
	B. Earlier Tunnels in Hawaii	8
	C. Description of Bore	10
	1. Tunnel Driving Methods	12
	2. Anticipated Ground Conditions in the Kalihi Bore	16
	3. Tunnel Lining	18
	4. Tunnel Drainage	23
	5. Provisions for Utilities	25
	6. Tunnel Paving	26
III	RECOMMENDED VENTILATION SYSTEM FOR THE KALIHI TUNNEL	
	A. Importance of Ventilation	26
	B. Carbon Monoxide Recording Instruments	30
	C. General Types of Tunnel Ventilation	32
	1. Unventilated Tunnels	32
	2. Tunnels Supplied with Fresh Air by Longitudinal Distribution	32
	3. Transverse-Longitudinal Tunnel Ventilation	34
	4. Longitudinal Ventilation of Tunnels	35
	5. Transverse Ventilation of Tunnels	36
	D. Recommended Ventilation for the Kalihi Tunnel	37
IV	TUNNEL LIGHTING	
	A. Visibility Requirements	40
	B. Approach Treatment - Daytime	44
	C. Tunnel Entrance Lighting - Daytime	46
	D. Tunnel Interior Lighting - Daytime and Night	51
	E. Approach Road Lighting - Night	52
	F. Emergency Lighting	53
	G. Controls	53
V	KALIHI APPROACH TO THE TUNNEL	
	A. Drainage Problem and Stream Relocation	53
	B. Portal	59
	C. Ventilation and Control Building	60
	D. Stage Development	62

INDEX (Cont'd)

		Page
VI	KANEOHE APPROACH TO THE TUNNEL	
	A. Problems Posed by the Topography of the Pali	64
	B. Portal	66
	C. Stage Development	68
VII	ELECTRIC SERVICE AND DISTRIBUTION	
	A. Service	70
	B. Power Requirements for the First Bore	70
	C. Electrical Equipment and Distribution	70
VIII	SUMMARY OF PROPOSED FIRST STAGE CONSTRUCTION	72
Appendix A - Estimated Cost of Construction For Stage 1		75
Appendix B - Core Drilling Data		77

Plates

		Page
1.	Regional Map	3
2.	Vicinity Map	5
3.	Tunnel Project Plan	7
4.	The Tunnel Section	11
5.	Geology	17
6.	Sections	27
7.	Types of Tunnels	33
8.	Ventilation System	39
9.	Ventilation Building	41
10.	Tunnel Lighting	45
11.	Lighting Details	47
12.	Kalihi Approach Plan	55
13.	Kalihi Portal	61
14.	Kalihi Approach Stage 1	63
15.	Kaneohe Approach Plan	65
16.	Kaneohe Portal	67
17.	Kaneohe Approach Stage 1	69
18.	One Line Electrical Diagram	71

Photographs

A.	Aerial View of Model	9
B.	Sectional Model	19
C.	General view of model from Kalihi Side	58

KALIHI TUNNEL REPORT

I. Introduction

The feasibility of a tunnel to connect Honolulu and Windward Oahu has been for many years a subject for debate among the Territory's residents. As early as 1929 the Honolulu Sewer and Water Commission submitted a report to the Legislature in which it was concluded that "any vehicular tunnel project designed to connect Honolulu with Windward Oahu is now, and will in the near future be, infeasible..."

However, the rapid growth of the city's population, the development of residential areas on the Windward side, and above all the urgent needs of the armed services during World War II convinced all farsighted citizens and public officials that building such a tunnel was inescapable. It became obvious that the narrow Nuuanu Pali road, picturesque as it is, could never serve the transportation needs of the rapidly growing communities on the Windward side. Furthermore, the expansion of naval and air facilities at Kaneohe made it imperative that an additional route be developed to link the defense establishments on both sides of the Koolau Range.

Although the building of a tunnel came to win wide popular support, the location of this projected tunnel aroused sharp differences of opinion. The "Puka in Da Pali", as the tunnel is often termed locally, produced a long drawn out controversy, much of which was carried on in the public press. Many sincere and qualified persons

came forward with their arguments for the choice of a route -- through Kalihi, or Nuuanu, or Manoa Valley. (See Regional Map, Plate 1)

Traffic counts were made, population growth was studied, military opinion was solicited, and financial programs were analyzed in an effort to settle upon one of these routes. In December of 1946, for example, the Honolulu Planning Commission submitted a report to the Mayor and Board of Supervisors which stated that the Kalihi route was preferable to Nuuanu, partly because it would open up new lands for development and thereby widen the tax base. On the other hand, the Territorial Administration strongly favored the Nuuanu route because it would ease the traffic problem between already existing population centers, thus making it eligible to receive Federal funds. A third opinion was expressed by the municipal affairs committee of the Chamber of Commerce, which stated that both the Kalihi Tunnel and an improved Nuuanu route would have to be developed if the long-range needs of the island of Oahu were to be met adequately.

It is widely realized that eventually the community, which gives every indication of a sustained and vigorous growth, will need both the Kalihi Tunnel and the Nuuanu route. Inasmuch as the Territory, assisted by Federal Funds, intends to improve the Nuuanu route, the Territorial Legislature has passed a bill authorizing the City and County to issue obligation bonds of $6,000,000 for the Kalihi Tunnel and approach roads. At the request of the Legislature, Hawaii's dele-

PLATE I

REGIONAL MAP

KALIHI TUNNEL REPORT

CITY & COUNTY OF HONOLULU
BUREAU OF PLANS
AND
LAW & WILSON
ARCHITECTS & ENGINEERS

gate to Congress introduced a bill in July 1951, which secured Congressional approval of the bond issue.

The Territory has agreed to finance some of the tunnel approach roads with the aid of Federal funds of the secondary road basis. This financing is contingent upon the City having proper access roads. It is contemplated that these access roads will be financed by improvement district. It was recognized that the $6,000,000 bond issue would not be sufficient to finance the entire connecting highway route but that it would construct the first stage of the tunnel development to connect with existing roads on each side. (See Plate 2 - Vicinity Map)

II The Tunnel Project

A. Description of the Tunnel Project.

The total construction of the Kalihi Tunnel Project will proceed in three stages, as follows:

1. A single bore with divided highway approach roads from Kalihi and Kaneohe.
2. A second bore similar to the first, the completion of which would then permit two lanes of one-way traffic in each bore.
3. A Kailua approach road to the tunnel.

It is to be noted that this "stage-development" plan permits of an orderly, synchronized job. Construction required in the first stage can start immediately, and the planning for it constantly keep in view

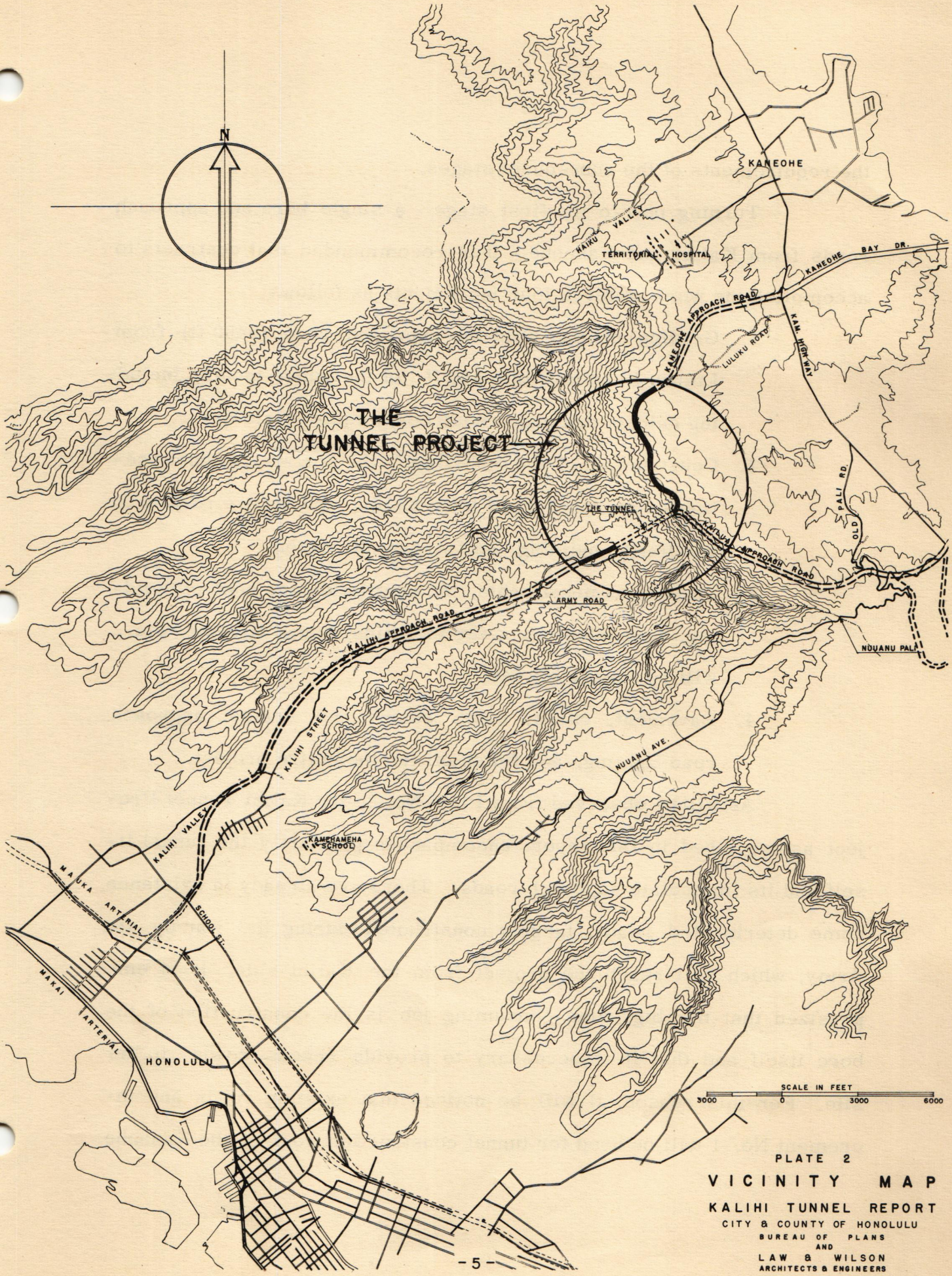


PLATE 2

VICINITY MAP

KALIHI TUNNEL REPORT

CITY & COUNTY OF HONOLULU
BUREAU OF PLANS
AND
LAW & WILSON
ARCHITECTS & ENGINEERS

the requirements of the subsequent stages.

Turning now to the first stage - a single bore and approach roads from Kalihi and Kaneohe - it is recommended that contracts to accomplish the work be let in four increments as follows:

1. Grading of the Kaneohe approach road (5450 ft) from Luluku Road to within 400 ft. of the tunnel mouth, including culbert drainage requirements (See Plate 3).
2. Construction of the bore itself, the portals, a short section of approach road from Kalihi, and access road to the ventilation building, and stream diversion.
3. As soon as practicable, the ventilation and control building, fans, electric power facilities, tunnel lighting, etc., will be separately let.
4. Pavement, curbs, catch basins and drains, approach road lighting, and finish off for the entire project.

As will be observed from Plate No. 3, the Kalihi Tunnel Project as described in this report encompasses primarily the tunnel itself and its immediate approach roads. There are already in existence some deteriorated roads, largely constructed during the war by the Army, which will reach the project from the Kalihi side. It is emphasized that the big, time-consuming job is the construction of the bore itself and that it is necessary to provide access roads to the site. For this reason, it will be noticed that existing roads and increment No. 1 will be used for tunnel construction work on the Kaneohe

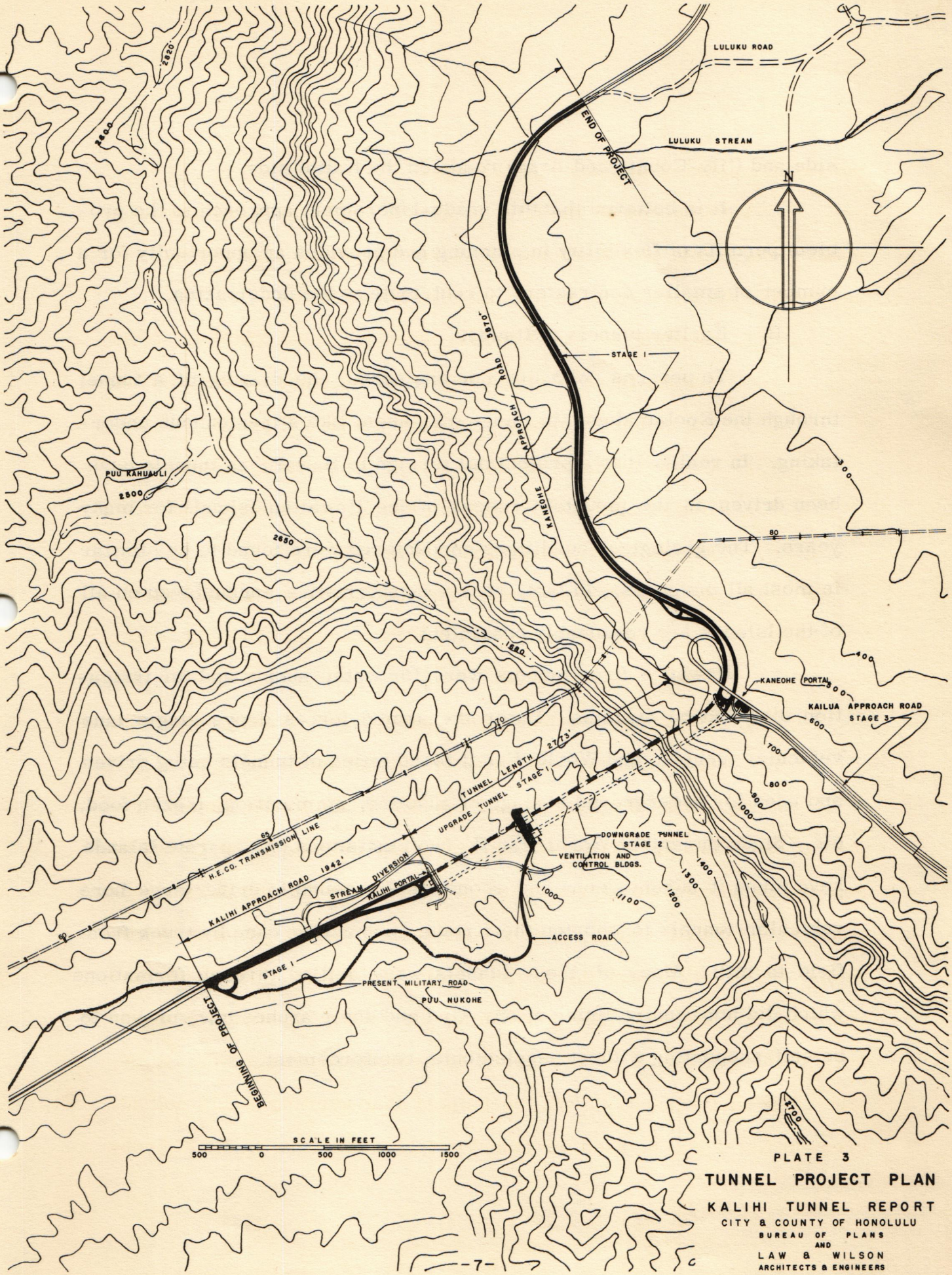


PLATE 3

TUNNEL PROJECT PLAN

KALIHI TUNNEL REPORT

CITY & COUNTY OF HONOLULU
BUREAU OF PLANS
AND
LAW & WILSON
ARCHITECTS & ENGINEERS

side and City-County and Army roads on the Kalihi side.

It is believed that this gradual increment approach to the problem permits of flexibility in planning and provides an opportunity for a number of smaller contractors to contribute to the undertaking.

B. Earlier tunnels in Hawaii

To persons who are not engineers, the driving of a tunnel through the Koolau Mountain Range may seem like a tremendous undertaking. In reality it is a project not foreign to Hawaii, as tunnels have been driven in the mountain ranges of the Hawaiian Islands for many years. The geological conditions encountered were found to be similar in most all instances. In fact, rock characteristics encountered on all of the Islands are reasonably consistent.

Hawaii's first tunnels were for water supply and for irrigation distribution systems. Later the armed forces drove single lane vehicular tunnels, and World War II found miles of tunnels being driven and used for underground storage of gasoline, ammunition, frozen food, etc. Since the end of World War II, two plantations on separate Islands have found it advantageous and economically sound to drive large bore vehicular tunnels to shorten their route for hauling cane by truck from field to mill. Many of these tunnels were drilled through formations which did not require lining of any kind and their arches have proven to be self-supporting without supplemental reinforcement.

PHOTOGRAPH "A"

Municipal Reference & Records Center
MUNICIPAL REFERENCE LIBRARY
CITY AND COUNTY OF HONOLULU

Core drillings (See Appendix "B") on the Kalihi Tunnel alignment indicate that rock and/or soil formations are typical of formations found in other tunnels, and it is not envisioned that the actual excavation will present any particularly difficult problems.

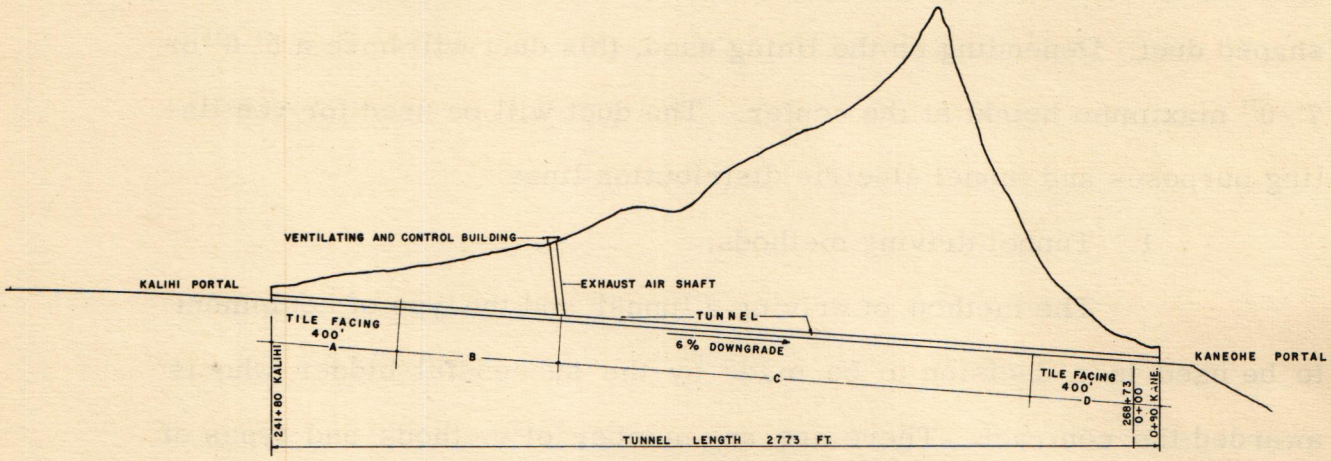
C. Description of bore.

This section of the report will devote considerable space to the drilling of the bore itself, since this is the stage which is of most immediate interest. Without going into extensive technical detail, we submit the following information concerning tunnel driving methods, ground conditions, tunnel lining, grouting, drainage, provision for utilities, tunnel paving, etc.

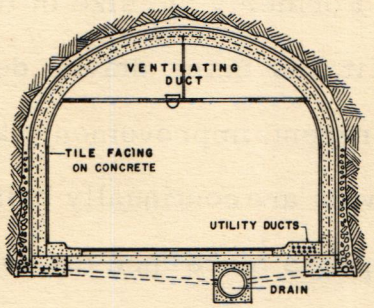
Designing the size and shape of the tunnel bore is a problem requiring consideration of all present functions of the tunnel, as well as future demands upon it.

Kalihi tunnel at this stage will be a single bore providing for two 11 1/2-foot traffic lanes. The bore will be 2773 feet long with a constant grade of 6% falling from the Kalihi portal to the Kaneohe portal. Typical sections of the tunnel are shown on Plate No. 4, "The Tunnel Section."

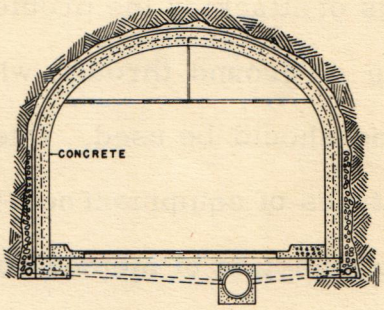
The lower portion of the bore, almost rectangular in shape, provides sufficient width for the two traffic lanes, plus a two-foot curb on one side and a four-foot walk on the other. The vertical clearance height between the pavement and the ceiling slab is 15 feet. Above



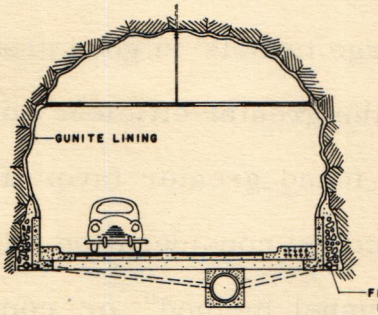
LONGITUDINAL SECTION THRU TUNNEL



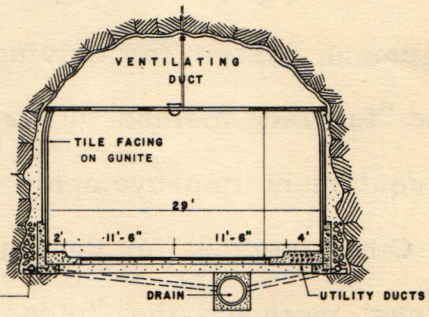
TUNNEL ENTRANCE
SECTION-A
(BROWN CLAY)



TYPICAL SECTION-B
(BROWN CLAY)



TYPICAL SECTION-C
(ROCK)



TUNNEL ENTRANCE
SECTION-D
(ROCK)

PLATE 4

THE TUNNEL SECTION

KALIHI TUNNEL REPORT

CITY & COUNTY OF HONOLULU
BUREAU OF PLANS
AND
LAW & WILSON
ARCHITECTS & ENGINEERS

the ceiling slab, running the length of the bore, is a "segment of circle" shaped duct. Depending on the lining used, this duct will have a 5' 6" or 7'-0" maximum height at the center. The duct will be used for ventilating purposes and tunnel electric distribution lines.

1. Tunnel driving methods.

The method of driving a tunnel and the type of equipment to be used is a decision to be made by the successful bidder who is awarded the contract. There are any number of methods and types of equipment, and the descriptions below are merely indicative of the general methods of attacking the problem. Formerly the size of the tunnel and the type of ground through which it was being driven determined which method should be used. Due to recent improvements and additions to the types of equipment new methods are continually being developed and the selection of method now depends more upon the availability of the equipment.

In the past the "top heading and bench method" was the Standard American System for driving large tunnels in good ground. Recently the "full face method" utilizing the greater efficiency of the most modern equipment improvements has found greater favor and use in Hawaii. Other methods for the contractors' consideration might be the "pilot tunnel method", the "pioneer tunnel method" or combinations thereof.

As the name indicates the "full face method" calls for a pattern of holes for explosives that break loose the full cross sectional area of the face at one time. This system has usually been used in small tunnels, and since the development of the multiple drill Jumbo and more efficient mucking machines it has been generally adopted for tunnels of any size in good rock.

A Jumbo, or drill carriage, is a device usually operating on rails with a number of air drills so mounted on its frame that the drills may be operated simultaneously and can be adjusted to various levels and angles. The Jumbo, with drills in the drilling position, practically fills the whole frame of the tunnel, so naturally all mucking must be completed before drilling starts. In working on only one face there is some loss of time between the operations of drilling, shooting, and mucking, but present day equipment and material (such as fast operating air drills, instantaneous and delayed action electric blasting caps, air movers for clearing out powder fumes, and efficient mucking machines) make it possible for a drill crew to make two and more rounds of holes in eight hours. Assuming that each round of holes were eight feet deep (eight-foot hole will normally pull seven-feet of muck) two rounds of holes should be averaged per 8-hour shift; it therefore is quite possible to visualize driving operations proceeding at a rate of 40-50 linear feet of tunnel excavation per 24-hour day.

Designing the Jumbo is an art in itself, and its design will allow experienced men to follow closely the theoretical outline and shape of the bore without costly overbreak. (Overbreak means the amount of rock that is dislodged outside of the dimension line of the tunnel and results in extra excavation and additional backfill where the tunnel is to be finished to a neat line.)

Excavated material is usually removed by either one of two means: (1) Special equipment, mounted on a railway track, and dumping into railway cars, a method very common in small tunnels but also used in large ones - or (2) Specially designed crawler shovels which dump into trucks - feasible in large tunnels.

The "heading and bench method", as previously mentioned, was standard practice for many years. It consists of driving a heading at the top of the tunnel about eight feet high and the full width of the proposed opening. The lower or remaining part of the tunnel is removed in one or more steps or benches. The bench is usually carried one round behind the upper face or heading.

Drilling is ordinarily done from bars or columns and may be carried on while mucking is in progress if the previous round was loaded and fired so that most of the muck from the heading was thrown clear of the bench. Either vertical or horizontal holes may be used in the bench; in the former case the holes may be drilled as soon as the top of the bench is mucked off; in the later case, drilling waits until the

mucking operation has been completed.

Another technique, known as the "pilot tunnel method", has been used in driving many large tunnels. A drift or pilot tunnel 8 ft. x 8 ft. or 10 ft. x 10 ft. (large enough for men to work and use appropriate length drills) is driven in the center of the proposed tunnel by conventional methods. The drilling may be from a Jumbo or by means of columns or bars. As a rule this heading is driven all the way from portal to portal before any enlargement is attempted, although this is not necessary if some practical way can be devised to dispose of muck from both the drift and the enlargement at the same time. Holes for the enlargement are drilled from posts or bars and can be drilled the same time as the heading. They are usually drilled in a series of rings four or five feet apart, perpendicular to the axis of the tunnel, and arranged so that the outer ends of the holes of each ring are three to four feet apart at the perimeter of the full cross section. Templates are usually provided so that drillings can be accurately made and drills of proper size are used to reach the outside limits of the tunnel.

A method which has been used for long railroad tunnels is the "pioneer tunnel method", often in combination with the "pilot tunnel" just described. A small drift, say 8 ft. x 8 ft., is driven parallel to and about 50-70 feet away from the main tunnel; this is called the "pioneer" tunnel. It is normally pushed considerably ahead of the face of

the main tunnel, thus giving warning of any major change in the rock in ample time to allow for different procedure in the main heading. Also, every few hundred feet across, cuts are driven from the pioneer to the center line of the main bore, opening up two more faces in the main bore and allowing drill crews to work in two directions, fore and aft. The pioneer tunnel not only serves to open up a large number of faces in the main tunnel to allow faster driving, but also furnishes a muck haulage way and a means of improving ventilation at the various headings.

2. Anticipated ground conditions in the Kalihi bore.

It is a readily understood fact that in driving tunnels it is impossible to know exactly what type of ground condtions will be encountered. This fact makes tunnel construction hazardous and renders undetermined the type of construction that is best for the situation. For this reason the quantity of different items of construction may be varied to meet the conditions encountered. The Kalihi tunnel overburden varies considerably in depth with a maximum of about 780 feet. It is composed of brown clay deposits and stratified volcanic rock, including porous rock, hard rock and gray rock. As indicated on Plate No. 5 - Geology (a profile of the proposed tunnel and the findings revealed by core drilling) as derived from Appendix "B" to this report, some eight hundred feet of the tunnel will be through the brown clay deposit and the rest of the way through the volcanic rock which is believed to be the

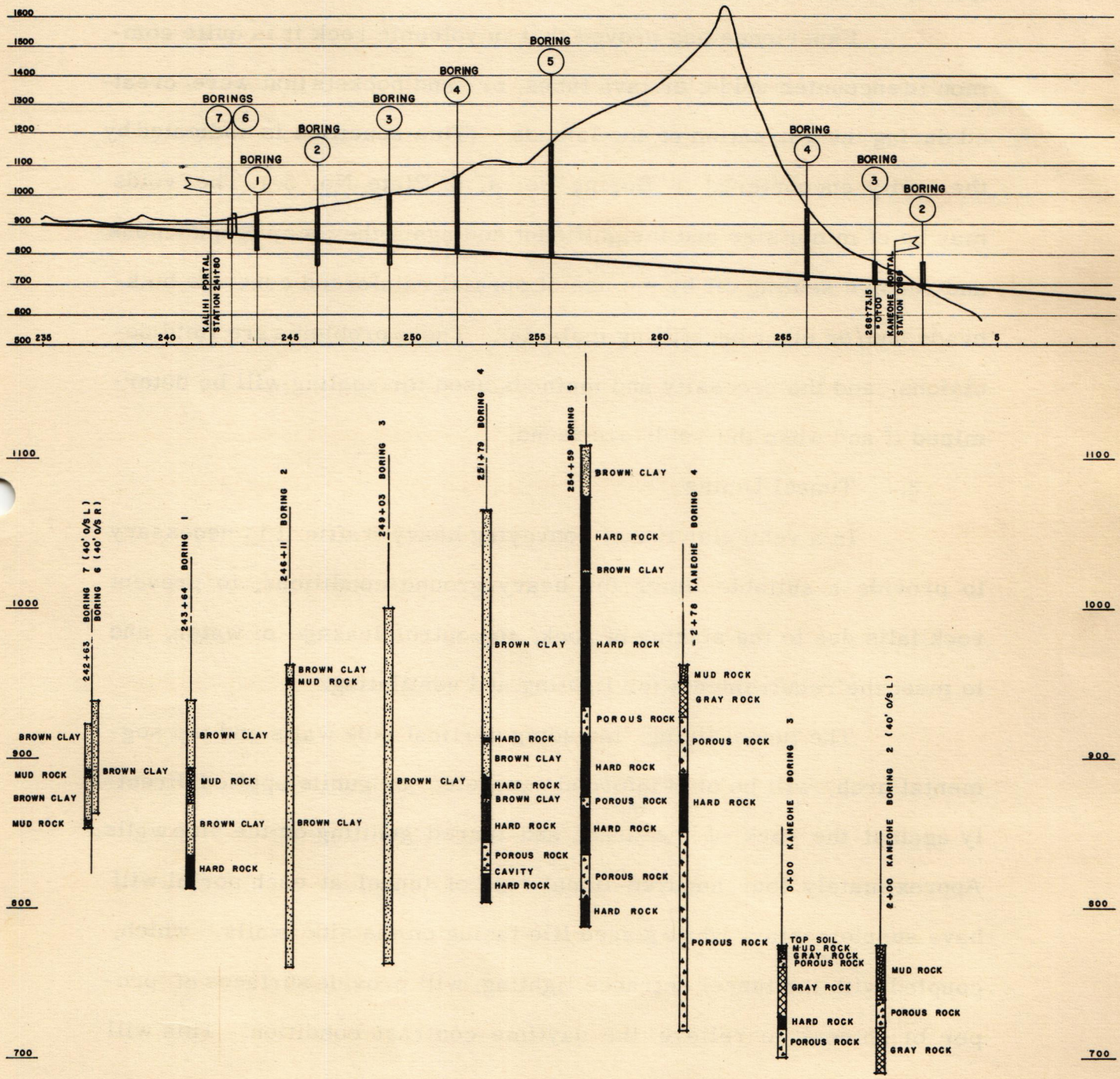


PLATE 5

G E O L O G Y

KALIHI TUNNEL REPORT

CITY & COUNTY OF HONOLULU
BUREAU OF PLANS
AND
LAW & WILSON
ARCHITECTS & ENGINEERS

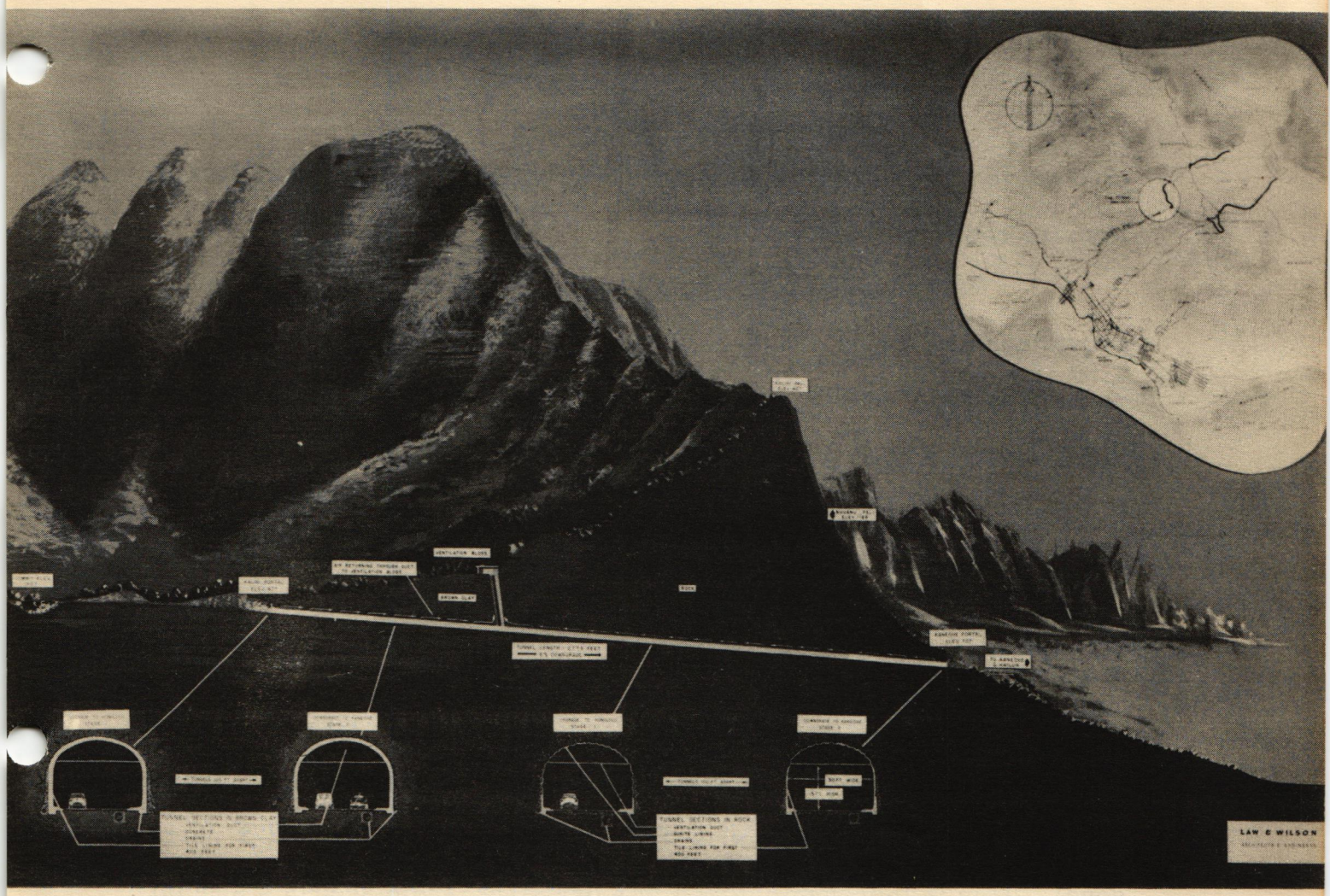
type found on all the Islands of Hawaii.

Experience has proved that in volcanic rock it is quite common to encounter voids, or lava tubes, or sand pockets that were created during the formation of the Islands. (This condition is indicated by the cavity encountered in Boring No. 4, of Plate No. 5.) The voids may be of minor size and insignificant and again they may be enormous and require sealing off by the use of special reinforced concrete bulkheads and/or other backfilling material. These problems are field decisions, and the necessity and methods used for sealing will be determined if and when the voids are found.

3. Tunnel Lining.

In a vehicular tunnel conveying heavy traffic it is necessary to provide a suitable lining for heavy ground conditions, to prevent rock falls due to the slaking of rock, to control leakage of water, and to meet the requirements for lighting and ventilating.

The tunnel lining, including vertical side walls and top segmental arch, will be of reinforced concrete; or gunite applied directly against the rock of the arch, and furred guniting on the side walls. Approximately four hundred lineal feet of tunnel at each portal will have supplementary white glazed tile facing on the side walls, which, coupled with the tunnel entrance lighting, will provide surfaces of proper brightness to relieve the daytime contrast condition. This will



PHOTOGRAPH "B"

PHOTOGRAPH OF SECTIONAL MODEL SHOWING THE MOUNTAIN CUT LONGITUDINALLY AND THE FOUR CROSS SECTIONS INDICATING THE VARIOUS TYPES OF TUNNEL LININGS, VENTILATION SYSTEM, GRADES AND RELATIVE ELEVATIONS, WITH THE REGIONAL MAP SUPERIMPOSED ON THE UPPER RIGHT HAND CORNER OF THE MODEL.

also serve to simplify the maintenance problems, as the glazed facing is more easily cleaned.

Where gunite is applied directly against the rock of the arch, provisions are made for low pressure "grouting" to consolidate all rock formations on the outer side of the lining and provide an impervious umbrella of rock and grout to direct all water away from the wall to the drainage system.

For the information of persons not familiar with the processes of guniting and grouting, the following descriptions of the two processes are given.

"Gunite", as used herein, is the trade name given to a mixture of sand and cement of the proportions specified for different types of work. (The average mix is 1 part Portland cement and 3 parts sand). This is thoroughly mixed in a dry state, and placed in a special machine that transports the material through hose by pneumatic pressure to a nozzle where water is added at the instant the mixture is propelled at high velocity against the surface to be covered.

"Gunite" is particularly adaptable for various types of construction work such as protection of steel from fire and corrosion: lining tunnels, mines, reservoirs and canals; and restoring masonry or concrete structures. "Gunite" machines were first introduced in this country in 1910, and through promotion and used in the last 40 years the process has gained popularity and recognition as being eco-

nomical and practical for many types of construction.

Experiments and actual use show that the adhesion between "Gunite" and the surface against which it is applied is stronger than the material of that surface. Other tests show that the compression value of "Gunite" is from 5000 lbs. to 10,000 lbs. per square inch after 30 days, depending upon the character of sand and the mixture used. The density of "Gunite" is due to the method of application, and particularly significant are tests made by the University of California, as reported in Transactions A. S. C. E. 1917 Issue, Page 906:

"Several Plaster slabs, 5/8 inch to 1 1/2 inch thick made at Gem Lake, were tested at from 700 to 1600 ft. for several hours, with no water coming through the slab. One 1-inch slab held a head of 1610 ft. for 2 1/2 hours without showing moisture; then the pressure was raised gradually to 3400 ft., and the specimen broke in bending, having leaked a little before breaking."

Other tests have shown that the modulus of elasticity of "Gunite" approximates 4,670,000 lbs. per sq. inch, and the expansion is almost identical with that of low carbon steel.

The properties of "Gunite" are largely due to two factors: (a) Placement under pressure against a surface, and not in forms which results in the natural rejection of excess materials: (b) The water content is reduced to a point only necessary to ensure proper hydration of the cement.

World War II found lots of guniting being done in Hawaii and provided experience and training for many local craftsmen. Various local contracting firms do guniting; however, there are firms that make guniting a speciality and have modern machines and trained workmen.

"Grouting" in tunnel construction is a process of placing grout under pressure through the medium of a pump into undisturbed ground formations. The grout itself is a mixture of Portland cement and water, and under certain conditions sand is added to the mix. The proportions of the mix are dependent upon the use for which it is intended and the size of seams or cracks which are to be plugged. The grout under pressure finds its way through voids and cracks in the ground. When allowed to "set", it solidifies and consolidates all sand pockets, rock strata, seams, etc., into a solid mass. Very likely in this tunnel the desired results can be obtained by using a mix with a consistency like that of honey, under a maximum pressure of 25 - 30 pounds.

Four typical tunnel linings are proposed for the Kalihi Tunnel, each meeting a certain situation within the tunnel and each incorporating the requirements for ventilation. These are indicated on Plate No. 4 - The Tunnel Sections and further described as follows:

Section A - indicates a reinforced concrete lining for heavy ground conditions and with walls finished with glazed structural facing units to meet the requirements for entrance lighting.

Approximately 400 lineal feet are required inward from the Kalihi portal.

Section B - indicates a reinforced concrete lining for heavy ground conditions, with the exposed surfaces finished to meet the requirements for interior lighting. Approximately 400 lineal feet required from the ending of Section A.

Section C - indicates a gunited lining to seal exposed rock, with the finish of the exposed surfaces meeting the requirements for interior lighting.

Approximately 1573 lineal feet required from the ending of Section B to Section D.

Section D - indicates a gunited lining for the arch to seal exposed rock and with furred gunite walls finished with glazed structural facing units to meet the requirements for entrance lighting. Approximately 400 lineal feet required inward from the Kaneohe portal.

4. Tunnel drainage.

Though the rainfall in the vicinity of the tunnel is large, it is not envisioned that a large volume of water will be found in its construction. There is little doubt that water will be encountered

and will flow continually. The amount of this flow will vary with the rainfall but it is not estimated to exceed an amount that will be easily carried away by the suggested drainage system of the tunnel or will be of sufficiently constant flow and quantity to be of use in the City and County Suburban Water Supply system. It is also anticipated after construction that the grouting of the arch of the tunnel will act as an umbrella thereby forcing a portion of water outside of the tunnel drainage system. However, should any portion of such water seep down along the wall sections, French drains of a coarse dry material placed behind the vertical walls is to be provided for the entire length of the tunnel. At the bottom of the French drains the seepage water will be collected by open joint drain tile. The open joints of this tile will permit the water to flow into the natural channels on down to its normal subterranean level or will be intercepted at intervals and connected to the tunnel drainage system.

Measures will be taken in detailing the tunnel lining construction to provide water-stops at construction joints to insure a water-tight tunnel structure.

During the construction, perched water may be encountered which will initially give considerable flow but as this water is drained from the pocket the flow will diminish. This action is anticipated inasmuch as the high elevation of the tunnel allows only a small infiltra-

tion basin and it has been surmised that the tunnel would pass through few dyke complexes.

On the undisturbed rock at the bottom of the roadway section of the tunnel a 9-inch layer of crushed rock will be placed for subgrade drainage. Appropriate drain pipes will be placed below the 9-inch layer of crushed rock drainage fill and connected to the drainage system.

Continuous gutters will run along each roadway curb and empty into catch basins as required, and the overflow pipes from the catch basins will be tied to the principal drain system. The primary function of the gutters and catch basins will be to carry off water used by servicing crews in washing down the tunnel. The construction adjacent to the upper portal is designed to keep almost all exterior surface water from draining into the tunnel.

5. Provision for utilities.

Ample provisions will be provided for any utility company requiring right of way through the tunnel. It is believed that the only utility requiring right of way other than the U.S. Army Signal Corps will be the Mutual Telephone Company. The tunnel itself will require electrical distribution systems which will be described later.

After all demands are summarized, sufficient and suitable sized ducts will be incorporated into final construction drawings.

6. Tunnel paving.

Concrete paving will be provided over a 9-inch crushed rock subgrade drainage.

Curbs will be white concrete with light reflectors cast in place.

The traffic lanes will be separated by a corrugated white concrete line marker poured between, and flush with, adjacent pavement. Such a marker will give a motorist driving on the marker a triple warning: by sound (a high-pitched whine from the tires), and by feel (a slight vibration in the steering wheel) as well as by sight.

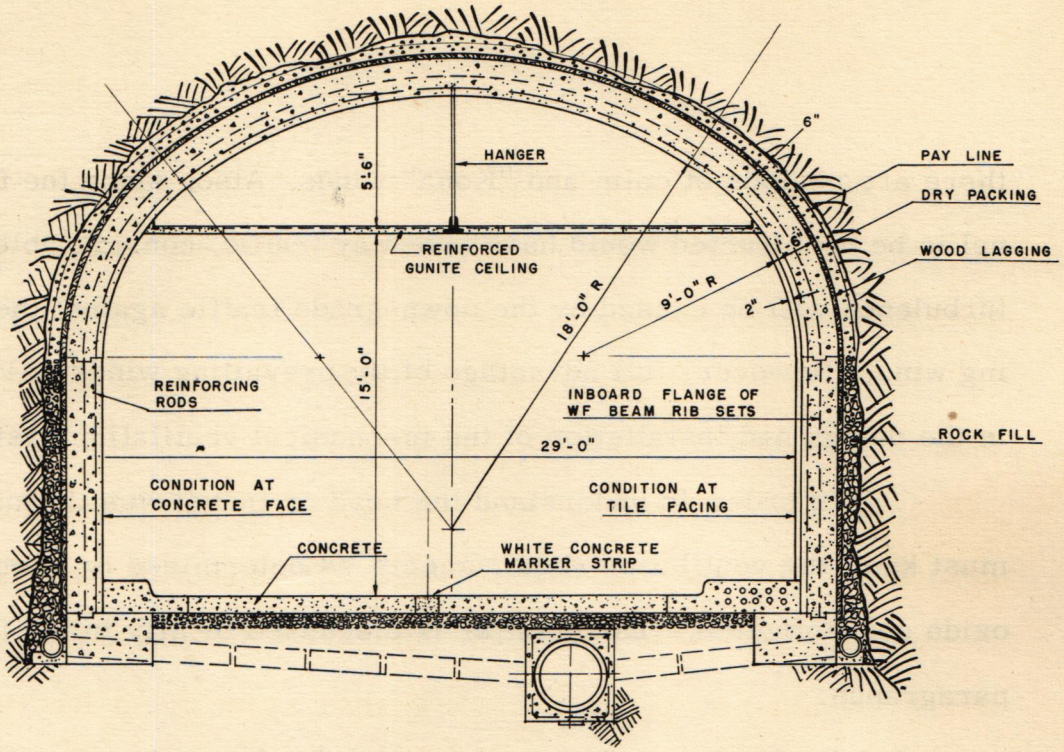
The features described above are shown in more detail on Plate No. 6 - Sections.

III. Recommend ventilation system for the Kalihi Tunnel.

A. Importance of ventilation.

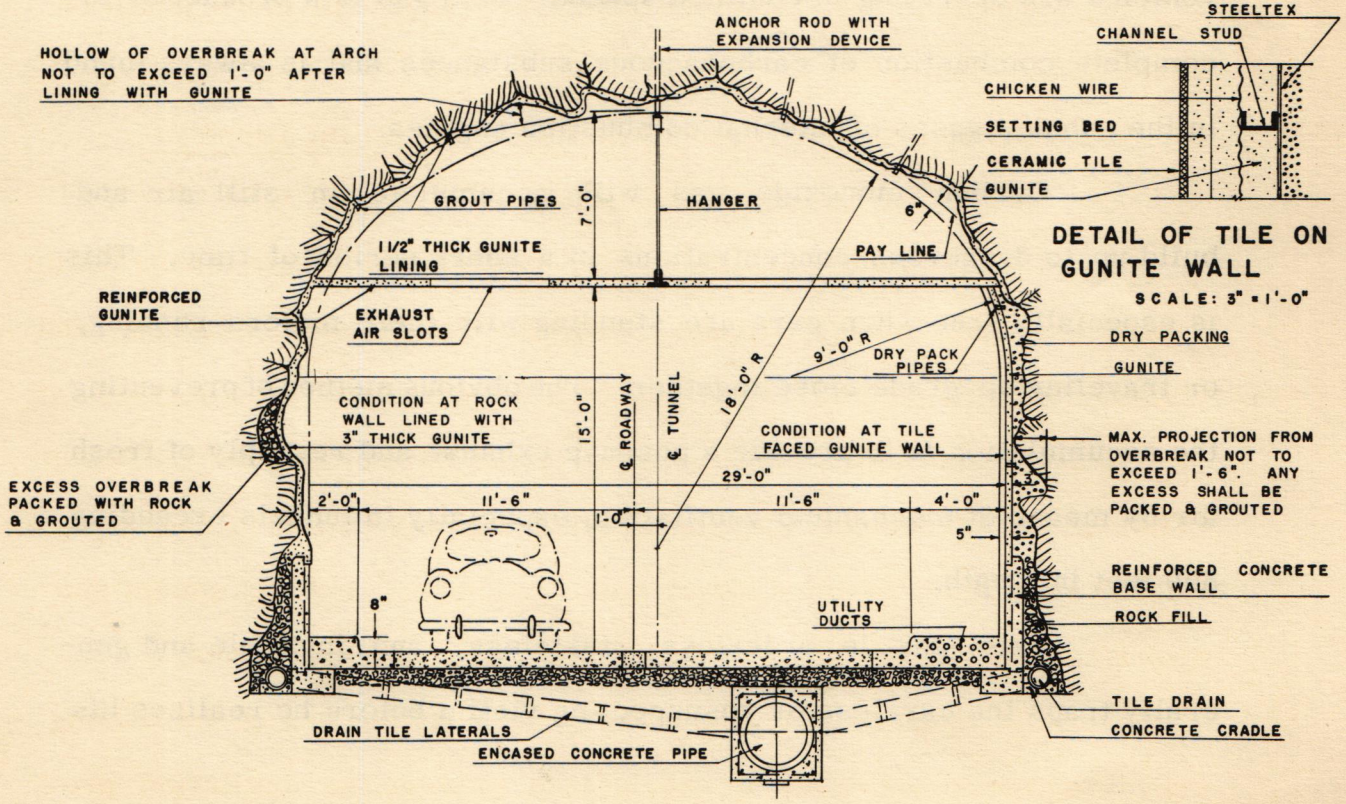
The determination of the necessary ventilation for the Kalihi Tunnel has taken much study and research. The recommendations and comments contained in this section of the report have been arrived at after discussions with Tunnel experts in the Bureau of Public Roads Office in San Francisco, California State Highway Office in Sacramento, Engineering Dept. of the City of San Francisco, and equipment suppliers, as well as the study of numerous technical publications.

Much thought was given to the possible use of the strong prevailing northeast winds in the Islands to solve the ventilation problem. It is inadvisable to place reliance on the trade winds since



CROSS SECTION THRU BROWN CLAY

SCALE: 1/4" = 1'-0"



CROSS SECTION THRU ROCK

SCALE: 1/4" = 1'-0"

PLATE 6

S E C T I O N S

KALIHI TUNNEL REPORT

CITY & COUNTY OF HONOLULU
BUREAU OF PLANS
AND
LAW & WILSON
ARCHITECTS & ENGINEERS

there are periods of calm and "Kona" winds. Also, since the first tunnel to be constructed would have two-way traffic, considerable loss and turbulence will be caused by the down-grade traffic against the prevailing wind. However, full advantage of the prevailing winds will be taken in the design and installation of the mechanical ventilation system.

In order to understand the need of tunnel ventilation, one must know the ventilation requirements as determined by carbon monoxide concentration. This matter is discussed briefly in the following paragraphs.

Carbon monoxide gas is one of the hazards existing where vehicles are operating in confined spaces. This gas is a product of incomplete combustion of carbonaceous substances and is always found in the exhaust gases of internal combustion engines.

Carbon monoxide gas will accumulate in still air and build up to dangerous concentrations in a short period of time. This is especially true when cars are standing with their motors running, or traveling up-grade close together. The obvious method of preventing the accumulation is to provide a positive exhaust and resupply of fresh air by means of mechanical ventilation, especially in tunnels exceeding 800 feet in length.

This gas is orderless, tasteless, and invisible and generally traps the careless or unsuspecting victim before he realizes his

danger. A resistance cannot be built up by the body against this gas, since repeated exposures produce the same results each time. The hemoglobin of the blood attracts carbon monoxide about 300 times as strongly as it does oxygen, which results in certain ill effects according to the proportion of saturation of the carbon monoxide. A blood saturation of 20% usually results in headaches, 40% in unconsciousness, and 60% in death.

The fuel used by passenger cars will generate dangerous concentrations of carbon monoxide gas unless it is correctly mixed with the proper amount of oxygen in the carburetor and completely burned in the combustion chamber of the engine. If most vehicles could be adjusted to a carburetor mixture ratio of about one part gasoline to 16 parts of oxygen and if properly vaporized, they would leave little carbon monoxide in the exhaust fumes. Many cars are operated on a rich mixture in order to get rapid acceleration with power. This mixture may be in the vicinity of one part gasoline to 12 parts of oxygen which results in an incomplete combustion of around 30% and produces carbon monoxide concentrations of 6 to 8% with an average exhaust of 98 cubic feet per hour. Badly worn vehicles may produce concentrations of 14% or more.

A certain percentage of the traffic through a tunnel is bound to be diesel-powered trucks. The U. S. Bureau of Mines has made extensive investigations of the effect of diesel engines operated in

tunnels. The toxic gases in the diesel exhaust are nitrogen oxide, carbon monoxide, carbon dioxide, and sulfur dioxide - an extremely dangerous combination under certain circumstances. In general, the ventilation provided to take care of the passenger cars will take care of the smaller percentage of diesel truck traffic. However, the mistake of ignoring the potentially deadly effect of diesel exhaust should not be made.

B. Carbon Monoxide Recording Instruments.

It is desirable to maintain the carbon monoxide concentrations below 3 parts in 10,000 parts of air. A concentration of from 2 to 2 1/2 parts in 10,000 can be maintained with a 1 1/2 minute air change in the tunnel, for an estimated 1000 to 1200 vehicles per hour. 4 parts in 10,000 is considered the maximum safe concentration for short periods. At this concentration, a 15 to 30 minute exposure will not adversely affect most people. Some people can stand this concentration up to 1 hour without any ill effects.

There have been many studies to determine the amount of air required to be circulated to take care of the carbon monoxide. By the volume method an air change every 1 1/2 minutes has been found to be satisfactory. By the linear foot method for one way traffic the following are representative figures:

	Cubic feet per Minute per Linear Ft. of Tunnel
Up-grade	275
Down-grade	150
Level	225

It can be seen that with one way traffic a down grade tunnel requires only 55% to 65% of the capacity of the ventilation required on an up-grade tunnel. With two way traffic the piston effect of the cars proceeding in one direction is broken up and the ventilation requirements are usually greater.

The concentration of carbon monoxide gas existing in the tunnel is determined by chemical analysers that are connected to representative locations in the tunnel by one inch pipe. Continuous samples of air are drawn through the pipes at the rate of some 2 cubic feet per minute by the use of rotary air pumps. The sample air is passed through a cleaning process consisting of charcoal, activated alumina, soda-lime, calcium chloride and a hydrostatic flow meter where it is cleansed of dust, dirt, moisture or other foreign impurities and accurately regulated to a constant predetermined value. The sample then passes through a hopcalite cell consisting of thermocouples, half of which are imbedded in hopcalite and the other half in pumice. The hopcalite reacts with any carbon monoxide present in the sample by catalytic oxidation, the resultant heat being proportional to the concentration of gas. This heat in turn generates an electronic flow of current in the thermocouples, the intensity of which is proportional to the degree of chemical heat. The electric current thus generated is conducted through a balanced bridge galvanometer where its intensity is is graphically recorded on a chart calibrated to read in tenths of a part

from zero to 5 parts of carbon monoxide gas contained in 10,000 parts of air.

The hopcalite cell requires repacking every year. At this time the instrument must be re-calibrated. The calibrater uses bottled carbon monoxide gas and the re-calibration is very simple.

The recording instruments can be connected to the fans by a series of electrical relay controls that automatically start, stop and control air delivery in proportion to the carbon monoxide gas concentration on a prearranged schedule of fan operation. When the concentration reaches 4 parts in 10,000 a contact operates traffic signals to prevent traffic entering the tunnel until the ventilation system has reduced the concentration to a predetermined concentration.

C. General Types of Tunnel Ventilation (See Plate 7).

1. Unventilated tunnels.

These tunnels are in most cases some 800 feet long as a maximum. The time an automobile is in the tunnel is considered short enough to cause little hazard under normal conditions. The turbulence caused by the traffic is considered sufficient to exhaust the fumes overhead and out through the portals.

2. Tunnels supplied with fresh air by longitudinal distribution with supply at one end only. (See Fig. 1)

This method of ventilation is used extensively in railroad tunnels and is applicable to vehicular tunnels up to 1500 to 1800

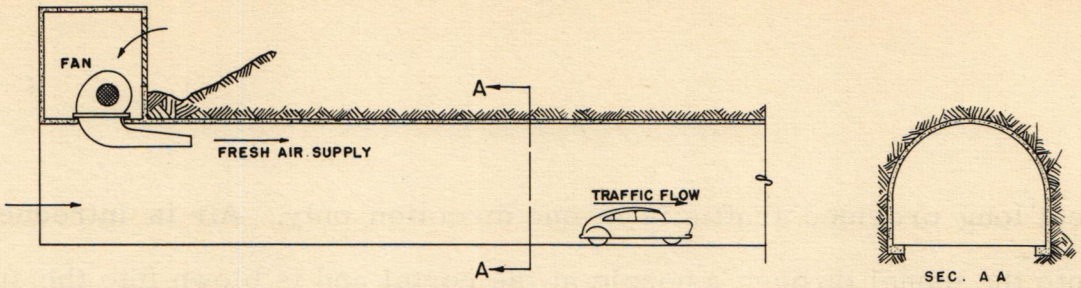


FIG. 1
LONGITUDINAL DISTRIBUTION WITH FRESH AIR SUPPLIED FROM ONE END ONLY.

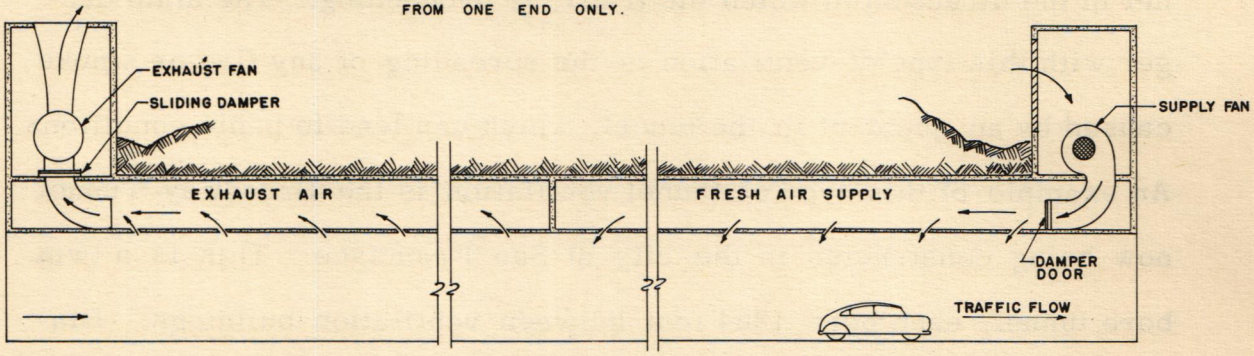


FIG. 2
TRANSVERSE - LONGITUDINAL TUNNEL VENTILATION.

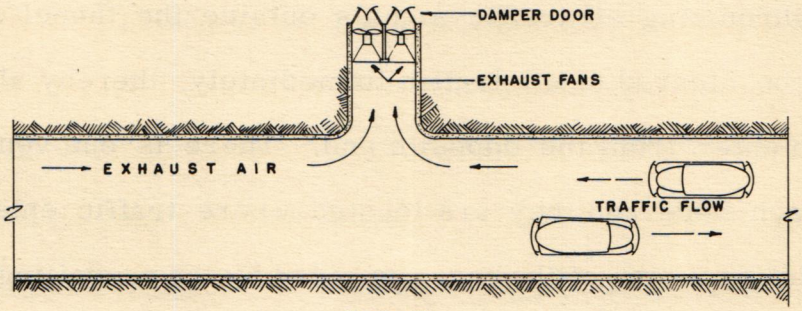


FIG. 3
LONGITUDINAL VENTILATION OF TUNNELS WITH CENTER ADIT.

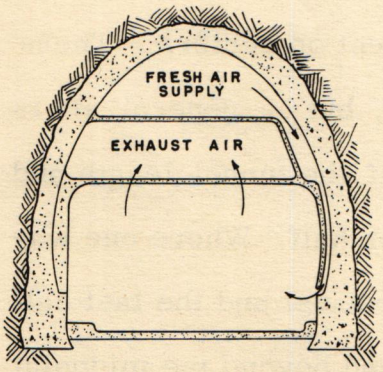


FIG. 4
TRANSVERSE VENTILATION OF TUNNELS

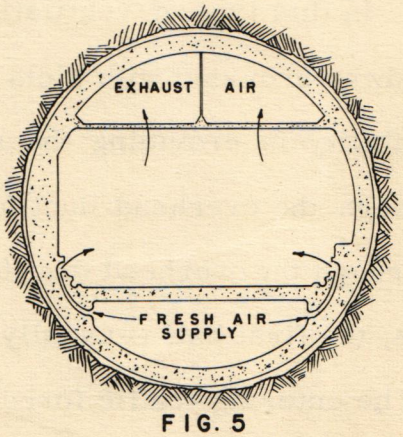


FIG. 5
TRANSVERSE VENTILATION OF TUNNELS

PLATE 7

S E C T I O N S

KALIHI TUNNEL REPORT

CITY & COUNTY OF HONOLULU
BUREAU OF PLANS
AND
LAW & WILSON
ARCHITECTS & ENGINEERS

feet long provided traffic is in one direction only. Air is introduced into the tunnel through a nozzle at the portal and is blown into the tunnel in the direction in which the traffic is proceeding. The main danger with this type of ventilation is the spreading of any fire or smoke caused by an accident in the tunnel, which can lead to panic conditions. An example of this type of tunnel ventilation is the Broadway Tunnel now being constructed in the city of San Francisco. This is a twin bore tunnel, each bore 1364 feet between ventilation buildings. Elaborate safety provisions have been made to clear the tunnel in case of fire by synchronizing all traffic signals outside the tunnel so that the tunnel can be cleared of all traffic immediately, thereby allowing fire engines to enter from the opposite end. There is one ventilation building for each bore and they are located where traffic enters the tunnel. Ventilation in one of the bores is aided by the prevailing wind.

3. Transverse-longitudinal tunnel ventilation. (See Fig. 2)

In this type of ventilation there is one overhead duct above the roadway provided with slots some 15 feet on centers. There is some flexibility in providing the ventilation, but in general air is supplied through the overhead duct for one half the tunnel length and exhausted through the overhead duct for the other half. Where one way traffic exists, the first half is usually made to exhaust and the last half to supply. The entering traffic forces air in, and beyond the midpoint

fresh air is supplied for the autos to force out of the other end.

There is some danger of spreading fire and smoke with this system. The supply fans should be arranged to change to exhaust in case of fire. This requires the necessary dampers and by-passes, along with an attendant at all times. A variation of this operation is to exhaust continually from the overhead duct and supply by air entering the portals.

This type of ventilation is quite satisfactory in tunnels about 2000 feet long. This is the general type of ventilation used in the Pennsylvania Turnpike tunnels. For two way traffic it is probably more satisfactory to exhaust continuously from the overhead duct.

Another variation of this type of ventilation is that used in the Washburn Tunnel under the Houston Ship Channel. In this tube fresh air is supplied from a duct located beneath the roadway and the fumes are exhausted through the portals. This is more dangerous in case of fire than in the other method.

4. Longitudinal ventilation of tunnels. (See Fig. 3)

In this type of tunnel ventilation there are no ducts, the tunnel section itself being used to transmit the air. Most of the air travel occurs in the arched space above the vehicles. There are many applications of this type of ventilation. The ideal situation is where

there can be an adit or shaft at the tunnel midpoint to house the fans. In this manner tunnels of some 4000 to 5000 feet can be adequately ventilated. The fans are usually reversible to provide either supply or exhaust. This type of ventilation usually calls for fans operating at low pressure, and a straight vane type fan can be used. Fresh air enters the portals and is exhausted through the central adit or shaft. Fans can also be used to supply and assist the prevailing natural draft when feasible.

An example of this type of ventilation is that used in the Wawona Tunnel at Yosemite Valley in California. This type of ventilation is suitable only for relatively light or seasonal traffic. It is dangerous in case of fire in the tunnel inasmuch as the draft will spread the fire and smoke. There are some theories that the fire and smoke will travel in the overhead section only, but panic conditions would result in any case.

5. Transverse ventilation of tunnels. (See Figs. 4 & 5)

This is the most desirable and safest type of ventilation for vehicular tunnels. In this system there are two ducts, one for supply of fresh air and one for exhaust of the vitiated air. This is the type of ventilation used in the Holland Tunnel at New York and in most underwater tubes. Air is usually supplied under the roadway and diffused through slots slightly above the road surface. Exhaust slots are located some 15 feet on centers on the ceiling and the exhaust duct is

above the roadway. This method is also used with a horseshoe tunnel section by dividing the overhead into two ducts with fresh air supplied in the duct at the crown and the exhaust duct being immediately below it but above the roadway. The Broadway Tunnel at Oakland California is ventilated in this manner.

This type of ventilation is considered the safest because any fire or smoke is localized and will not spread through the tunnel. This was demonstrated when a major fire occurred in the Holland Tunnel and there was no loss of life. The flames and products of combustion were drawn into the exhaust duct and out of the tunnel section. The intense heat damaged the exhaust fans somewhat, but they did not fail. With any other type of ventilation there would probably have been spreading of the fire and extreme panic conditions.

D. Recommended ventilation for the Kalihi Tunnel.

After due consideration of the funds available for construction of the tunnel, it is recommended that a straight exhaust system of ventilation should be provided. Although this is not the ultimate in tunnel ventilation, it will provide adequate protection.

The recommended system (See Plate 8) would consist, in general, of a centralized fan installation in a ventilation and control building located above the tunnel and connected to the tunnel duct by a shaft. The shaft would intersect the tunnel duct at the one-third point measured from the Kalihi portal. This will divide the tunnel ventila-

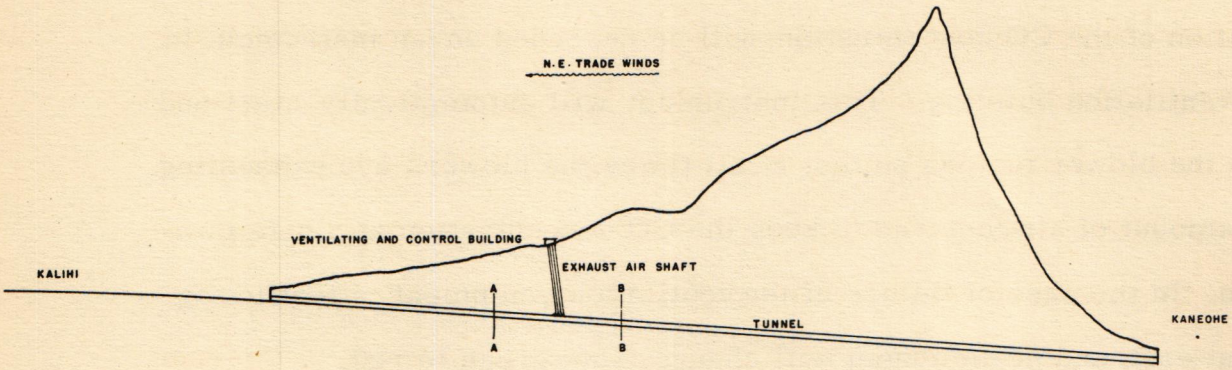
tion into two sections. The longest section, about 1851 feet, will face the Kaneohe portal and the prevailing trade winds. Utilizing the trade winds will naturally require less power for operation at peak loads. The shorter section will be about 922 feet long. Air would be admitted through both portals and exhausted through the ceiling by use of exhaust openings spaced some 16 feet on centers over each roadway.

The reasons for placing the ventilation house at the spot indicated in the diagram are two-fold: (1) Advantage may be taken of the natural inrush of the prevailing winds from the Kaneohe side along an up-grade tunnel, (2) construction at the portals would be far more costly - at the Kaneohe portal the terrain is exceedingly precipitous, and at the Kalihi portal there are serious drainage problems.

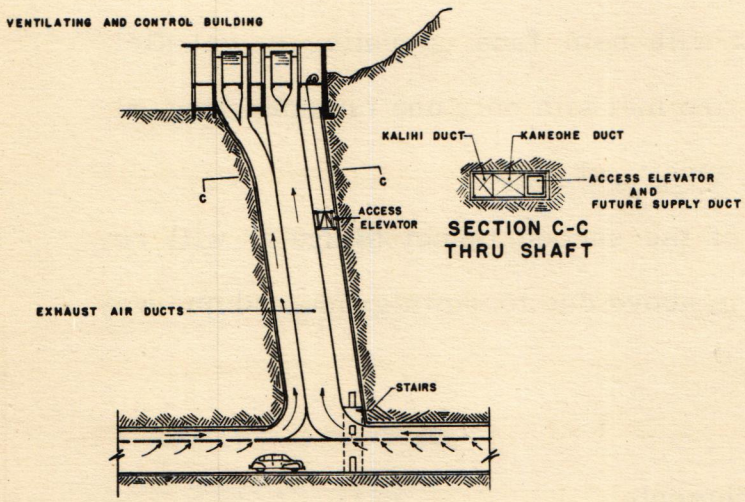
It is proposed to install two identical fans for each exhaust air duct, or four fans in all. (See Plate 9). Both fans would operate at once (in parallel) during normal operations. Three speeds would be provided. Maximum power would be needed only during peak traffic loads. In the event that any one fan was down for repairs, the remaining fans could supply about 64% of the total requirements and could keep the tunnel ventilation system operating.

The effect of operating on one fan only would be to actuate the "Stop" light at the tunnel entry occasionally until the fan could catch up with the load.

The amount of ventilation to be provided at any given time

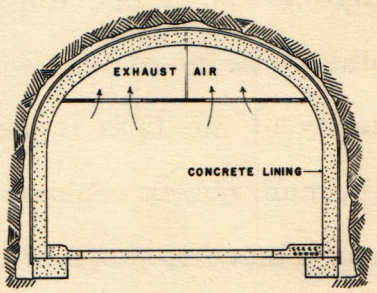


LONGITUDINAL SECTION THRU TUNNEL



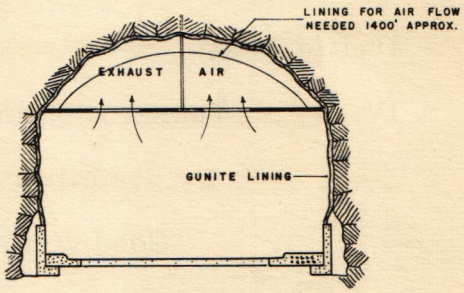
SECTION C-C THRU SHAFT

VERTICAL SECTION OF EXHAUST AIR SHAFT



SECTION A-A

KALIHI PORTION



SECTION B-B

KANEOHE PORTION

PLATE 8

VENTILATION SYSTEM

KALIHI TUNNEL REPORT

CITY & COUNTY OF HONOLULU
BUREAU OF PLANS
AND
LAW & WILSON
ARCHITECTS & ENGINEERS

is determined by the carbon monoxide concentration. A continuous indication of the CO concentration will be recorded on an instrument in the ventilation building. This instrument will automatically start and stop the blower motors so that at all times the blowers are exhausting the amount of air required to keep the CO concentration at a safe minmum. In the case of failure of the ventilation equipment, a traffic signal at each end of the tunnel will change from green to red.

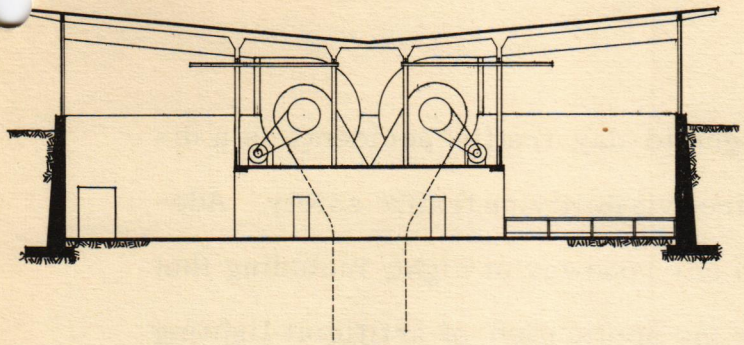
The fans can be operated singly or in parallel with approximately the same HP requirements at the given speeds. When only one fan is operating, the output in CFM will be about 64% of the total capacity of the two fans operating in parallel. Maximum efficiency of the fans is realized with both fans operating in parallel. Minimum power requirements are met with only one fan operating, although there is a sacrifice in capacity of air.

The ventilation of the second tunnel (Stage 2) will require considerably less than the above due to down grade and one way traffic flow.

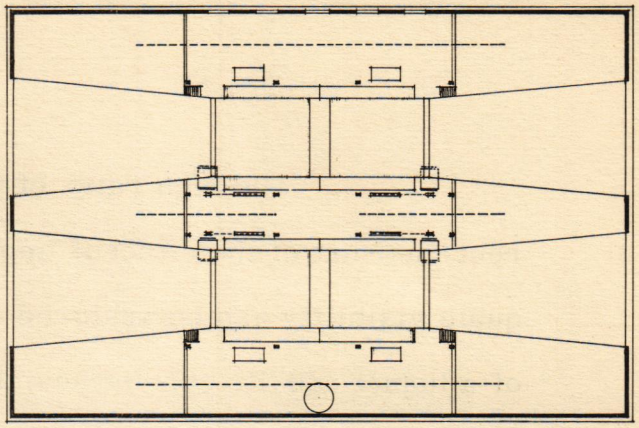
IV. Tunnel Lighting.

A. Visibility requirements.

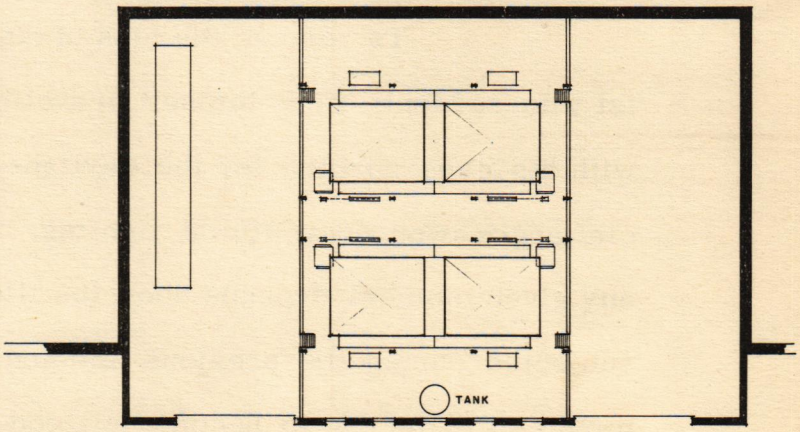
Good visibility is essential to the safe and expeditious movement of traffic. All the attributes of good visibility are present on a daylighted roadway as long as a substantial portion of the sky remains unobstructed and the sun or its direct reflection is not within 10° of the line of sight.



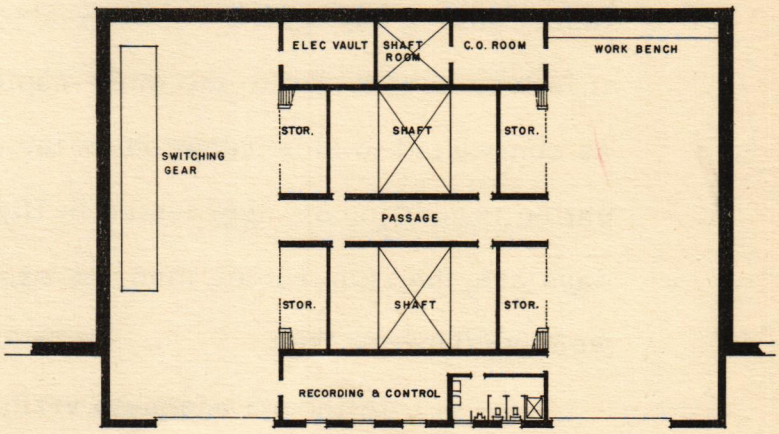
LONGITUDINAL SECTION



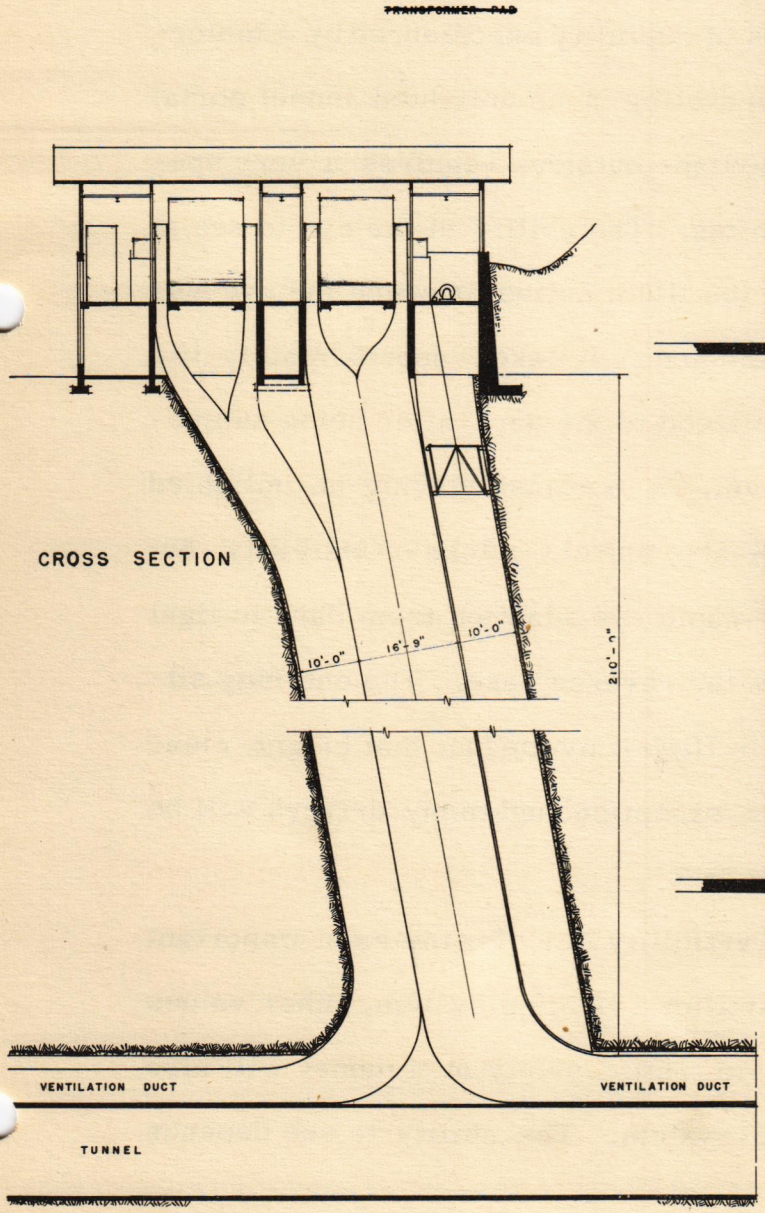
UPPER PART OF MEZZANINE



MEZZANINE FLOOR



GROUND FLOOR



CROSS SECTION

SCALE IN FEET

15 0 15 30 45

PLATE 9

VENTILATION & CONTROL BLDG.

KALIHI TUNNEL REPORT

CITY & COUNTY OF HONOLULU

BUREAU OF PLANS

AND

LAW & WILSON

ARCHITECTS & ENGINEERS

The high ratio of night-to-day traffic accidents is a direct measure of the effect of impaired visibility on traffic safety. Adequate visibility can be restored on any roadway at night, including that of a tunnel and its approaches, by the application of artificial lighting in accordance with the simple and economical recommendations of the American Standard Practice for Street and Highway Lighting.

To restore the loss of visibility experienced by a motorist who suddenly finds himself traveling in an unlighted tunnel portal with his eyes adapted for the daylight outside, requires a very special application of artificial lighting. The ability of the eye to see at any given moment depends upon the illumination to which the eye was subjected during the previous moment. It takes approximately two minutes for the eye to become adapted to the dark after being subjected to a medium illumination level. A motorist leaving an unlighted tunnel onto a daylighted roadway also suffers a loss of visibility, but it is less severe due to the more rapid eye adaption from dark to light as contrasted to slow adaption in the reverse case. The entering situation is additionally aggravated in Hawaii by the fact that bright, clear days are the rule rather than the exception and many drivers will be wearing dark glasses.

Although adequate visibility is by far the most important value that must result from an artificial lighting system, other values that will particularly contribute to traffic safety in a tunnel will also result from a properly designed system. The ability to see depends

not only upon light but also upon the psychological and physiological condition of the motorist. Certain aspects of a tunnel react much more adversely on this condition than anything encountered on an open roadway.

In the narrow confines of a tunnel, a motorist must be continually assured of his relative position from the wall on one side and passing vehicles on the other. The center strip of the roadway becomes less dependable as a guide in the confusion of many moving vehicles, thus it is of least help at the time when roadway delineation is needed most. The proper selection of luminaires (artificial light sources) and careful positioning of them with respect to traffic lanes will provide a highly effective means of orientation for vehicles under any condition of traffic throughout the length of the tunnel.

A tunnel by its very nature has a forbidding appearance and an atmosphere which can easily induce panic in the event of the slightest untoward circumstance inside. A properly designed artificial lighting system can actually make the portals appear inviting and carry the motorist through the tunnel in a reassuring, cheerful atmosphere.

The question may arise as to why the use of head-lamps would not obviate the use of fixed tunnel lighting. It is hoped the explanation of the eye-adaption problem has answered this. In a two way unlighted tunnel, headlamps are more of a hazard than a help. In a

two-way, well-lighted tunnel, whether head-lamps are on or off will make little difference. The glare of bright head-lamps will be alleviated in a well-lighted tunnel as it is on the open roadway during the daylight. The beacon effect of tail lights on the car ahead may be reassuring to the motorist following.

B. Approach treatment - daytime.

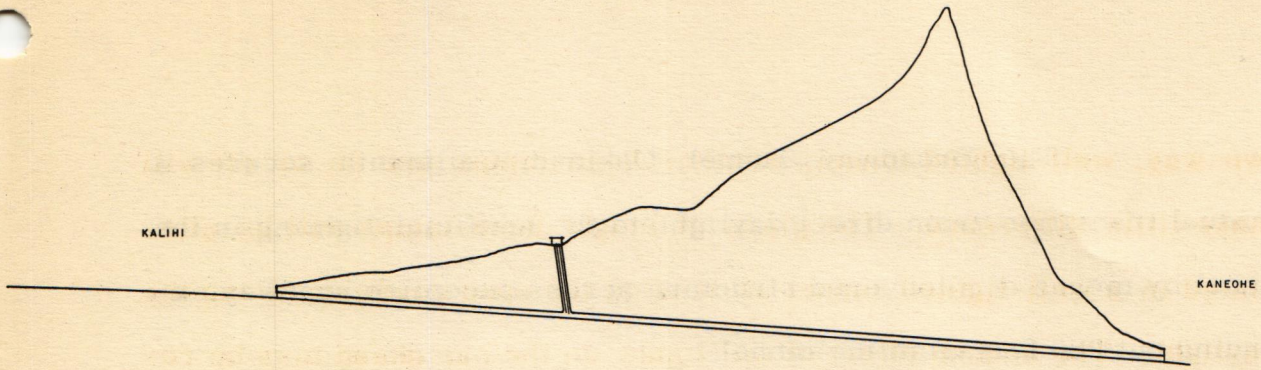
It is on the approach roads immediately outside the tunnel that the problem of light-to-dark eye adaption can be anticipated and reduced in severity. On the open roadway in direct sunlight, the lighting intensity will be 10,000 foot-candles. The motorist will have, in his field of view, surfaces which have an average brightness of 2,000 foot - lamberts. (Foot - lamberts = Foot candles x reflection factor) Any treatment that will reduce this brightness within 500 feet of the tunnel will ease the eye adaption problem at the portal and reduce the artificial lighting requirements in the tunnel entrance.

Regarding all vehicular tunnels, there is a general agreement that:

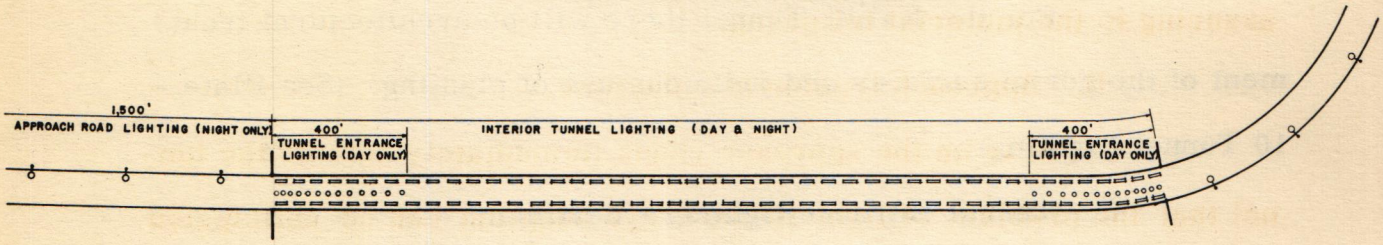
(1) The exterior surface of the portal area should be a dull, low reflecting color.

(2) The approach roadway surface up to the portal should be dark.

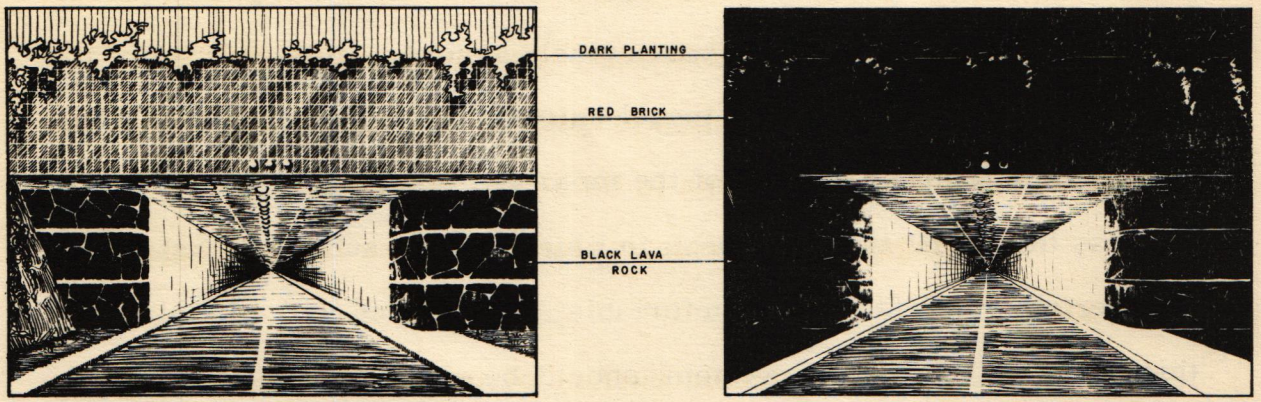
(3) The approach roadway within 500 feet of the tunnel should be shaded from direct sunlight by foliage or some mechanical means.



TUNNEL SECTION (SCHEMATIC)

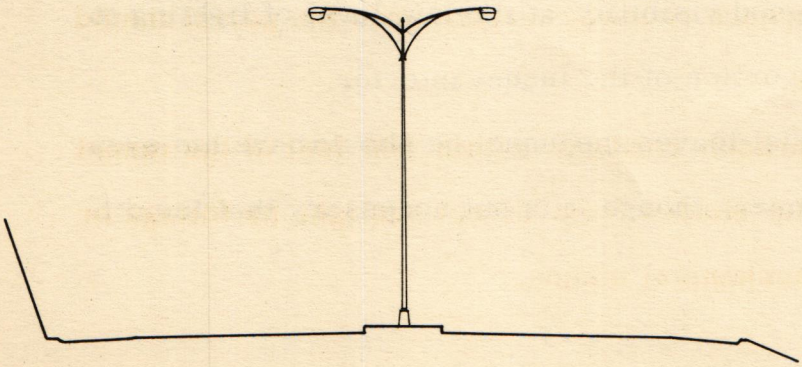


TUNNEL PLAN (SCHEMATIC)



TUNNEL - DAY

TUNNEL - NIGHT



APPROACH ROAD LIGHTING (TYPICAL)

PLATE 10

TUNNEL LIGHTING

KALIHI TUNNEL REPORT

CITY & COUNTY OF HONOLULU
BUREAU OF PLANS
AND
LAW & WILSON
ARCHITECTS & ENGINEERS

The Broadway Tunnel, Oakland, California secures a gradual transition from direct daylight to the artificial lighting in the tunnel by means of a louvered structure across the entire roadway extending out 200 feet from the tunnel.

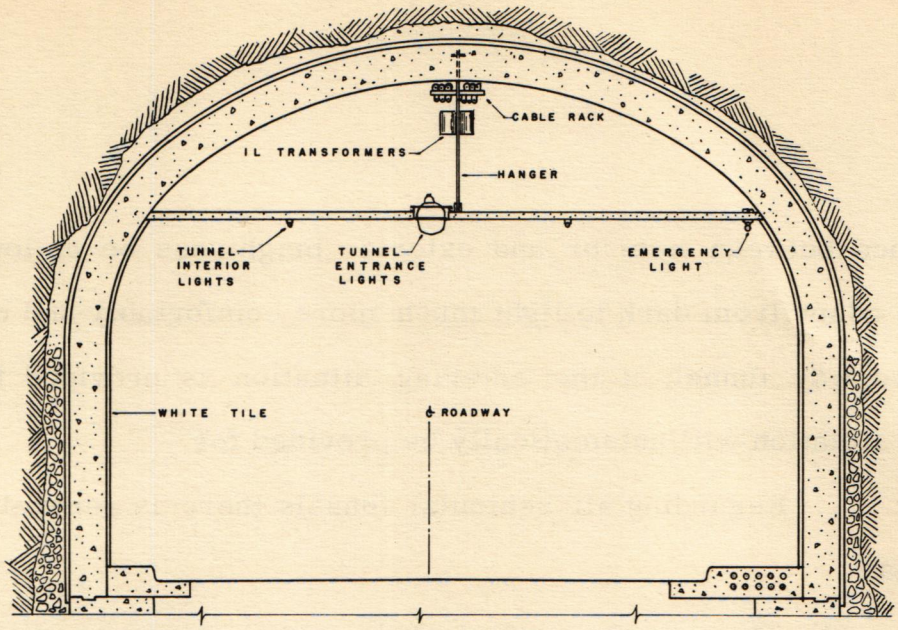
For the Kalihi Tunnel there will be architectural treatment of the portal surfaces and judicious use of planting. (See Plate - 10 Tunnel Lighting)

C. Tunnel entrance lighting - daytime.

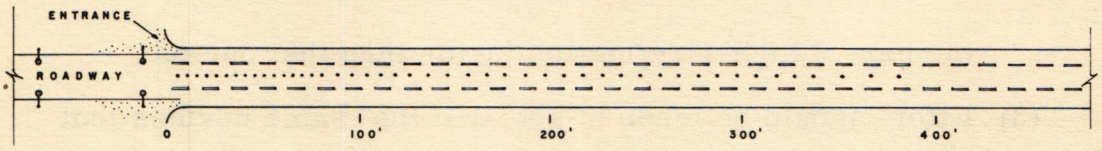
It is in the tunnel entrances that no compromise can be made on the illumination to be provided. Ninety-five percent of all accidents inside poorly lighted tunnels have been within the first 500 feet and are caused by the entering motorist. In two-way tunnels the accident experience has been particularly severe.

The purpose of tunnel entrance lighting should be to provide, within the field of view of the motorist, surfaces of a brightness not less than 1/10 the brightness to which he was subjected just prior to entering. Satisfactory, comfortable eye adaption will take place at this ratio. The lighting system should be designed to provide the motorist with surfaces of continuously lowering brightness until his eye has been adapted for good visibility at the low level of lighting to be provided for the major portion of the tunnel interior.

As the motorist leaves the tunnel he should have his eyes adapted in the reverse manner, though it is not necessary that the dif-



TUNNEL LIGHTING
COMPOSITE CROSS SECTION AT ENTRANCE



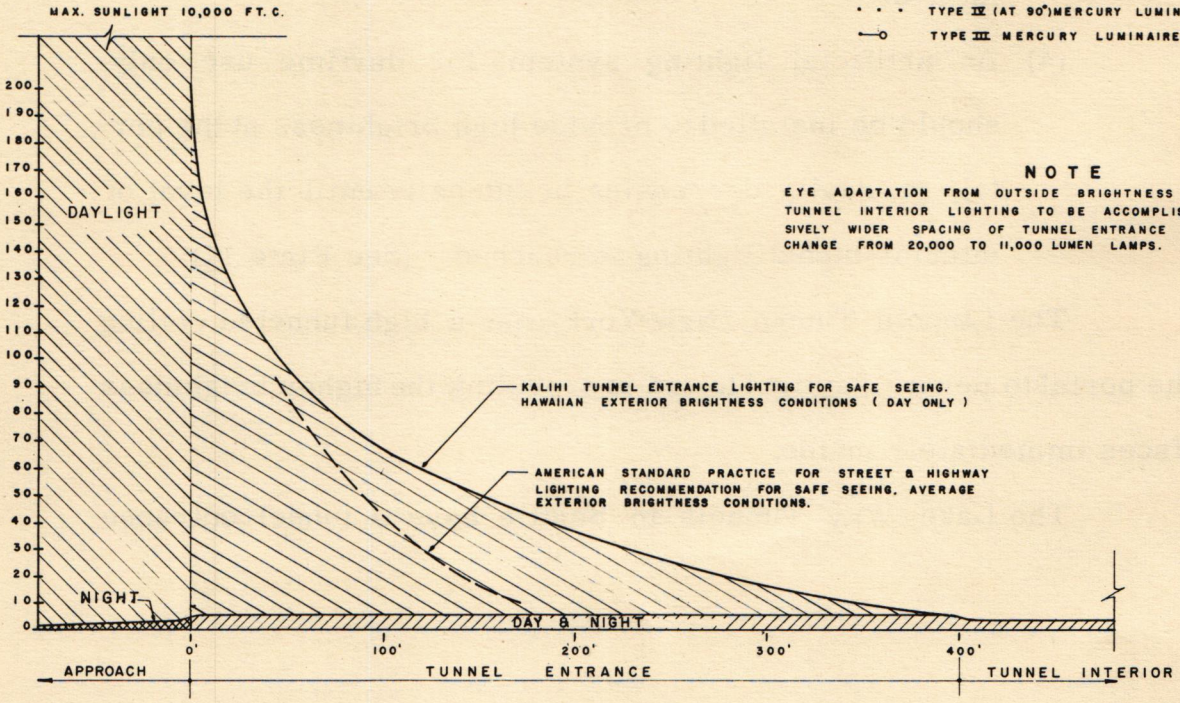
TUNNEL LIGHTING LAYOUT
PLAN VIEW

LEGEND

FLUORESCENT LUMINAIRES (DAY & NIGHT)
TYPE IV (AT 90°) MERCURY LUMINAIRES (DAY ONLY)
TYPE III MERCURY LUMINAIRES ON 30' LAMPOST (NIGHT ONLY)

NOTE

EYE ADAPTATION FROM OUTSIDE BRIGHTNESS CONDITIONS TO TUNNEL INTERIOR LIGHTING TO BE ACCOMPLISHED BY SUCCESSIVELY WIDER SPACING OF TUNNEL ENTRANCE LUMINAIRES AND CHANGE FROM 20,000 TO 11,000 LUMEN LAMPS.



TUNNEL LIGHT INTENSITY

PLATE II
LIGHTING DETAILS
KALIHI TUNNEL REPORT
CITY & COUNTY OF HONOLULU
BUREAU OF PLANS
AND
LAW & WILSON
ARCHITECTS & ENGINEERS

difference between interior and exterior brightness be as low. The eye can adapt from dark to light much more comfortably and quickly. In a two-way tunnel, if the entering situation is provided for, the leaving situation will automatically be provided for.

Regarding all vehicular tunnels there is general agreement that:

(1) The interior surface of the tunnel entrances should be a bright, high reflecting surface.

(2) The roadway surface immediately inside should if possible have a higher reflection factor than that outside.

(3) Effort should be made to see that the same devices that shade the roadway outside will reflect daylight into the interior.

(4) An artificial lighting system, for daytime use only, should be installed to provide high brightness at the portal, gradually decreasing in intensity until the level of interior tunnel lighting is reached. (See Plate 11)

The Lincoln Tunnel, New York, has a high funneled ceiling at the portal to permit daylight to aid in providing the higher brightness surfaces immediately inside.

The Lake Way Tunnels in Seattle have a tunnel entrance

lighting system, consisting of conventional horizontal mercury vapor luminaires, which provides 50 foot candles at the entrance and tapers off to 4.3 foot candles at the interior. Wall surfaces at the entrances are painted white to provide bright surfaces in the field of view.

The Liberty Tunnel, Pittsburgh, Pennsylvania, has a tunnel entrance lighting system consisting of 1500, 1000, and 500 watt incandescent luminaires providing 100 foot candles at the entrance, decreasing to 20 foot candles 150 feet inside and to one foot candle at the interior. White tile has been added to the walls to provide the high brightness surfaces.

The Brooklyn Battery Tunnel in New York has a tunnel lighting system consisting of two continuous rows of slimline lamps. The lamps inside the entrances are operated at a higher current than the others to provide 30 foot candles at the entrances, tapering off for 1800 feet to the lower level inside. The entire tunnel has white tile surfaces.

The basis for the design of the Kalihi Tunnel entrance is to provide satisfactory eye adaption for motorists entering and leaving the tunnel at speeds up to 35 miles per hour. It is assumed that at the time of heaviest traffic, the average brightness of the outside surfaces in the field of view of the entering motorist will be 1000 foot-lamberts, and that of the outside surfaces and sky in the field of view of the leav-

ing motorist will be 2000 foot-lamberts.

The tunnel entrance lighting system will provide interior tunnel surfaces with a brightness of 120 foot lamberts for the entering motorist. This is within the one to 10 contrast ratio with respect to the outside surfaces that will provide satisfactory "light to dark" eye adaption for an entering motorist.

These same interior surfaces will present a brightness of 100 foot-lamberts to the leaving motorist. This one to 20 contrast ratio with respect to the outside surfaces will easily satisfy the more rapid "dark to light" eye adaption of the leaving motorist.

The tunnel entrance lighting equipment will extend 360 feet into the tunnel from each entrance and will be used during the day only. A special high reflecting surface will be maintained on the walls of the tunnel for 400 feet from each entrance.

Tunnel entrance lighting will be provided through the use of luminaires that are standard with the City and County Bureau of Street Lighting. Each will consist of a mercury vapor lamp, burning in a horizontal position, in a reflector-refractor assembly providing a Type IV light distribution. The luminaires will be mounted over the center line of the roadway with the normal street-side of the refractor facing entering traffic and the normal house-side of the refractor facing leaving traffic. In this position each luminaire will direct almost all its light output toward the white tile side walls with the maximum

candlepower projected slightly toward entering traffic. This will produce a higher apparent brightness on the tile for entering than for leaving motorists. The brightness of the luminaire itself will be extremely low as there is very little candlepower output from the street and house sides of the refractor.

At the portal, 20000 lumen lamps will be used on 5' spacing. The spacing will then be widened and finally the lamp size reduced so that the last luminaires, 360 feet inside the tunnel will contain 11000 lumen lamps on 15' spacing.

Each luminaire will be mounted so that only the refractor will extend below the ceiling line, and provision will be made for relamping from below or from the ventilation chamber above.

The isolating transformers and series circuits will be accessible in the ventilation chamber above.

D. Tunnel interior lighting - daytime and night.

Except for the use of tunnel entrance lighting to solve the daytime eye adaption problem, providing adequate visibility on a roadway through a tunnel poses only a slightly different problem than ordinary roadway lighting. A higher illumination level than on an open roadway is recommended to alleviate the oppresive atmosphere of a tunnel.

The Brooklyn Battery Tunnel, New York, and the Washburn Tunnel, Houston, are examples of tunnels using lines of slimline fluoescent lamps for the 24 hour a day interior lighting system. An in-

tensity of 4 to 6 foot candles is compatible with the nightime lighting level of the approach roads.

The basis for the design of the Kalihi Tunnel interior lighting is to provide roadway lighting in accordance with the American Standard Practice of Street and Highway Lighting. A lighting intensity of 4 foot candles will be provided and maintained. Because of the low mounting height, low brightness luminaires will be used to eliminate glare. They will be positioned over the center of each traffic lane to aid the motorist in orienting the position of his car with respect to the wall on one side and the center line on the other. The lighting system will extend from portal to portal and will be used continuously day and night.

The illumination here will be provided through the use of exposed 8' fluorescent slimline lamps mounted on the ceiling in rows. In each row the lamps will be on 16-foot centers, so arranged as to miss the ventilation exhaust openings.

Relamping is an infrequent but easy operation, and it is intended that it be accomplished from below.

E. Approach road lighting - night.

Visibility on the approach roads at night will be provided by the application of standard lighting equipment in accordance with the American Standard Practice of Street and Highway Lighting. It is not felt necessary to discuss the principles of silhouette seeing on an open

roadway in this report. An intensity of 1.2 horizontal foot-candles will be provided 1500 feet from the portal. This will be gradually increased to an intensity of 2.5 horizontal foot-candles just outside the portal.

The illumination for this purpose will be provided through the use of luminaires that are standard with the City and County Bureau of Street Lighting. Each will consist of a 20,000 lumen, mercury vapor lamp, burning in a horizontal position in a reflector-refractor assembly providing a Type III light distribution. The luminaires will be mounted on 30-foot metal lamp posts with a roadway overhang of 6 feet. The isolating transformer will be accessible in the base of the lamp post, and the series circuit may be overhead or underground depending upon the location.

Luminaires will be spaced as required to provide the average light intensity, and will be located as determined by the grade or curve of the roadway. (See Plate 10 - Tunnel Lighting and Plate 11 - Lighting Details)

F. Emergency Lighting.

In case of complete failure of the tunnel interior lighting, an emergency lighting system, battery operated, located over the walkway, will come into operation. This will be provided by exposed 15-watt, 120-volt, inside frosted incandescent lamps, spaced 40 feet apart over the walkway, from portal to portal. This will be a multiple cir-

cuit in conduit.

G. Controls.

The tunnel interior lighting will be operated continuously. The approach road lighting and tunnel entrance lighting will be turned on and off by photo-electric cells with time clocks in parallel to assure a reliable operating schedule.

V. Kalihi approach to the tunnel.

A. Drainage problem and stream relocation.

In view of the mountain streams which drop into the head of Kalihi Valley, especially during the rainy season, it is necessary to give careful consideration to the problem of drainage at the portal. A detailed study has been made by Mr. Sam Hirota, Civil Engineer of the City and County Bureau of Plans, which, it is believed, will meet the problem successfully.

It is planned to divert Kalihi Stream into a lined channel, as indicated in Plate No. 12 - Kalihi Approach Plan.

This channel will gather the run-off and divert it before it reaches the tunnel entrance. After by-passing the entrance, the channel will conduct the run-off to the Valley's regular drainage system. Proper drainage at the tunnel entrance is absolutely necessary in order to prevent any flooding into the down-grade bore of the tunnel.

Stream Diversion is a portion and an integral part of the Kalihi Tunnel - Kalihi Approach Road. It is about 2400 feet long, in-

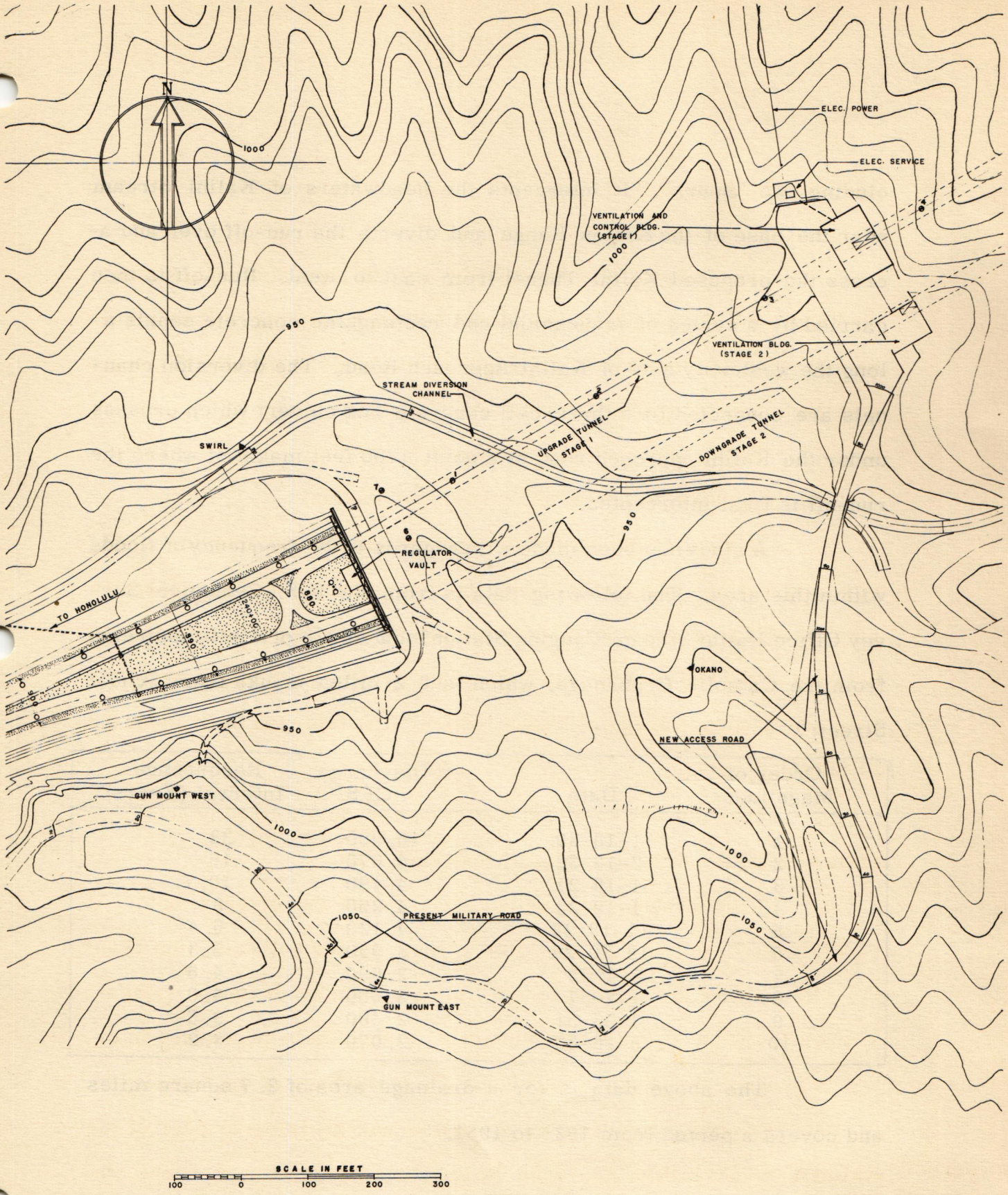


PLATE 12

KALIHI APPROACH PLAN

KALIHI TUNNEL REPORT

CITY & COUNTY OF HONOLULU
BUREAU OF PLANS
AND
LAW & WILSON
ARCHITECTS & ENGINEERS

cluding two "spurs". It intercepts the headwaters of Kalihi Stream near the base of the Koolau Range and diverts the run-off over and across the proposed Kalihi Tunnel from east to west. Run-off is then carried by a series of trapezoidal and rectangular concrete canals along the westernly side of Kalihi Approach Road. The diversion channels are connected to a three-cell concrete box culvert which crosses under the Kalihi approach road at a point 1700 feet makai of where the run-off is first intercepted.

A study has been made with regards to the frequency of floods within this area. The following data is from the U.S. Geological Survey Office Kalihi Stream Gauging Station located 3/8 of a mile upstream from the Catholic Orphanage, which is 2.2 miles mauka from School Street:

Order of Magnitude	Date	Discharge CFS	Recurrence Interval (Years)
1	11-18-30	16,900	32
2	2-13-32	4,670	16
3	1-16-21	4,490	10.7
4	1-19-23	4,250	8
5	11-18-28	4,120	6.4
6	12-30-24	3,930	5.3
7	2-7-35	2,690	4.6
8	1-7-37	2,660	4.0
9	3-26-51	2,400	3.6
10	5-16-50	2,070	3.2

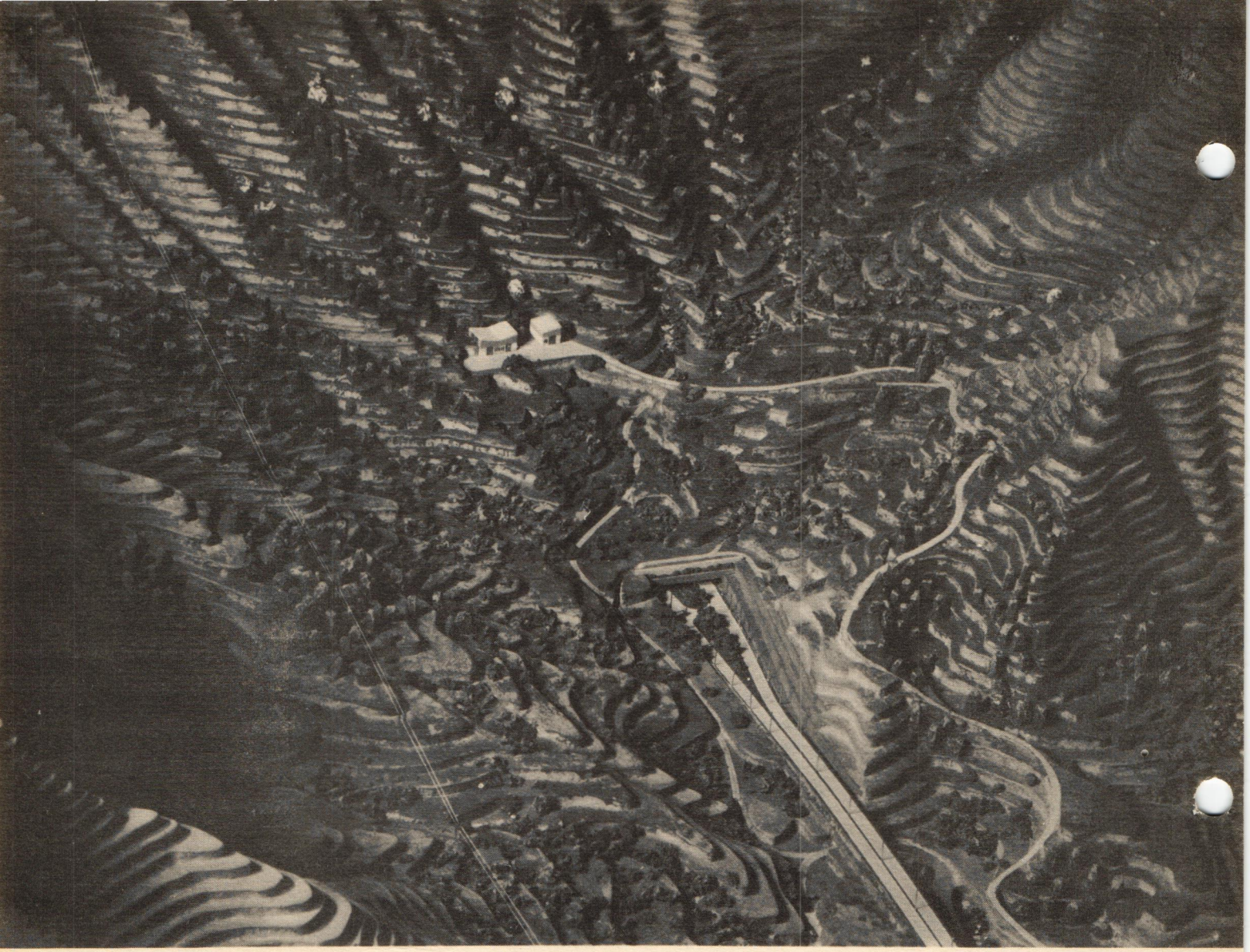
The above data is for a drainage area of 2.7 square miles and covers a period from 1921 to 1951.

The following rainfall data from records of the Board of Water Supply at the Kalihi Reservoir Site Rain Gauge is tabulated below. They are only the high rainfall and are chronologically arranged from 1930 to 1950:

Date	Rainfall Inches per hour
4-11-30	1.7
11-18-30	4.0
2-18-32	1.6
3-3-33	2.0
2-27-35	2.2
9-16-35	1.2
1-1-37	1.3
9-28-37	2.0
2-28-39	2.2
2-6-42	2.6
3-16-47	2.5
1-22-50	3.6
5-16-50	2.6
8-2-50	2.2
12-3-50	5.5

Drainage area east of the Kalihi Tunnel is approximately 150 acres, and run-off from this area will almost entirely collect at the proposed Kalihi Tunnel Portal. There is an area of about 211 acres west and makai of the portal. Run-off from the combined areas totaling 361 acres will then be collected and passed through a three cell concrete box culvert, under the Kalihi Approach Road from west to east.

The "Stream Diversion" is ~~is~~ located in an area where topo-



PHOTOGRAPH "C"

PHOTOGRAPH OF MODEL SHOWING THE KALIHI APPROACH ROAD AND THE KALIHI PORTAL. THE VENTILATION AND CONTROL BUILDINGS ARE SHOWN LOCATED AT THE BASE OF THE STEEP KOOLAU MOUNTAIN RANGE APPROXIMATELY OVER THE ONE-THIRD POINT OF THE TUNNELS. STREAM DIVERSION CHANNEL CAN BE SEEN TO THE LEFT OF THE APPROACH ROADS AND OVER THE TUNNEL PORTAL. THE HAWAIIAN ELECTRIC POWER LINES ARE SHOWN ON THE EXTREME LEFT SIDE OF THE PICTURE.

graphy is rough and crossed by many sharp and narrow ridges. It is just leeward of the Koolau Range where maximum precipitation can be expected.

Invert grade of the channel was laid in a series of flat and steep grades. This was necessitated due to the heavy excavation encountered if it were laid on one continuous grade. To reduce excavation, rectangular sections were designed where grades are steep instead of the trapeziodal sections. Stilling basins will be constructed at the ends of these "chutes" to dissipate high velocity and control flow around bends.

Every precaution has been taken to keep the water from topping the east banks since the invert of the channel is higher than the finished Kalihi Approach Road grade. For a distance of 700 feet, the Kalihi Approach Road is in cut with the grade downhill towards the Kalihi Tunnel. If the east banks of the Stream Diversion should breach there will be danger to life with water and debris rushing thru the Tunnel towards Kaneohe.

For the design of this project, the Rational Formula was used with intensity of rainfall of 12-inches per hour. Originally the channel was designed for a cement rubble masonry structure, but with a concrete lined channel the capacity will be greater. Also in the design computations, an allowance of two feet free-board was made. The channel is mostly in excavation with the top of cut above the top of

channel. There is a small section in fill where there will be a berm 15 feet wide. Excavated material will be wasted along these areas to increase the height of banks and thus increase the factor of safety.

B. Portal.

The portal itself will be constructed of concrete, red brick, and black rock. Red brick and black rock were chosen because of visibility considerations. (See Plate 13 - Kalihi Portal) These materials, at the height where they are used, give a minimum reflection of light.

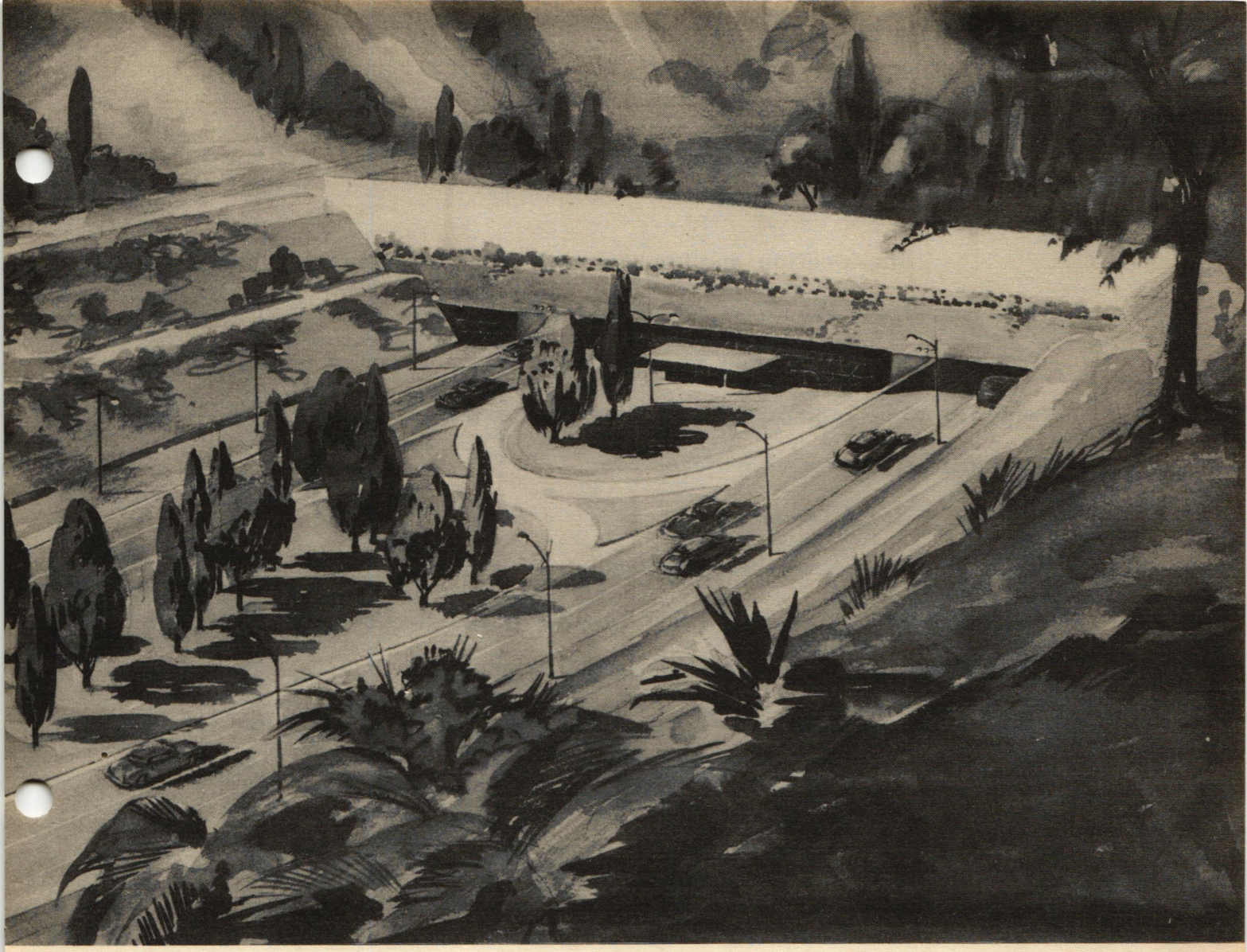
Another factor which assists good visibility is a slight turning of the tunnel at the entrance so that it gives a view of green planting which is soothing to the eyes. This slight turning means that the motorist is not harassed all the way through the tunnel by a bright pinpoint of light which is constantly in his view.

Adequate planting at the portal will also help to give a pleasant lighting effect, as well as preventing erosion of the earth.

Located behind the portal facing and over the tunnel will be the electric vault for the constant current regulators that supply the tunnel entrance and approach road lighting.

C. Ventilation and Control Building.

This installation is a very important feature in the construction of the Kalihi Tunnel. It is depicted on Plate No. 8 - Ventilation System, and Plate No. 9 - Ventilation and Control Building.



PERSPECTIVE SKETCH OF KALIHI PORTAL

PLATE 13

KALIHI PORTAL

KALIHI TUNNEL REPORT

CITY & COUNTY OF HONOLULU

BUREAU OF PLANS

AND

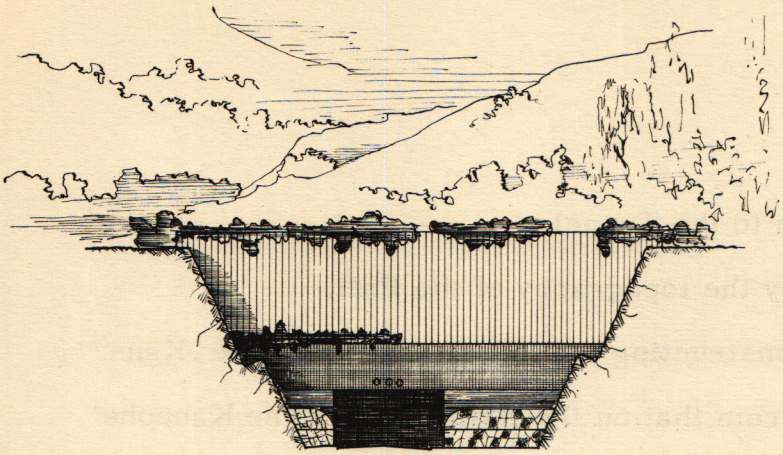
LAW & WILSON

ARCHITECTS & ENGINEERS

Its location and function have been previously described in this report. It should be noted that access to the ventilation and control building is provided by utilization of the existing military road which is to be improved, resurfaced and extended approximately 1000 feet under this tunnel project.

D. Stage Development.

The developments described above represent the ultimate completed project (Stages 1 and 2 on Kalihi side). Under Stage 1, however, only one tunnel (2 way traffic) is to be constructed. Therefore the divided highway will merge into a two lane highway at the tunnel portal, only a portion of which will be constructed now. (See Plate 14)



ELEVATION SHOWING STAGE I
CONSTRUCTION AT PORTAL

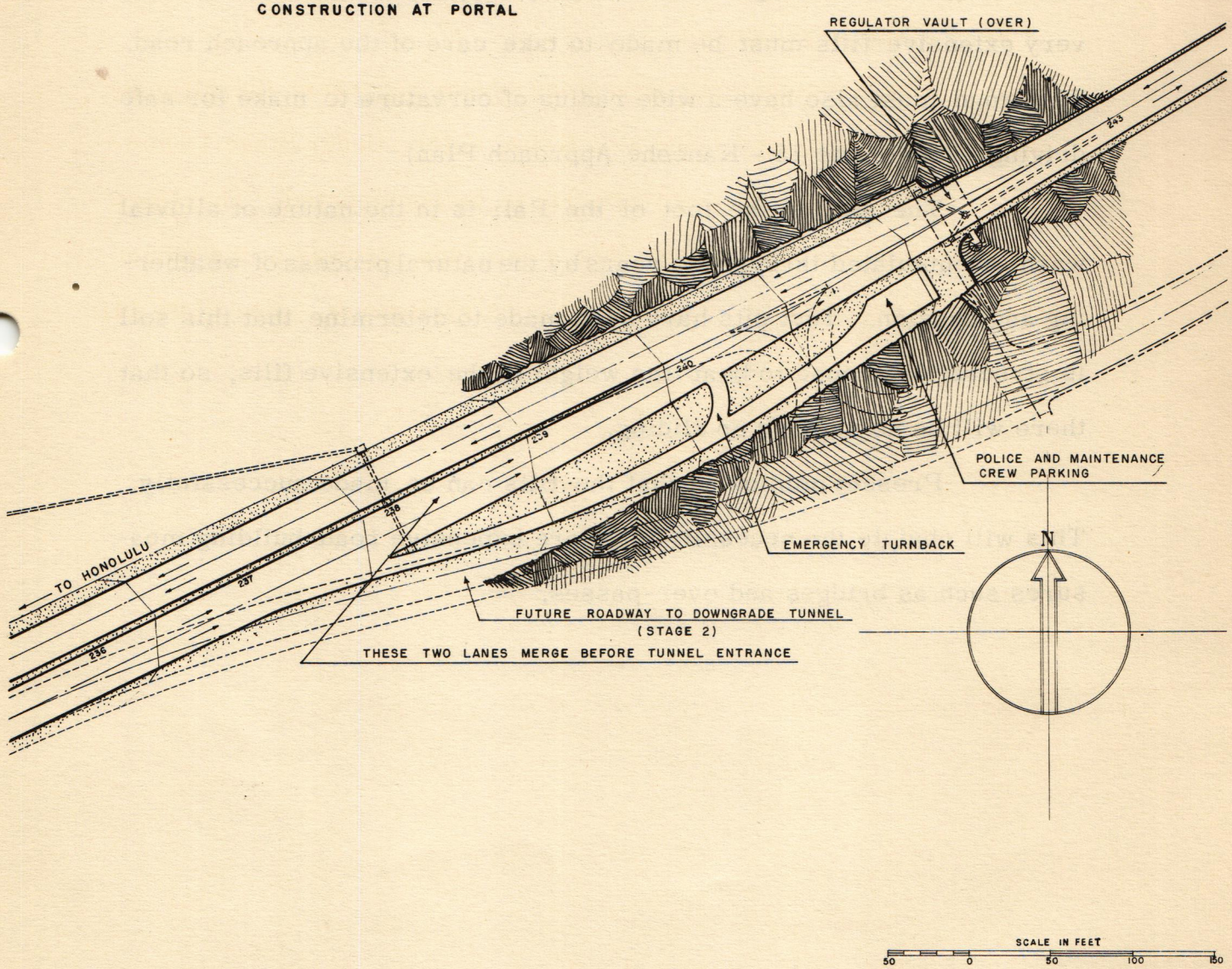


PLATE 14

KALIHI APPROACH (1st STAGE)

KALIHI TUNNEL REPORT

CITY & COUNTY OF HONOLULU
BUREAU OF PLANS
AND
LAW & WILSON
ARCHITECTS & ENGINEERS

VI. Kaneohe Approach to the Tunnel.

A. Problems posed by the topography of the Pali.

The problem of constructing an approach from the Kaneohe side is quite different from that on the Kalihi side. The Kaneohe side of the Koolau Range is sheer and precipitous, which means that very extensive fills must be made to take care of the approach road. This road must also have a wide radius of curvature to make for safe driving. (See Plate 15 - Kaneohe Approach Plan)

The soil at the foot of the Pali is in the nature of alluvial wash, accumulated through the years by the natural process of weathering and erosion. Test pits have been made to determine that this soil is structurally sound to bear the weight of the extensive fills, so that there will be no settling or sliding.

Present opinion is that the fills can be made successfully. This will obviate the necessity for more expensive road-building measures such as bridges and over-passes.

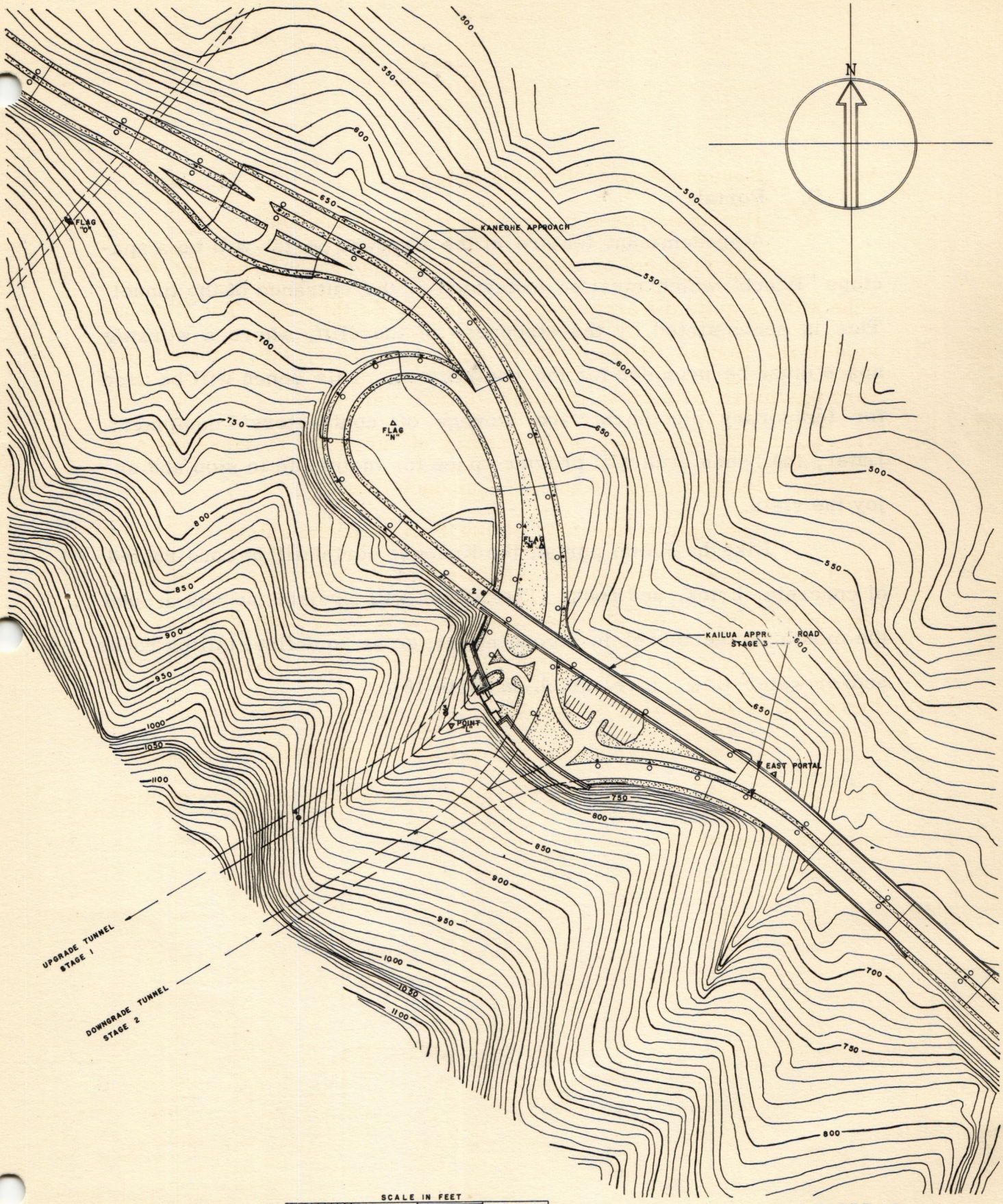


PLATE 15

KANEOHE APPROACH PLAN

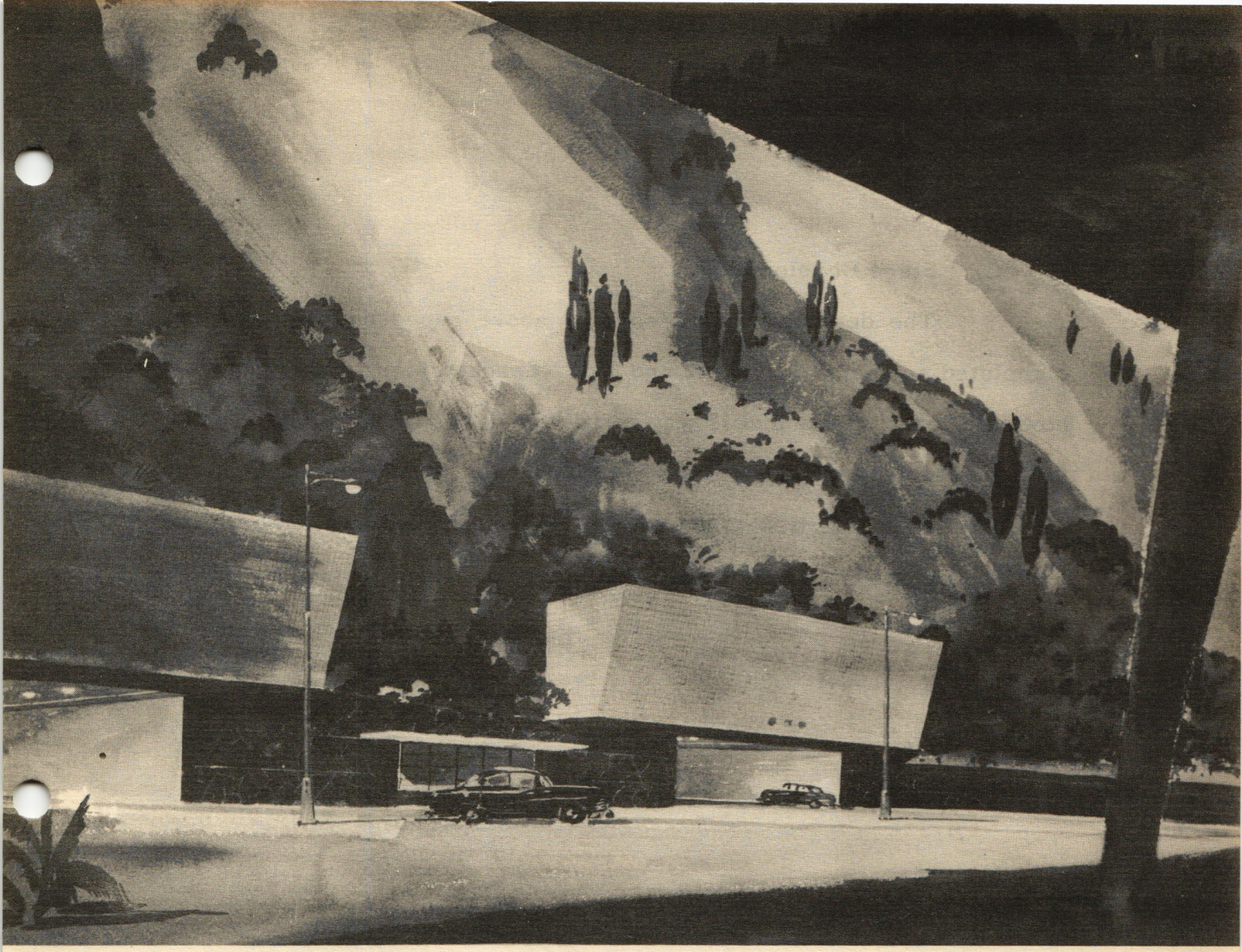
KALIHI TUNNEL REPORT

CITY & COUNTY OF HONOLULU
BUREAU OF PLANS
AND
LAW & WILSON
ARCHITECTS & ENGINEERS

B. Portal.

A predominant feature of the Kaneohe portal will be a spacious "Bench" which must be excavated at the entrance of the tunnel. This is necessitated by the steepness of the cliff, where a working space must be provided for the contractors. This bench will be used for temporary placement and storage of contractors' equipment. Later, the bench area will provide space for motorists to stop and enjoy the vista.

Like the Kalihi portal, the Kaneohe portal will be constructed of concrete, brick, and rock. The portal will project out and around the mouth of the tunnel in a cone effect, so as to deflect falling rocks and/or water-flow. (See sketch on Plate 16).



PERSPECTIVE SKETCH OF KANEOHE PORTAL

PLATE 16

KANEOHE PORTAL

KALIHI TUNNEL REPORT

CITY & COUNTY OF HONOLULU

BUREAU OF PLANS

AND

LAW & WILSON

ARCHITECTS & ENGINEERS

C. Stage Development.

The developments described above represent the ultimate completed project (Stages 1, 2 and 3 on Kaneohe side). Under Stage 1 however, only one tunnel (2 way traffic) is to be constructed. Therefore the divided highway will merge into a two lane highway at the tunnel portal only a portion of which will be constructed now. (See Plate 17) The parking area indicated thereon is to be constructed under Stage 1.

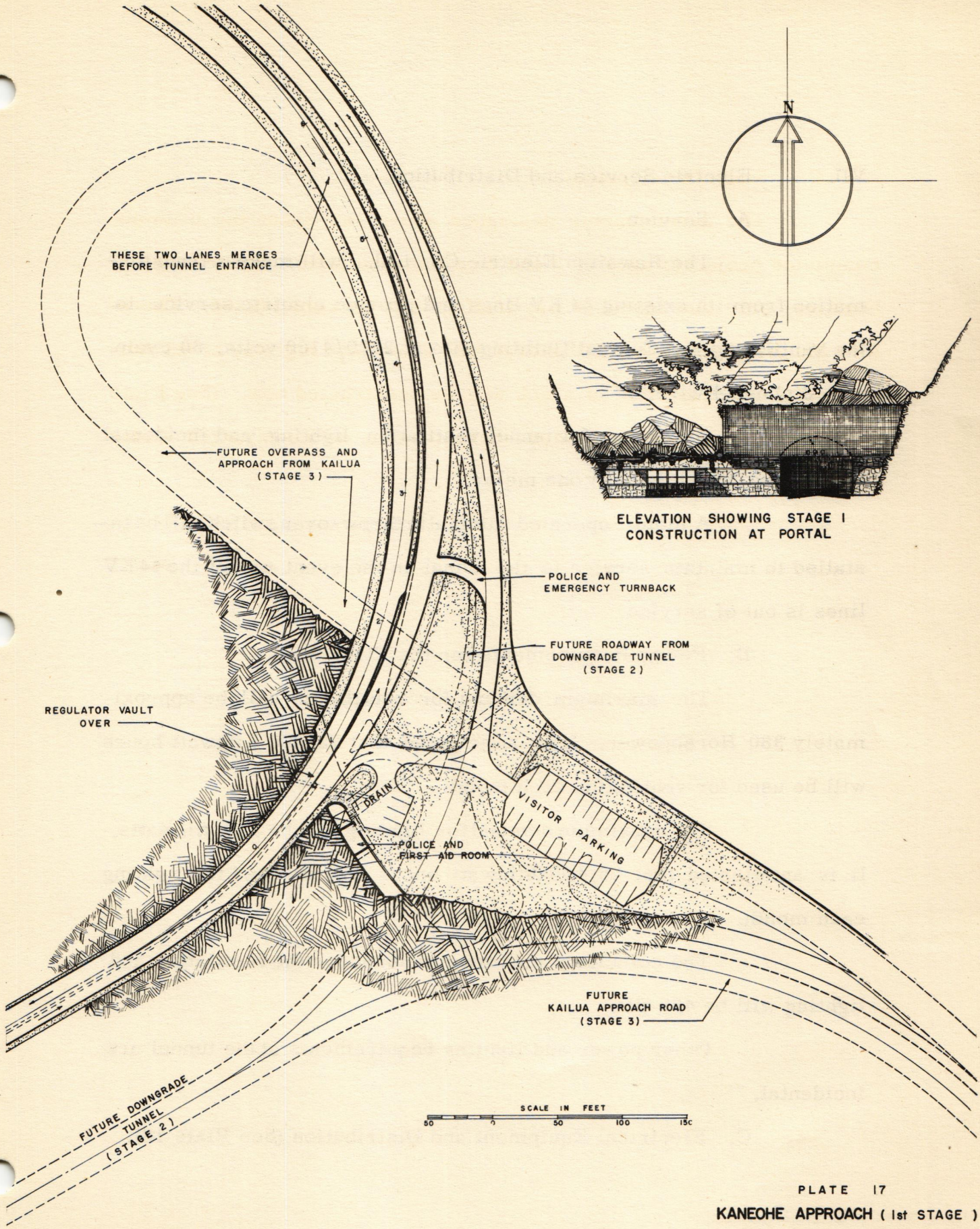


PLATE 17

KANEOHE APPROACH (1st STAGE)

KALIHI TUNNEL REPORT

CITY & COUNTY OF HONOLULU
BUREAU OF PLANS
AND
LAW & WILSON
ARCHITECTS & ENGINEERS

VII. Electric Service and Distribution.

A. Service.

The Hawaiian Electric Co. Ltd., will make a transformation from its existing 44 KV lines and provide electric service to the Ventilating and Control Building site at 2400/4160 volts, 60 cycle, a-c 3 phase 4 wire.

All energy for tunnel ventilation, lighting, and incidental use will be billed through one meter.

A motor-operated automatic throw-over switch will be installed to maintain service to the tunnel in the event one of the 44 KV lines is out of service.

B. Power Requirements for the First Bore.

The maximum demand for ventilation will be approximately 380 Horsepower. It is anticipated that 72,000 Kilowatt hours will be used for ventilation each month.

The maximum demand for lighting will be 110 Kilowatts. It is anticipated that 76,400 Kilowatt hours will be used for lighting each month.

The coincident maximum demand for the ventilation and lighting will be 460 HP.

Other power and lighting requirements at the tunnel are incidental.

C. Electrical Equipment and Distribution (See Plate 18).

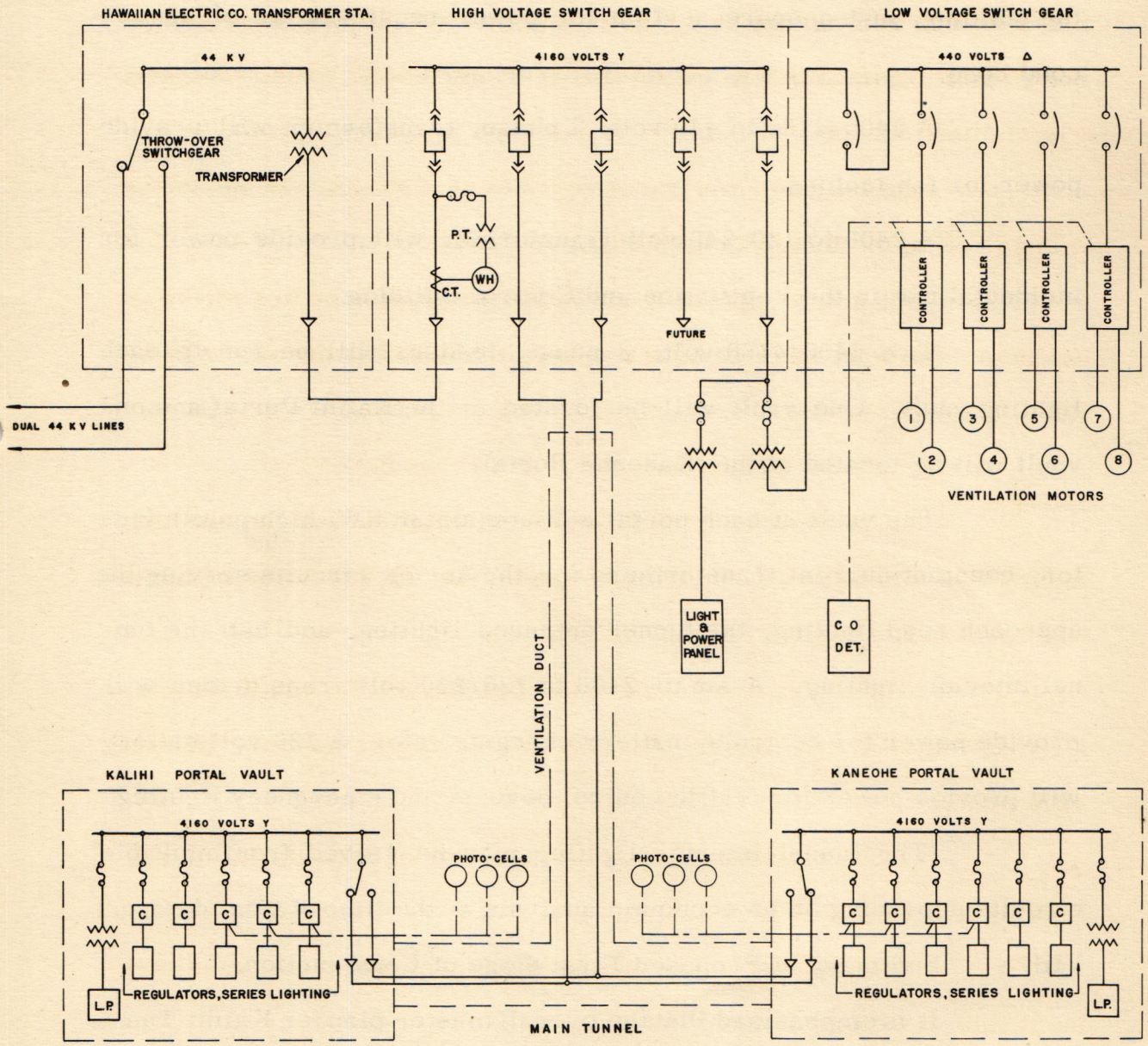


PLATE 18

ONE LINE ELECTRICAL DIAGRAM

KALIHI TUNNEL REPORT

CITY & COUNTY OF HONOLULU

BUREAU OF PLANS

AND

LAW & WILSON

ARCHITECTS & ENGINEERS

An assembly of metal-clad switchgear in the Ventilation and Control Building will provide for the main disconnect, metering, distribution circuits to the portal vaults and to the transformer banks in the building, and a spare section for power requirements of the second bore.

A 2400/4160 to 440 volt, 3 phase, transformer will provide power for fan motors.

A 2400 to 120/240 volt transformer will provide power for incidental use in the Ventilation and Control Building.

Two 2400/4160 volt, 3 phase, feeders will be run to each lighting vault. One vault will be located at the Kalihi Portal and one vault will be located at the Kaneohe Portal.

The vault at each portal will contain 30 KW, high power factor, constant current transformers for the series circuits serving the approach road lighting, the tunnel entrance lighting, and half the tunnel interior lighting. A small 2400 to 120/240 volt transformer will provide power for controls, battery charging, etc. A 120 volt battery will provide power for traffic control devices and emergnecy lighting.

(The tunnel interior lighting may be served from multiple circuits depending on an economic analysis at the time of final design.)

VIII. Summary of Proposed First Stage of Construction.

It is emphasized that the overall master plan for Kalihi Tunnel envisages three stages of developments to provide for present

needs and at the same time look ahead to future expansion.

The project as planned for Stage One and the pertinent development covered by this report is to be accomplished in four separate increments of construction hereinbefore outlined.

In summary and conclusion of this report, data showing estimated costs and the target dates for work to be started and completed is indicated in the table below.

(For Detailed Estimates of the Cost of Construction - See Appendix A)

Increment No.	Description	Contract Target Date	Completion Target Date	Estimated Cost
I	Kaneohe Approach Road and Drainage	Oct. 52	Mar. 53	$ 448,250
II	Tunnel Bore and Appurtenant Work	Feb. 53	May 54	3,112,330
III	Ventilation Bldg. and Equipment and Tunnel Lighting	May 53	Dec. 54	703,000
IV	Complete Roads and Tunnel Interior	Apr. 54	Oct. 54	515,570
	TOTAL ESTIMATED COST OF CONSTRUCTION FOR STAGE I			$4,779,150

As indicated in the above table, Increment No. III will probably be the last part of the work to be completed under Stage 1, since some items of the specialized control gear which is to be installed under Increment No. III may require several months for delivery. Depending upon which items these may be, it might be possible that interim use of the tunnels may be obtained by jury-rigging or temporary

by-passing of such controls.

In conclusion, it appears that certain monies will be available from the bond issue of the City and County of Honolulu for this project to assist other phases of the project. However, due to the many unknown and unforseen conditions in tunnel construction work the monies available for "other phases" should not be allocated until the construction contracts have been let and sufficient construction progress has been made. The tunnel, complete with its appurtenances, should be in operation by December 1954.

APPENDIX A

ESTIMATED COST OF CONSTRUCTION FOR STAGE I OF KALIHI TUNNEL

Construction Sequence	Description	Estimated Cost	Accumulated Cost Each Increment
Increment I	Kaneohe approach road from Sta. 5+00 to 59+50, including Rough Grading and below ground drainage.	$407,500.00	
	Plus 10% for contingencies - Engineering - Advertising - Supervision	40,750.00	
	TOTAL ESTIMATED COST FOR INCREMENT NO. I	$448,250.00	$448,250.00
Increment II			
A.	Kalihi approach road from Sta. 222+38 to 241+80 (Kalihi Portal) including rough grading and below ground drainage.	202,400.00	
B.	Access road to Ventilation Bldg.	105,000.00	
C.	Rough grading of balance of Kaneohe Approach Road Sta. 0+80 (Kaneohe Portal) to 5+00	163,800.00	
D.	Excavation for tunnel and shaft.	496,750.00	
E.	Structural excavation for Ventilation Building.	76,000.00	
F.	Concrete lined Stream Diversion.	205,000.00	
G.	Tunnel lining.	980,440.00	
H.	Shaft lining.	41,000.00	
I.	Drainage within tunnel	109,000.00	
J.	Portal structures.	300,000.00	
K.	Mobilization	150,000.00	
	Sub-total	2,829,390.00	

Construction Sequence	Description	Estimated Cost	Accumulated Cost Each Increment
	L. Plus 10% for contingencies - Engineering - Advertising - Supervision	$ 282,940.00	
	TOTAL ESTIMATED COST FOR INCREMENT II	$3,112,330.00	$3,560,580.00
Increment III			
	A. Ventilation Bldg. and Equipment.	$ 537,900.00	
	B. Tunnel entrance and tunnel interior lighting.	101,220.00	
	Sub-Total	$ 639,120.00	
	C. Plus 10% for Contingencies - Engineering - Advertising - Supervision.	63,900.00	
	TOTAL ESTIMATED COST FOR INCREMENT III	$ 703,000.00	$4,263,530.00
Increment IV			
	A. Completion of Kalihi and Kaneohe approach roads.	$ 304,300.00	
	B. Completion of tunnel paving - glazed tile facing units and other miscellaneous work.	153,300.00	
	C. Pave access road.	11,100.00	
	Sub-Total	$ 468,700.00	
	D. Plus 10% for Contingencies - Engineering - Advertising - Supervision.	46,870.00	
	TOTAL ESTIMATED COST FOR INCREMENT IV	$ 515,570.00	$4,779,150.00
	TOTAL ESTIMATED COST FOR STAGE I - INCLUDING INCREMENTS I - II - III - IV		$4,779,150.00

APPENDIX B
CORE DRILLING DATA

CORE BORINGS INTERPRETED BY DAN A. DAVIS, DISTRICT GEOLOGIST
U. S. GEOLOGICAL SURVEY

No. Kalihi 1 Altitude: 937.89 feet

Location: Station 243 + 64, C & C Kalihi Tunnel Project, Head of Kalihi Valley.

Total Depth: 125 feet Driller: Samson & Smock

Depth (feet) From	To	Progress (feet)	Core Length	%	Description	Drillers Log
0	6	6	--		4-5 Unconsolidated brown soil with roots.	Brown clay
6	18.3		2.5	22	Basalt, brownish gray slightly weathered with olivines near bottom end. Probably boulder in talus.	Boulders and clay.
18.3	21	2.7	--	--	20-21 Brown clay with gravel size basalt aggregates. Probably weathered talus.	Brown clay.
21	44	23	--	--	31-32 Brown clay with some unweathered gravel size basalt aggregates. Probably weathered talus. 40-41 Reddish brown clay with some unweathered gravel size basalt aggregates. Probably weathered talus.	Clay
44	52	8	2.5	31	Basalt, brownish gray to brown, partly weathered to thoroughly weathered. Probably weathered boulders, in weathered talus.	Mud rock.
52	60	8	--	--	Basalt, bluish gray to brownish gray, partly weathered. Top, very vesicular, with small vesicles. Bottom, dense with scattered large vesicles. Probably boulders.	Cracked mud rock with blue clay.

No. Kalihi 1

Depth (feet) From	To	Progress (feet)	Core Length	%	Description	Drillers Log
60	68	8	2.6	32	Basalt, bluish gray, very vesicular, bottom end appears more weathered than top. White vug filling. Probably unweathered boulder.	Medium hard porous rock, possibly a boulder.
68	76	8	--	--	75-76 Bluish clay. Probably weathered talus or weathered basalt in situ.	Blue Clay with small rock.
76	79	3	--	--	Do.	Same as above.
79	101	22	--	--	No sample. Probably same as above.	Brown clay with small mud rock.
101	104	3	--	--	No sample. Probably same as above.	Clay.
104	113	9	--	--	No sample. Probably same as above.	Soft mud rock with pieces of hard rock.
113	125	12	7.7	64	Basalt, bluish gray, top 3.0 feet of core dense with very little vesicles, some smoky white vug filling. Rest of core very vesicular except for bottom end where it becomes dense. Probably unweathered bed rock.	Hard blue porous rock.

No. Kalihi 2 Altitude: 962.72 feet

Location: Station 246 + 11, C & C Kalihi Tunnel Project, Head of Kalihi Valley.

Total Depth: 201 feet. Driller: Samson & Smock

Depth (feet) From	To	Progress (feet)	Core Length	%	Description	Driller's Log
0	12	12	--	--	4-5 Dark brown soil with roots. 9-10 Brown clay mixed with bluish gray basalt aggregates. Probably weathered talus and-or alluvium.	Clay.
12	18	6	--	--	No sample. Probably same as above.	Clay with pieces of mud rock.
18	19	1	--	--	No sample.	Boulders.
19	31	12	--	--	26-27 Aggregates of weathered basalt. Probably weathered talus.	Clay with pieces of mud rock.
31	66	35	--	--	41-42 Brown clay with basalt aggregates. Probably weathered talus. 52-53 Same as above.	Brown clay.
66	105	39	--	--	66-67 Same as above. 79-80 Same as above. 104-105 Aggregates of thoroughly weathered basalt. Probably weathered talus or weathered talus or weathered basalt in situ.	Brown clay
105	148	43	--	--	115-116 Aggregates of thoroughly weathered basalt. Probably weathered talus or weathered basalt in situ. 142-143 Same as above.	Brown clay.
148	201	53	--	--	166-167 Same as above. 200-201 Aggregates of weathered basalt. Probably weathered talus or weathered basalt in situ.	Brown clay

No. Kalihi 3 Altitude: 1002.7 feet

Location: Station 249 + 03, C & C Kalihi Tunnel Project, Head of Kalihi Valley

Total Depth: 240 feet Driller: Samson & Smock

Depth (feet) From	To	Progress (feet)	Core Length	%	Description	Driller's Log
0	70	70	--	--	4-5 Brown soil mixed with roots. 14-15 Same as above. 29-30 Brown clay with aggregates of weathered basalt. Probably weathered talus. 44-45 Same as above. 59-60 Same as above.	Brown clay
70	147	77	--	--	74-75 Aggregates of weathered basalt. Probably weathered talus to weathered basalt in in situ. 94-95 Same as above. 114-115 Same as above. 134-135 Fine clay with aggregates at weathered basalt. Probably same as above.	Brown clay
147	200	53	--	--	149-150 Same as above. 164-165 Same as above. 179-180 Aggregates of weathered basalt. Probably same as above. 194-195 Same as above.	Brown clay.
200	240	40	--	--	214-215 Same as above. 228-229 Same as above.	Brown clay

No. Kalihi 4 Altitude: 1064.4 feet

Location: Station 251 + 79, C & C Kalihi Tunnel Project, Head of Kalihi Valley.

Total Depth: 260 feet Driller: Samson & Smock

Depth (feet) From	To	Progress (feet)	Core Length	%	Description	Driller's Log
0	45	45	--	--	Chopped basalt aggregates. Probably weathered talus.	Brown clay
45	150	105	--	--	Chopped basalt aggregates. Probably weathered talus to weathered basalt in situ.	Brown clay
150	152	2	0.4	20	Basalt, medium gray, fine grained, scattered vesicles.	Blue rock
152	176	24	--	--	No sample. Probably weathered basalt.	Clay and mud rock.
176	180	4	1.3	38	Basalt, medium gray to bluish gray, fine grained. Small scattered vesicles.	Blue rock
180	189	9	0.8	9	Basalt, medium gray to bluish gray, scattered vesicles. Appears slightly weathered.	Hard, blue cracked rock.
189	194	5	--	--	No sample. Probably weathered basalt.	Clay, unable to core.
194	205	11	4.6	42	Basalt, medium gray to bluish gray, fine grained. Scattered vesicles. White vug filling stained with limonite contains weathered olivines.	Medium hard cracked rock.
205	209	4	--	--	No sample. Probably weathered basalt.	Hard clay, unable to core.
209	221	12	6.1	51	Basalt, medium gray to bluish gray, fine grained. Scattered small to large vesicles. Last few inches very vesicular.	209-216 Very hard rock. 216-221 Hard blue rock.

Kalihi 4

Depth (feet) From	To	Progress (feet)	Core Length	%	Description	Driller's Log
221	228	7	1.5	21	Basalt, reddish brown, very vasicular, appears weathered.	Soft red porous rock
228	235	7	3.7	53	Basalt, brown to brownish gray, very vesicular, vesicles much larger in lower half of core and rock is less weathered.	Medium hard, gray, porous rock. Lost water circulation at 221 feet, returned at 226 feet.
235	255	20	--	--	Lost core. No recovery. Basalt.	235-239 Medium hard, gray, porous rock. 239-240.5 cavity 240.5-255 Gray, porous rock with small cavities Lost water circulation at 239 feet. Lost core recovery from 235-246
255	260	5	6.57	100	Core: 0-0.9 Basalt, medium gray, very vesicular with some white vug filling. Appears slightly weathered. 0.9-4.8 Basalt, medium gray to bluish gray, very vesicular. Scattered small to large vesicles. 4.8-6.0 Basalt, bluish gray, very fine grained, scattered very small vesicles. 0.0-3.5 Basalt, medium gray fine grained. Scattered small to large vesicles. Bottom portion dense.	Gray rock. Used carbaloy bit, bit plugged at 225'. Took off carbaloy bit and put on diamond bit. Hole filled with 25 ft. of cuttings.

No. Kalihi 5 Altitude: 1108.9 feet

Location: Station 254 + 59, C & C Kalihi Tunnel Project, Head of Kalihi Valley.

Total Depth: 320 feet Driller: Samson & Smock

Depth (feet) From	To	Progress (feet)	Core Length	%	Description	Driller's Log
0	11	11	--	--	Reddish brown soil	Brown clay.
11	35	24	3.3	14	Top half, basalt, weathered, reddish brown, numerous small vesicles. Bottom half, basalt, brownish gray, numerous small vesicles.	Mud rock and clay.
35	48	13	5.5	42	Basalt, bluish gray to brownish gray, very vesicular. Vesicles larger and more near the top end. Appears partly weathered.	Medium hard rock.
48	55	7	2.5	36	Basalt, bluish gray, very fine grained. Large scattered vesicles. Some filled with white material.	Hard, gray rock.
55	95	40	4.6	11	Basalt, bluish gray, very fine grained. Few and scattered vesicles.	Hard rock and hard cracked rock. Clay 83-85.
95	112	17	4.6	27	Basalt, bluish gray, fine grained, large scattered vesicles. 0.5' of red brown basalt in middle section of core.	Hard, cracked rock.
112	128	16	3.1	19	Basalt, bluish gray, fine grained, vesicular, vesicles increase at lower end.	Cracked rock.
128	147	19	4.9	26	Basalt, medium gray to bluish gray, fine grained. Vesicles large, increasing in number at lower end.	Hard, cracked rock.

Kalihi 5

Depth (feet) From	To	Progress (feet)	Core Length	%	Description	Driller's Log
147	168	21	7.0	33	Core: 0-4.0 Basalt, partly weathered brownish gray, fine grained. Vesicles small near top to large and scattered near end. 4.0-6.3 Basalt, brownish gray, very vesicular, partly weathered. 6.3-7.0 Basalt, brownish gray, partly weathered. Scattered vesicles.	Cracked rock, porous.
168	173	5	0.7	14	Basalt, brownish gray, partly weathered. Scattered vesicles.	Very hard, cracked rock.
173	193	20	4.9	25	Basalt, partly weathered, gray to brownish gray, very vesicular. Appears more weathed at lower end.	173-180 Soft brown porous rock. 180-193 Porous cracked rock.
193	200	7	5.1	73	Basalt, gray to brownish gray. Scattered vesicles, less vesicular toward lower half.	Hard, cracked rock.
200	221	21	10.4	50	Top 2' of core. Basalt, brownish gray, partly weathered. Large scattered vesicles. Remainder of core. Basalt, medium gray, very fine grained. Small scattered vesicles. Appears fresher lower half.	Hard, cracked rock.
221	233	11	2	18	Basalt, medium gray, very fine grained. Numerous small scattered vesicles.	Hard, cracked rock.
233	240	7	4.3	62	Basalt, brown becoming gray at lower end. Very vesicular, fine grained. Brownish part appears weathered.	Soft red porous rock.

Kalihi 5

Depth (feet) From	To	Progress (feet)	Core Length	%	Description	Driller's Log
240	243	3	0.7	23	Basalt, gray, fine grained, very vesicular. Probably pahoehoe.	Hard, cracked rock.
243	264	21	3.4	16	Basalt, gray, fine grained vesicular but with dense zones. Appears slightly weathered. Probably pahoehoe,	Cracked, porous rock with cavities.
264	271	7	3.1	44	Basalt, gray, fine grained, irregularly vesicular. Appears slightly weathered. Probably pahoehoe.	Hard, cracked rock.
271	277	6	2.7	45	Basalt, gray to brownish gray, generally very vesicular. Appears slightly weathered. Probably pahoehoe.	Soft, red, porous rock.
277	283	6	2.9	48	Basalt, gray to brownish gray, very vesicular at top, slightly vesicular at bottom. Some white vug filling. Appears weathered with few small olivines at bottom.	Hard, cracked porous rock.
283	295	12	4.4	37	Basalt, fine grained, gray to brownish gray, generally very vesicular. Appears somewhat weathered. Few small olivines.	Cracked porous rock.
295	301	6	1.7	28	Basalt, fine grained, brownish, slightly weathered, very vesicular throughout except for few inches at top of core.	Soft, cracked, red, porous, rock with cavities.

Hole No. 5, Kalihi

Depth (feet) From	To	Progress (feet)	Core Length	%	Description	Driller's Log
301	310	9	4.9	55	Basalt, fine grained, gray, appears fresh. Very small scattered vesicles. Olivine phenocrysts. Increasingly more vesicular toward very end of core.	Hard, cracked rock.
310	320 Bottom	10	2.9	29	Basalt, gray, fine grained, very vesicular. Appears slightly weathered.	Hard, cracked, porous, rock with cavities.

No. Kalihi 6 Altitude: 938.74 feet

Location: Station 242 + 63, C & C Kalihi Tunnel Project, Head of Kalihi Valley

Total Depth: 75 feet Driller: Samson and Smock

Depth (feet) From	To	Progress (feet)	Core Length	%	Description	Driller's Log
0	15	15	--	--	9-10 Brown clay: Probably weathered talus and/or alluvium.	Soft brown clay.
15	18	3	--	--	No sample. Probably same as above.	Brown clay.
18	23	5	--	--	Brown clay and weathered boulders. Probably weathered talus and/or alluvium.	Brown clay with small mud rock boulders.
23	50	27	--	--	32-33 Brown clay. Probably thoroughly weathered talus and/or alluvium. 43-44 Same as above.	Brown clay.
50	75	25	--	--	55-56 Same as above. 65-66 Same as above. 66-75 Same as above.	Brown clay, with soft mud rock.

No. Kalihi 7 Altitude: 921.43 feet

Location: Station 242 + 63, Kalihi Tunnel Project, Head of Kalihi Valley.

Total Depth: 67 feet Driller: Samson & Smock

Depth (feet) From	To	Progress (feet)	Core Length	%	Description	Driller's Log
0	11	11	--	--	9-10 Yellow-brown clay. Probably throughly weathered talus and/or alluvium.	Brown clay with small boulders.
11	19	8	--	--	No sample. Same as above.	Hard, brown clay.
19	28	9	--	--	20-21 Brown clay. Same as above.	Hard, brown clay.
28	32	4	--	--	Weathered basalt. Probably talus.	Mud rock boulders.
32	50	18	--	--	44-45 Weathered basalt in brown clay. Probably weathered talus.	Brown clay with small mud rock boulders.
50	53	3	--	--	No sample. Probably weathered talus.	Brown clay.
53	61	8	--	--	No sample, same as above.	Hard, brown clay.
61	67	6	1.5	25	Weathered basalt, reddish gray to brownish gray, numerous scattered small vesicles. Probably talus.	Medium hard mud rock boulders.

No. Kalihi 8 Altitude: 880.44 feet

Location: Station 232 + 00, C & C Kalihi Tunnel Project, Head of Kalihi Valley.

Total Depth: 22 feet Driller: Samson & Smock

Depth (feet) From	To	Progress (feet)	Core Length	%	Description	Driller's Log
0	5.5	5.5	--	--	Brown soil mixed with roots.	Brown clay.
5.5	13	7.5	--	--	Basalt, blue gray. Probably a boulder in alluvium	Clay and boulders.
13	22	9	--	--	Unconsolidated brown alluvium.	Soft sandy brown clay.

No. Kaneohe 1 Altitude: 687.4 feet

Location: Station 15 + 00, Windward approach C. &. C. Kalihi Tunnel Project, 1.7 miles NW Nuuanu Pali.

Total Depth: 66 feet Driller: Samson & Smock

Depth (feet) From	To	Progress (feet)	Core Length	%	Interpretation	Driller's Log
0	10	10	--	--	(Samples not available) Probably weathered talus to weathered basalt in situ.	Brown clay.
10	46	36	--	--	Probably weathered basalt in situ.	Soft mud rock.
46	49	3	--	--	Same as above.	Soft mud rock.
49	66	17	--	--	Same as above.	Soft mud rock mixed with clay.

No. Kaneohe 2 Altitude: 774.7 feet

Location: Station 2 + 00, Windward approach C & C Kalihi Tunnel Project, 1.5 miles NW Nuuanu Pali.

Total Depth: 85 feet Driller: Samson & Smock

Depth (feet) From	To	Progress (feet)	Core Length	%	Description	Driller's Log
0	25	25	--	--	Unconsolidated mud aggregates. Probably weathered basalt situ.	Decayed mud rock.
25	35	10	--	--	Unconsolidated silt with aggregates of of weathered basalt. Probably weathered basalt in situ.	Decayed mud rock.
35	45	10	1.3	13	Basalt, partly weathered, brownish gray, very vesicular. Contains fresh to weathered olivines.	Soft, gray "Puka Puka" rock.
45	55	10	1.5	15	Same as above.	Soft, reddish "Puka Puka" rock.
55	66	11	4.2	38	Basalt, medium gray, very vesicular. Contains fresh to weathered olivines.	Medium hard, gray, "Puka Puka" rock. Soft in places.
66	76	10	1.3	13	Basalt, medium gray, very vesicular. Appears slightly weathered.	Medium hard gray, cracked, "Puka Puka" rock.
76	85	9	1	11	Basalt, medium gray, large scattered vesicles, some filled with white vug filling.	Medium hard, gray, "Puka Puka" rock.

No. Kaneohe 3 Altitude: 775.7 feet

Location: Station 0 + 00, Windward approach, C & C Kalihi Tunnel Project.
1.5 miles NW Nuuanu Pali.

Total Depth: 75 feet Driller: Samson & Smock

Depth (feet) From	To	Progress (feet)	Core Length	%	Description	Driller's Log
0	2	2.0	--	--	Reddish brown soil.	Soft soil and loose rock.
2	5	3.0	--	--	Brownish gray aggregates of weathered basalt. Probably weathered basalt in situ.	Soft mud rock.
5	8.7	3.7	1.3	35	Basalt, medium gray, very fine grained with scattered small to large vesicles.	Medium hard, gray rock.
8.7	9.5	0.8	0.4	50	Basalt, brownish gray, numerous small vesicles. Appears partly weathered.	Medium hard, red, porous, rock cracked.
9.5	12	2.5	1.3	52	Basalt, medium gray, very fined grained, scattered small to large vesicles, some with white vug filling.	Gray rock, cracked. Medium hard.
12	13.7	1.7	0.3	18	Basalt, reddish brown, scattered small vesicles. Appears weathered.	Red, porous, cracked rock. Medium hard.
13.7	15	1.3	0.3	23	Same as above.	Red cracked rock. Medium hard.
15	20	5.0	0.9	18	Basalt, medium gray, fine grained. Vesicles scattered, some filled with white material.	Medium hard, cracked, gray rock.
20	26	6.0	3.0	50	Basalt, medium gray, very fine grained. Few and scattered vesicles except at lower end where they become larger and more numerous.	Hard, cracked gray rock.

Kaneohe 3

Depth (feet) From	To	Progress (feet)	Core Length	%	Description	Driller's Log
26	27	1.0	0.5	50	Basalt, brownish gray, with scattered vesicles. White filling material.	Gray rock, medium hard, cracked.
27	28	1.0	0.6	60	Basalt, reddish brown, small and scattered vesicles. Contains fresh olivine phenocrysts.	Red and gray rock, cracked.
28	48.5	20.5	11.8	58	Basalt, bluish gray, very vesicular. Numerous olivine phenocrysts. Lower 2.5' of core less vesicular.	Medium hard gray porous rock, cracked.
48.5	56	7.5	2.1	28	Basalt, bluish gray, very vesicular. Small vesicules.	Medium hard blue rock, cracked.
56	64	8.0	3.3	41	Basalt, bluish gray, very vesicular. Vesicles small in top 1/3 of core, increase in size toward lower end.	Medium hard, gray, porous rock cracked.
64	75 Bottom	11.0	4.7	43	Basalt, bluish gray, very vesicular. Appears slightly weathered.	Medium hard, cracked, "Puka puka" rock.

No. Kaneohe 4 Altitude: 960.0 feet

Location: Station - 2 + 78, Windward approach C & C Tunnel Project, 1.5 miles NW Nuuanu Pali.

Total Depth: 242 feet Driller: Samson & Smock

Depth (feet) From	To	Progress (feet)	Core Lenght	%	Description	Driller's Log
0	8.3	8.3	--	--	Aggregates of weathered basalt. Probably weathered basalt in situ.	Decayed mud rock.
8.3	11.8	3.5	1.5	43	Basalt, medium gray, very fine grained. Few and scattered large vesicles.	Medium hard, cracked, gray rock.
11.8	12.9	1.1	0.8	73	Same as above.	Same as above.
12.9	31	18.1	5.2	29	Basalt, medium gray, fine grained, scattered small to large vesicles. Small section in middle very vesicular and appears slightly weathered.	Medium hard, cracked, gray rock, very small pores.
31	34.4	3.4	3.4	100	Basalt, gray, very fine grained, scattered small to large vesicles. Slightly more vesicular toward the lower end.	Medium hard, cracked, gray rock.
34.4	37.2	2.8	1.1	40	Basalt, brownish gray, numerous small vesicles. Appears partly weathered.	Medium hard, cracked, reddish "Puka Puka" rock.
37.2	39	1.8	1.4	78	Basalt, medium gray, very vesicular. Appears slightly weathered.	Medium hard, cracked, gray "Puka Puka" rock.
39	53	14.0	5.3	38	Basalt, brownish gray, very vesicular. Slightly weathered.	Medium hard, cracked gray "Puka Puka" rock. Soft in places.

Hole No. 4 Kaneohe.

Depth (feet) From	To	Progress (feet)	Core Length	%	Description	Driller's Log
53	63	10.0	2.3	23	Basalt, medium gray, generally vesicular. Appears partly weathered near top.	Medium hard, cracked, "Puka Puka" rock. Soft in places.
63	72	9.0	2.4	27	Basalt, medium gray, very vesicular. Appears slightly weathered.	Medium hard, "Puka Puka" rock.
72	74	2.0	0.9	45	Basalt, medium gray. Top, fine grained with little vesicles. Bottom, very vesicular.	Hard rock.
74	80	6.0	4.3	64	Basalt, gray to brownish, very vesicular. Bottom portion weathered more.	Medium hard "Puka Puka" rock.
80	83	3.0	1.0	33	Basalt, brownish gray, very vesicular. Vesicles small.	Medium hard "Puka Puka" rock.
83	91	8.0	2.8	35	Basalt, medium gray to brownish gray, very vesicular. Appears less weathered near bottom part of core.	Medium hard cracked rock.
91	100	9.0	4.1	46	Basalt, brownish gray, very vesicular. Lower 1.0' less vesicular.	Medium hard cracked rock.
100	104	4.0	4.0	100	Basalt, brownish gray to medium gray, very vesicular. Top portion less vesicular and weathered more.	Medium hard cracked rock.
104	109	5.0	2.8	56	Basalt, medium gray, fine grained. Few large and scattered vesicles except near the bottom of core, where it becomes increasingly more vesicular.	Hard rock.

Hole No. 4, Kaneohe

Depth (feet) From	To	Progress (feet)	Core Length	%	Description	Driller's Log
109	113	4.0	1.1	28	Basalt, medium gray, very vesicular.	"Puka Puka" rock.
113	120	7.0	2.6	37	Basalt, contains olivine phenocrysts near bottom.	"Puka Puka" rock.
120	130	10.0	3.4	34	Top, brownish gray, very vesicular. Contains olivine phenocrysts.	Medium hard "Puka Puka" rock.
					Bottom, more vesicular and weathered more. No visible olivines.	Do.
130	140	10.0	5.5	55	Basalt, very vesicular, partly weathered. Bottom half of core less weathered and less vesicular.	Medium hard, "Puka Puka" rock.
140	147	7.0	0.3	4	Basalt, appears weathered with little vesicles in general. Top portion very vesicular.	Medium hard, cracked "Puka Puka" rock.
147	157	10.0	8.0	80	Basalt, medium gray, very vesicular. Small to large vesicles.	Medium hard, reddish "Puka Puka" rock.
157	166	9.0	3.9	43	Basalt, very vesicular throughout. Upper third and last few inches weathered brown. Rest of core partly weathered.	Medium hard "Puka Puka" rock.
166	175	9.0	0.8	9	Basalt, brownish gray, very vesicular, middle section more vesicular. Appears weathered in general. Olivine phenocrysts at bottom end.	Medium hard cracked "Puka Puka" rock.
175	182	7.0	2.0	29	Upper and lower third, basalt, medium gray, fine grained. Small and scattered vesicles. Olivines.	Medium hard "Puka Puka" rock.
					Middle third, basalt, brownish gray, partly weathered, vesicular. Olivines appear altered.	Medium hard "Puka Puka" rock.

Hole No. 4, Kaneohe

Depth (feet) From	To	Progress (feet)	Core Length	%	Description	Driller's Log
182	190	8.0	1.9	24	Basalt, brownish gray, fine grained, contains olivine phenocrysts. Small and scattered vesicles. Core in general appears partly weathered.	Medium hard "Puka Puka" rock.
190	200	10.0	1.7	17	Do.	Medium hard "Puka Puka" rock. Soft in places.
200	206	6.0	1.1	18	Basalt, brownish gray, fine grained. Contains olivine phenocrysts. Small and scattered vesicles. Core is broken in small pieces and appears weathered.	Medium hard "Puka Puka" rock.
206	216	10.0	2.3	23	Basalt, medium gray, fine grained, small and scattered vesicles. Lower third partly weathered.	Medium hard cracked "Puka Puka" rock.
216	223	7.0	1.8	26	Basalt, brownish gray, very vesicular. Contains olivine phenocrysts. Appears partly weathered, increasing toward lower end.	Soft "Puka Puka" rock.
223	235	8.0	3.4	43	Top half, basalt. Medium gray, fine grained, contains olivine phenocrysts. Vesicles, few and scattered. Bottom half, basalt, brownish gray, very vesicular. Olivine Phenocrysts. Appears weathered.	Medium hard "Puka Puka" rock.
235	242	7.0	1.6	23	Basalt, medium gray, very vesicular. Contains olivine phenocrysts. Appears slightly weathered.	Medium hard cracked "Puka Puka" rock.

Municipal Reference & Records Center
MUNICIPAL REFERENCE LIBRARY
CITY AND COUNTY OF HONOLULU

HE380 MRKCB8909034
U53
H658 / copy 3
Honolulu. Dept. of Public Works.
Bureau of Plans. * Law & Wilson.
Kalihi Tunnel report for the city and
county of Honolulu, Hawaii.
Honolulu: Sept. 1952.
97 p. ill.
Tunnels * Honolulu * Roads * Oahu
DATE: 11/52 COPIES: 3 COST: