HONOLULU RAPID TRANSIT PROGRAM

PRELIMINARY FEASIBILITY ASSESSMENT OF KAPIOLANI/WAIKIKI SUBWAY

DEPARTMENT OF TRANSPORTATION SERVICES
CITY AND COUNTY OF HONOLULU

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EXECUTIVE SUMMARY

PRELIMINARY FEASIBILITY ASSESSMENT OF KAPIOLANI/WAIKIKI SUBWAY

The purpose of this preliminary assessment is to evaluate the feasibility of extending the subway beyond downtown Honolulu under Kapiolani Boulevard and through Waikiki under Kalakaua and Kuhio avenues. The objective is to use existing information to provide a conceptual evaluation of underground alignments, station locations, cut-and-cover subway station options, and a preliminary comparison of environmental impacts between the aerial and underground alternatives within the study limits. In addition, this study includes an order-of-magnitude cost estimate for each alignment option based on generic tunnel configurations and anticipated geotechnical conditions.

The Kapiolani/Waikiki Subway Study area begins at the Hotel Street Subway Koko Head portal structure, near Ward Avenue. At this point, as currently envisioned, the proposed guideway emerges from below grade and transitions to an aerial structure. The study area parallels Kapiolani Boulevard, and continues through Waikiki to Kapahulu Avenue. The guideway alignment that extends towards the University of Hawaii via the UH/Quarry alignment option is also included within the study area. Three fixed guideway alignment options have been evaluated for the preliminary assessment of the Kapiolani/Waikiki Subway. They are illustrated in Figure 1 and described as follows:

> Option "A" is an aerial alignment that is consistent with the configuration defined by the System Vendor Request for Proposals but restricted to the study area using only the UH/Quarry option. From the Hotel Street Subway portal, the aerial alignment follows Waimanu and Kona streets to Atkinson Drive. The guideway then continues beyond Atkinson Drive to a transfer station located near the intersection of Kalakaua Avenue and Kapiolani Boulevard and adjacent to the Aloha Motors site. At the transfer station, the aerial alignment divides into two segments. One segment continues as a mainline toward the University following Kapiolani Boulevard and University Avenue. The remaining line starts at the transfer station and extends along Kalakaua and Kuhio avenues to service Waikiki as an independent shuttle, or "pinched loop" operating segment.
>
> Option "B" is a subway alignment that continues from the Hotel Street Subway along Kapiolani Boulevard and through Waikiki. Beyond the Kalakaua/Kapiolani Station, the mainline emerges above grade and continues toward the University as an aerial guideway. The Waikiki line functions as a "pinched loop" emulating the transit system operation defined by Option "A."
>
> Option "C" is a subway alignment that continues from the Hotel Street Subway along Kapiolani Boulevard and through Waikiki. Beyond the Kalakaua/Kapiolani Station, the mainline remains below grade and services Waikiki, and the University line emerges as an aerial guideway functioning as a "pinched loop" transit operation.

The preliminary assessment entailed an evaluation of the subway options in terms of impacts on system planning and operation, guideway geometry and alignment constraints, right-of-way, geological conditions, construction methods, building protection schemes, environmental impacts, and estimated construction costs.

The right-of-way impacts associated with the Kapiolani/Waikiki Subway options are most severe near the required portal structure Koko Head of the Kalakaua/Kapiolani Station. The portal, located in the median of Kapiolani Boulevard, facilitates the transition to the original University-bound aerial alignment. The existing roadway would be widened to maintain the original traffic capacity, resulting in property takes on the makai side of the road. Eight parcels of property have been identified for acquisition at this portal location, which would result in the displacement of 22 residences, 14 businesses, and the demolition of six structures. Other portal solutions with associated environmental impacts exist and are addressed as a part of the technical memorandum.

The subsurface conditions along the proposed subway alignment are highly complex. From the available soils data, it appears that geotechnical conditions are similar to those anticipated for the Hotel Street Subway. Several known tunneling and station construction methods are technically feasible and appropriate for most of the anticipated soil conditions. Therefore, it is assumed that tunneling methods proposed for the Hotel Street Subway could also be used for the Kapiolani/Waikiki Subway options.

The eight aerial stations associated with Option "A" are replaced with seven underground passenger stations for Options "B" and "C." The geological conditions along the Kapiolani/Waikiki Subway alignment indicate that cut-and-cover techniques would be used for the passenger station construction. Recent exploratory tests at the proposed Civic Center Station site have indicated that the local soil conditions are not sufficiently impervious to withstand the expected hydrostatic head at the invert elevation of the station cavern. In addition, tests at this site indicate that during excavation the infiltration rate may exceed the feasible capacity of standard dewatering devices. Nonstandard methods of construction are applicable and could be successfully utilized to complete the underground stations. However, such construction is expensive, disruptive, and time-consuming.

Based on the available geotechnical information, initial estimates indicate that within the study limits, six of the seven subway stations would require special construction using methods similar to those described for Civic Center Station.

An order-of-magnitude cost estimate has been prepared for Option "A" and the two Kapiolani/Waikiki Subway configurations defined as Options "B" and "C." Conceptual-level plan and profile drawings were used to prepare the subway estimates. In addition, generic information has been extrapolated from the Hotel Street Subway Study and applied to appropriate line items.

The following table is a breakdown of total cost by alignment section. The alignment sections are depicted in Figure 1 and are used to identify system segment costs. The segment costs are only accurate for the specifically identified options. Combining Option "B," Section 2, with Option "A," Section 1, is invalid because it neglects cost implications associated with the guideway transition between the two options.

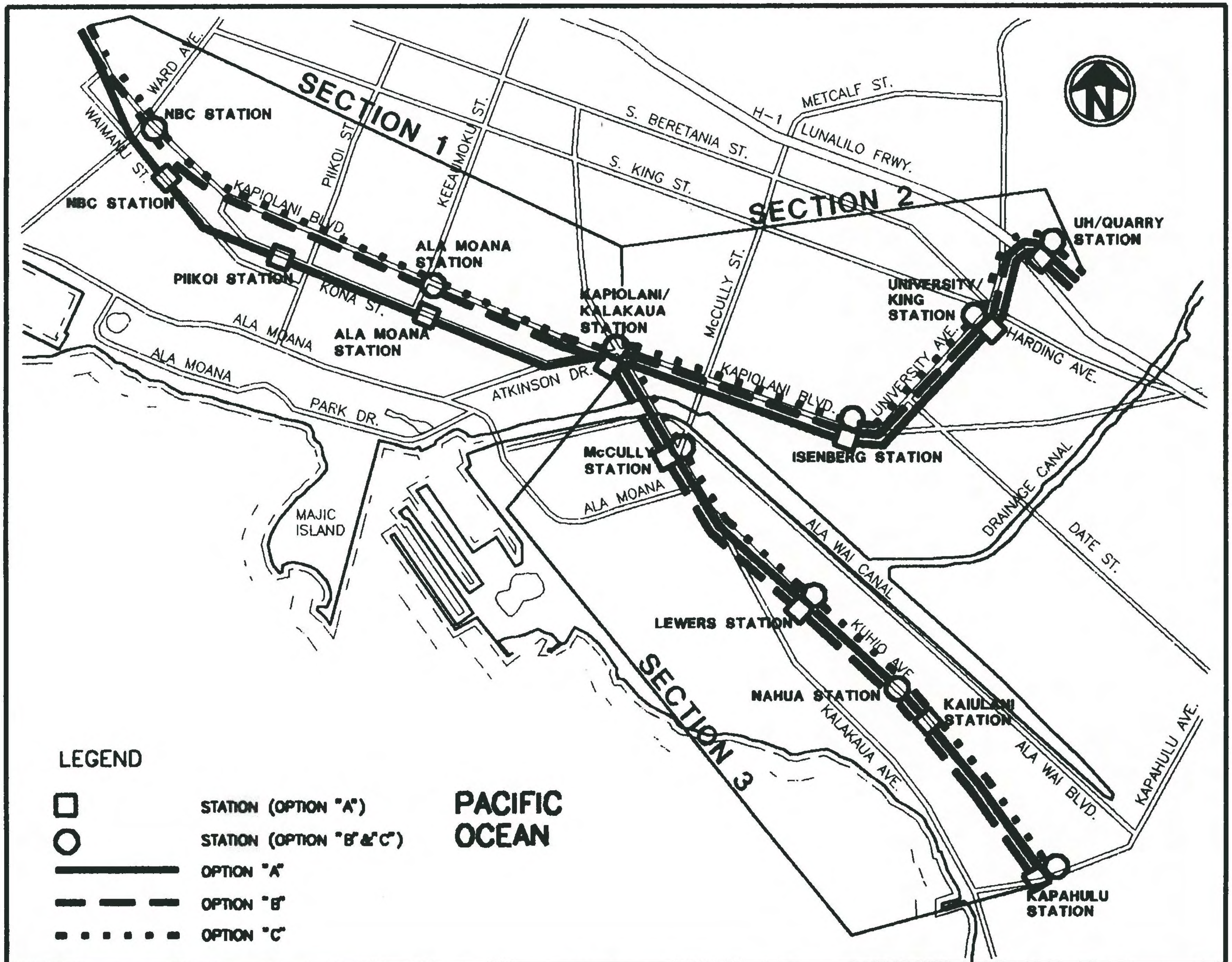
COMPARISON OF ALTERNATIVES: Total Cost By Section
(Note: All cost in $1000s)

	OPTION "A"	OPTION "B"	OPTION "C"
SECTION 1	153,520	433,376	433,376
SECTION 2	122,728	131,756	128,294
SECTION 3	131,789	393,317	449,977
TOTAL	$408,037	$958,449	$1,011,647

Option "B" is considered a fairly representative solution, with features that characterize a typical subway configuration for the Honolulu Rapid Transit Program. Option "C" was developed as an optimum subway configuration to be used primarily as a gauge to measure the variation of cost between alternative subway solutions.

The cost differential between Options "B" and "C" is relatively small in comparison with the cost differential associated between these options and the Option "A" solution. Other subway variations do exist and further engineering may reveal solutions that cost less than Option "B." An idealized lower boundary cost could theoretically be established by mathematically combining the respective lowest cost sections of Options "A" and "B." The resultant total cost of $670 million excludes guideway transition costs for required right-of-way, portal and station structures. At a minimum, these features would increase the total by approximately $88 million, resulting in an idealized least cost Waikiki Subway of $758 million or $350 million more than Option "A."

In conclusion, the preliminary assessment of the Kapiolani/Waikiki Subway indicates that a feasible underground solution does exist, at a substantial additional cost.



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GRAPHIC SCALE

KAPIOLANI/WAIKIKI SUBWAY STUDY

FIGURE 1

PRELIMINARY FEASIBILITY ASSESSMENT OF KAPIOLANI/WAIKIKI SUBWAY

INTRODUCTION

The Base System for the fixed guideway portion of the Honolulu Rapid Transit Program (HRTP) conforms with the general definition of the Locally Preferred Alternative (LPA). The System, as proposed, will be a fully automatic, electric-powered, grade-separated, transit facility that includes 24 passenger stations along 17.3 miles of fixed guideway structure.

The System is located in the City and County of Honolulu. It originates at the Waiawa Station and has a Mainline that extends to the University of Hawaii/Metcalf Station. The current alignment has one variation, designated as the UH/Quarry Option. This option involves the reorientation of a portion of the alignment into the lower campus of the University of Hawaii, and enhances the capability to extend the system to East Honolulu. Waikiki is served by an independent "pinched-loop," which interfaces with the Mainline at the Kalakaua/Kapiolani Station. The base system also includes approximately 1.5 miles of underground subway in Downtown Honolulu. The subway extends along Hotel Street through the Chinatown Special District, the financial district, and below the Hawaii Capital Special District, thereby mitigating adverse environmental impacts to these sensitive areas.

The purpose of this study is to evaluate the feasibility of extending the subway beyond Downtown Honolulu under Kapiolani Boulevard and through Waikiki under Kalakaua and Kuhio avenues. The objective is to use existing information and provide a conceptual assessment of underground alignments, station locations, cut-and-cover subway station options, and a preliminary comparison of environmental impacts between the aerial and underground alternatives within the study limits. In addition, this study includes an order-of-magnitude cost estimate for each alignment option based on generic tunnel configurations and assumed geotechnical conditions.

The limits of the Kapiolani/Waikiki Subway Study encompass the portions of the alignment Koko Head of the Hotel Street Subway portal near Dreier Street to the UH/Quarry Station at the University of Hawaii and through Waikiki to the Kapahulu Station. Three options have been evaluated for the preliminary assessment of the Kapiolani/Waikiki Subway. These are as follows:

> Option "A" — Aerial alignment which generally follows the Base System with the UH/Quarry Option as described above. The operation of the option differs from the Base System in the LPA Report in that the alignment to the UH/Quarry functions as the Mainline and the alignment to Waikiki functions as a pinched loop.
>
> Option "B" — Subway alignment continuing from the Hotel Street Subway to the Kalakaua/Kapiolani Station via Kapiolani Boulevard. The Mainline portals on Kapiolani Boulevard Koko Head of the Kalakaua/Kapiolani Station and continues towards the University Quarry in an aerial guideway configuration. The Waikiki Line is in a subway configuration through Waikiki and functions as a pinched loop operation similar to the aerial alignment described in Option "A."

Option "C" — Subway alignment continuing from the Hotel Street Subway to the Kalakaua/Kapiolani Station via Kapiolani Boulevard. The alignment is similar to Option "B" except the Mainline continues through Waikiki instead of to the University of Hawaii. The alignment to the UH/Quarry portals on Kapiolani Boulevard Koko Head of the Kalakaua/Kapiolani Station, and functions as a pinched loop operation.

These options are illustrated by Drawings 2 through 37 in Attachment 1. The underground options provide alternative means to bring the fixed guideway system through Waikiki in a subway configuration. Variations of these options are also discussed in some detail as part of this study.

PRELIMINARY SUBWAY ASSESSMENT

Alignment Description

For purposes of this study, Option "A" is regarded as the Base Option. The Subway Options "B" and "C" follow the general alignment and station location characteristics of the Base System; however, some modifications were necessary due to physical and right-of-way constraints.

Passenger station platforms are typically designed for an ultimate length to accommodate increased patronage and future expansion. Platforms for aerial and at-grade stations are initially constructed to the base length specifications. Subway stations are difficult to expand, and, therefore, the platforms are planned to be constructed to the ultimate lengths. The cost estimates reflect platform lengths based on the base for the aerial alignment and the "ultimate" for the subway alignment.

Option "A" begins as an aerial guideway at the termination of the Hotel Street Subway, which is located on Waimanu Street approximately 400 feet Ewa of Ward Avenue. Details of this alignment are depicted in Drawings 2 to 13 in Attachment 1. The following stations and associated attributes are characteristic of Option "A":

OPTION "A" — STATION ATTRIBUTES

STATION	TYPE Aerial/Subway	PLATFORM LENGTH (ft.) Base/Ultimate
(Mainline)		
Neal Blaisdell Center	A	240/320
Piikoi	A	240/320
Ala Moana Center	A	240/320
Kalakaua/Kapiolani (Transfer)	A	240/320
Isenberg	A	240/320
University/King	A	240/320
UH/Quarry	A	240/320
("Pinched Loop")		
Kalakaua/Kapiolani (Transfer)	A	100/100
McCully	A	100/100
Lewers	A	100/100
Kaiulani	A	100/100
Kapahulu	A	100/100

Details of Option "B" are shown in Drawings 14 to 25 in Attachment 1. Physical constraints along Waimanu and Kona streets present construction difficulties for a subway configuration, and an underground alignment be shifted to Kapiolani Boulevard provides for a wider and more accessible corridor. The additional right-of-way available along Kapiolani Boulevard permits the use of side-by-side subway tunnels. The alignment along Kapiolani Boulevard also provides access to the future "Super-Block" development mauka of Kapiolani Boulevard with associated joint-development opportunities. Other modifications include the consolidation of the Piikoi and Ala Moana Stations into a centralized location on Kapiolani Boulevard Ewa of Keeaumoku Street, and the relocation of the Kaiulani Station in the Ewa direction to the proximity of Nehua Street. Drawing 1 illustrates these changed conditions and a detailed discussion follows. The following table outlines the attributes characteristic of Option "B":

OPTION "B" — STATION ATTRIBUTES

STATION	TYPE Aerial/Subway	PLATFORM LENGTH (ft.) Base/Ultimate
(Mainline)		
Neal Blaisdell Center	S	320/320
Ala Moana Center	S	320/320
Kalakaua/Kapiolani (Transfer)	S	320/320
Isenberg	A	240/320
University/King	A	240/320
UH/Quarry	A	240/320
("Pinched Loop")		
Kalakaua/Kapiolani (Transfer)	S	100/100
McCully	S	100/100
Lewers	S	100/100
Nahua	S	100/100
Kapahulu	S	100/100

Option "C" retains the subway constraints associated with Option "B" and therefore reflects the same alignment modifications as previously described for Option "B." Details of Option "C" are shown in Drawings 26 to 37 in Attachment 1, and the station configurations are outlined in the following table:

OPTION "C" — STATION ATTRIBUTES

STATION	TYPE Aerial/Subway	PLATFORM LENGTH (ft) Base/Ultimate
(Mainline)		
Neal Blaisdell Center	S	320/320
Ala Moana Center	S	320/320
Kalakaua/Kapiolani (Transfer)	S	320/320
McCully	S	320/320
Lewers	S	320/320
Nahua	S	320/320
Kapahulu	S	320/320
("Pinched Loop")		
Kalakaua/Kapiolani (Transfer)	S	100/100
Isenberg	A	100/100
University/King	A	100/100
UH/Quarry	A	100/100

Configuration Changes

Alignment Shift: Waimanu/Kona to Kapiolani

To physically move the guideway from an aerial alignment to a subway configuration required some modifications to the original alignment. The most significant change occurred along Waimanu and Kona streets. A number of man-made physical constraints such as the Uraku Tower, Honfed Tower, Ala Moana Building, Ala Moana Pacific Center, 1601 Kapiolani (under construction), Ala Moana Hotel, and the Ala Moana Shopping Center parking garage, their foundations, and the limited 40-foot right-of-way typical along Waimanu and Kona streets necessitated shifting the alignment mauka to Kapiolani Boulevard. The implications of shifting the alignment to Kapiolani Boulevard are not significant in terms of ridership. The most significant impact would be the elimination of aerial structures within this study area.

Elimination of Piikoi Station

The consolidation of the Piikoi and Ala Moana Stations into a station location Ewa of Keeaumoku Street provides a centralized location with a good existing bus interface along Kona Street. It also affords an opportunity for potential joint development with properties adjacent to the intersection of Kapiolani and Keeaumoku. Although this station is projected to have one of the highest patronage levels (16,800 per day in the year 2005), only a 5.2 percent decrease in ridership is projected by the elimination of this station. Furthermore, the proposed Ewa entrance of the Ala Moana Station is only 850 feet from Piikoi Street.

Kalakaua/Kapiolani Transfer Station

The Kalakaua/Kapiolani Station functions as a transfer station for the three options evaluated within this study. The base system or Option "A" is configured such that, Waikiki-bound passengers must transfer from the Mainline to the Waikiki Line at the Kalakaua/Kapiolani Station. Under this scenario, the Waikiki Line functions as a "pinched-loop" operation. Option "B" emulates this operating scheme.

Option "C" transfers the "pinched-loop" operation from Waikiki to the University-bound alignment. Under this scenario the Mainline continues through Waikiki, and University-bound passengers would be required to transfer at the Kalakaua/Kapiolani Station.

The major implications of this variation entail ridership, station capacity, station platform lengths, and system cost. Introducing a mandatory transfer for all Waikiki fixed-guideway users is estimated to result in a 6.6 percent loss of ridership. Alternately, if University-bound passengers were required to transfer, the loss of ridership is estimated to be less than that generated by the mandatory Waikiki transfer. Inherent in the Option "C" scenario is the lengthening of station platforms in the underground stations in Waikiki to the ultimate length of 320 feet.

Station Relocation: Kaiulani to Nahua

The subway configuration in Waikiki includes the relocation of the Kaiulani station. This Station was shifted about 600 feet Ewa and renamed the Nahua Station to accommodate a horizontal curve between Kanekapolei Street and Kaiulani Avenue and to better serve the State's planned convention center.

Nimitz Option

The overall results of the Kapiolani/Waikiki Subway feasibility assessment are also valid for the Nimitz Option which was issued as Addendum No. 10 to the Request for Proposals and Contract Documents for System Design, Supply, Construction and Maintenance of the Honolulu Rapid Transit Development Project dated November 1, 1990.

The only significant impact to this study involves the selection of a suitable portal location near the NBC Station. The implications would be similar to the Hotel Street Koko Head portal, with land acquisition being the prinicipal consideration.

Alignment Constraints

Transferring the original aerial alignment to an underground configuration required evaluation of significant natural and man-made features such as streams, bridges, buildings, and streets. These constraints, considered in conjunction with the system geometric criteria, influence the design of the final system alignment.

The major alignment constraints associated with Option "B" include the following features:

1. Existing building foundations
2. Proposed Honolulu Convention Center
3. Ala Wai Canal
4. Potential portal locations
5. Potential transfer station locations

Option "C" includes all of the above constraints for Option "B" and entails switching the Mainline service from the University leg of the alignment to the Waikiki branch. This revision is reflected by a lengthening of the Waikiki Subway station platforms from 100 feet to 320 feet. Conversely, the typical station platforms on the University Line are shortened from 240 feet to 100 feet. To meet the system geometric criteria, several additional adjustments to the guideway alignment were required. The additional constraints associated with these adjustments include:

1. Increased length of station platforms in Waikiki
2. Dual guideway configuration entering Waikiki.

The alignment depicted on Drawings 14 through 37 is based on limited design information. Should the Waikiki Subway Option be exercised, refinement to the depicted alignments is to be expected.

Right-Of-Way

The right-of-way implications associated with the Kapiolani/Waikiki Subway options are most severe near the portal structure Koko Head of the Kalakaua/Kapiolani Station. This portal, which emerges on Kapiolani Boulevard in the vicinity of Puehana Street, allows the guideway to transition to the original University- bound aerial alignment along the median of the roadway. The existing roadway will require widening to maintain the original traffic capacity. To accommodate this road widening, property acquisition will be required on the makai side of the road. Eight parcels of property have been identified for acquisition which include 22 residential units in six structures.

Other portal alternatives are possible near the Kalakaua/Kapiolani Station. One solution, which involves shifting the portal approximately 900 feet Koko Head along Kapiolani Boulevard, eliminating the need to acquire residential property, but it does require some right-of-way acquisition from Ala Wai Park. The estimated right-of-way requirements are indicated on the Plan and Profile drawings included in Attachment 1.

The remaining right-of-way impacts are relatively minor and are also shown on the Plan and Profile drawings included in Attachment 1. Station entrances have not been shown at this time, and the location is related to joint development possibilities. The preliminary assessment has determined that additional residential property takes would probably not be required for station entrances. The entrances are planned to be located in public right-of-way or acquired private property. This initial assessment has restricted private property acquisition to vacant lots, parking lots, and commercial property.

Subway Variations

Typically, an alignment selection process entails the evaluation of many alignment alternatives or variations. As previously defined, the purpose of this preliminary assessment is to consider a restricted number of solutions, encompassing the viable upper and lower boundaries of the fixed guideway options. However, other alternatives exist that may warrant further consideration. Of particular interest, is to explore potential solutions with the objective of minimizing construction costs.

This variation was analyzed assuming that the Waikiki Line would remain underground Koko Head of the Ala Wai Canal through Waikiki. An operating plan similar to Option "A" was also assumed, resulting in "pinched-loop" service to Waikiki with mandatory transfers at the Kalakaua/Kapiolani Station. The Mainline would emerge from the Hotel Street Subway Koko Head portal and extend as an aerial guideway through the Kalakaua/Kapiolani Transfer Station and continue to the University.

To achieve this result, the following three scenarios were considered:

1. Portal connection
2. Independent operation
3. Mechanical transfer.

A description and summarized evaluation of each scheme are presented below:

Portal Connection

This scheme provides a portal structure Ewa of the Ala Wai Canal, permitting a guideway transition from the aerial alignment at the Kalakaua/Kapiolani Station transfer to the Waikiki Subway Line. Although the Waikiki Line is intended to operate as a "pinched-loop," the guideway configuration must allow for a transfer of vehicles between the Waikiki Line and the Mainline to accommodate vehicle servicing at the Waiawa Maintenance Yard.

A guideway transition, or interline connector, between the two-line segments is desirable from an operating perspective because it provides added flexibility. Transit vehicles can be quickly transferred between operating segments to adjust for ridership demands or to replace vehicles in the event of a failure. The increased flexibility is generally highly desirable if system or vehicle failures occur during revenue service.

In addition, the guideway geometry of this configuration provides for a transfer station that can readily accommodate passenger transfers between station platforms. This solution minimizes the variation between guideway elevations, and the extent of vertical circulation that would be required at the Kalakaua/Kapiolani Station. From the perspective of a patron, this scheme exhibits the lowest perceived hardship for transfers as compared to the independent operations and mechanical operation transfers described below.

The major disadvantage associated with the portal connection scheme concerns the right-of-way and land acquisition requirements for the portal structure. These issues are magnified when considered in conjunction with constraints that govern the profile of the current alignment. At the Ala Moana Center Station the track profile is approximately 50 feet above grade to circumvent conflicts with the Ala Moana Shopping Center. The Ala Wai Canal presents an opposing constraint, driving the alignment to a depth of approximately 70 feet below the ground surface. Consequently, the guideway transition, which is limited to a six percent grade, would require significant right-of-way that would conflict with the planned Honolulu Convention Center complex. The proposed alignment would bisect the Honolulu Convention Center property.

Independent Operation

With this design scheme the Waikiki Subway functions as an independent operating segment. This scenario would eliminate the portal structure ordinarily required for an interline connector between the aerial Mainline and the Waikiki Subway. The Mainline station structures would permit the alignment to remain an aerial configuration Koko Head of the Hotel Street portal at Dreier Street. The Mainline would be aerial from the portal to the UH/Quarry Station.

This scheme eliminates the Waikiki portal structure, isolating the Waikiki "pinched-loop" from the Mainline. This scenario requires that the Waikiki Subway Ewa of the Ala Wai Canal terminates in a subway station below the Kalakaua/Kapiolani Transfer Station.

A major disadvantage of this scenario pertains to passenger transfers. The geometric configuration at the Kalakaua/Kapiolani Station would require transferring passengers to traverse a vertical circulation path, which may exceed 70 feet of differential elevation. This perceived obstacle is a major impact to the concept and function of a transfer station.

The isolated operation of the Waikiki Line serves as a second and major disadvantage to this scheme. Transit vehicles require both daily and unscheduled maintenance. Using the Waiawa Maintenance Yard and Shops for this activity is precluded by the lack of a guideway connection between the Mainline and the Waikiki Line. The obvious alternative is to provide an independent yard and shop in Waikiki to maintain the isolated transit vehicles. The space requirements for this facility is estimated to be 4 acres.

A feasible solution or practical location for the independent Waikiki maintenance facility has not been identified. The concept of an underground maintenance facility has been investigated. However, such a structure would require construction by cut-and-cover methods with the associated problems of controlling groundwater. In addition, this alternative requires a duplication of the functions of the Waiawa Yard, including equipment and staff. It will also require a second ATC system for the independent operation. When considered in unison with the transfer station shortcomings, this scenario was considered to be less attractive than the Waikiki portal solution.

Mechanical Transfer

The third scenario attempts to overcome the previously described maintenance facility obstacle by providing a mechanical lift to integrate the operating systems between the aerial Mainline and underground Waikiki Line. The guideway arrangement would be similar to the configuration proposed for the independent operating scheme. The Waikiki Subway Line would extend Ewa of the Ala Wai Canal and terminate in a subway station below the aerial Kalakaua/Kapiolani Transfer Station. The primary variation would entail a mechanical lift used to transfer vehicles between the two operating segments. This lift would be located adjacent to, or at, the Kalakaua/Kapiolani Transfer Station.

The principal advantage of this scheme is the elimination of negative aspects associated with the first two scenarios; specifically, the Waikiki portal structure and the Waikiki maintenance facility. This scheme, however, does not solve the vertical circulation problem associated with transfers between aerial and subway level platforms proposed for the Kalakaua/Kapiolani Station.

Several additional major disadvantages that seriously hinder the feasibility of this concept have also been identified. A mechanical lift or elevator designed to transport transit vehicles from an underground subway to an aerial guideway would take on proportions similar to the cranes used to load and unload containerized cargo ships. The proportion of such a facility would provide a visual impact at the Honolulu Convention Center site.

The location of the mechanical lift poses additional difficulty with regard to land acquisition. This structure would probably infringe on the Honolulu Convention Center property, thereby diminishing the positive aspects initially associated with this solution. This scheme also exhibits the greatest adverse impacts relative to system operations. Transferring vehicles between the Mainline and the Waikiki "Pinched-Loop" Subway Line would be a time- and labor-consuming process. It would interrupt normal revenue service while isolated segments of each line are deenergized to permit the physical transfer of vehicles. This operating constraint would occur on a daily basis to meet the essential transit vehicle maintenance and operating requirements.

In conclusion, the shortcomings of the mechanical transfer solution are relatively severe, and, therefore, this scheme is considered less desirable than the Waikiki portal solution.

Geology

The subsurface conditions along the proposed subway alignments are highly complex. However, based on the available information, it is expected that several known tunneling and station construction methods may be technically feasible and appropriate for most of the anticipated soil conditions. From the limited soils data available, it appears that geotechnical conditions are similar to those anticipated for the Hotel Street Subway. The soil borings indicated the presence of coral algal reef and coral algal detritus deposits, recent and older alluvium, Honolulu basalts, lagoonal sediments, and like Hotel Street the water table is close to the ground surface. Accordingly, it is possible that the same type of tunneling machine that is used for Hotel Street could be used for the Kapiolani/Waikiki Subway Options.

Borings drilled for the aerial alignment have been used for this evaluation of tunneling conditions. Only four borings were drilled between Ward Avenue and Kalakaua Avenue, three of which were one to two blocks makai of the underground alignment option. Six borings were drilled in the section of Waikiki Subway alignment along Kalakaua Avenue and Kuhio Avenue. Borings are spaced between 500 and 2,100 feet. A total of 1,100 feet of exploration drilling has been completed for the 15,600-foot Kapiolani/Waikiki Subway. This geotechnical evaluation is considered very preliminary, and a more comprehensive geotechnical program is desirable if the subway option to Waikiki is proposed.

The Kapiolani/Waikiki Subway tunnels and stations will be built in soft ground and reef deposits. The soils encountered along the alignment consist of coral-algal reef and coral-algal detritus interbedded with recent and older alluvium. The coral-algal reef can be as hard as 5,000 to 8,000 psi, but is much weaker at many locations. The lagoonal sediments consisting of sands, silts, and clays are generally very soft. Along the Kapiolani/Waikiki Subway route, the only very hard rock encountered in the borings is one of the Honolulu Series basalt flows found along Kuhio Avenue at depths ranging between 70 to 100 feet. This young, unweathered rock could be shallower at some locations and can reach unconfined compressive strengths of 25,000 psi.

The street elevation of the alignment varies between El. +5 to +6, with fills 4 to 6 feet thick. The water table exhibits variations due to tidal influences and is at approximately El. +1. The base of all the excavations will be well below the water table, with accompanying difficulties in construction. The Flood Insurance Rate Map indicates that the subway portions of the Kapiolani/Waikiki alignment are within the 100-year recurrence flood plain. This will influence the proposed construction method and related design features of the permanent facility.

The temporary retaining structures used to support open cut excavations should be designed for the expected flood water elevations. In general, these provisions would not be as rigid as those imposed on permanent facilities which are open to public access and have a much longer service life, thus exposing them to a statistically higher recurrence of flood waters. The flood provisions associated with open cut subway construction would also be applicable to excavations for the aerial guideway pier foundations.

Permanent subway stations and portals would require design features that restrict flood water inflow or provide an effective means of water removal.

Tunneling along the alignment will encounter medium to very hard coral-algal reef, coralline sands and gravels, and alluvial clays, sands and gravels. A combination of the above materials will almost always be excavated at the tunnel face. Tunneling in Honolulu Series Basalt and Tuff is not expected in this alignment according to the information now available. The coral-algal reef and the coralline sands and gravel are very permeable and therefore the selected tunneling method should be equipped to handle the expected water pressure.

Within the reef deposits, the tunnel is expected to encounter a full face of hard, well-cemented coral (locally containing soft or loose filled cavities), flowing sand and gravel, and a mixed face of these conditions in the heading. Tunneling in the reef deposits will require a machine or technique with efficient hard-rock excavation capability and soft-ground-type ground support both at the face and behind the shield. Tunneling through the very soft lagoonal deposits will also require specialized tunneling methods or ground improvements.

There are many special buildings, particularly along Kuhio Avenue, that may require building protection or underpinning. The Outrigger Maile Sky Court, Royal Kuhio, Pacific Monarch and the Kaimana Villa are typical examples of special buildings that possibly require protection. If dewatering is required in localities where the dewatering zone of influence extends to areas with compressible soils, excessive ground settlement can be expected as demonstrated by past experience. This condition is analogous to the ground water lowering and subsequent surface settlement chronicled in Mexico City.

Station construction will also require special measures. The coral-algal sediments are very permeable and conventional dEwatering may not be feasible at some locations. The water conductivity of the coral-algal reef and detritus is very high and for station construction may make traditional dewatering methods for station construction impractical.

To obtain a dry excavation for station construction without dewatering, a watertight excavation should be provided. This could be achieved with intersecting drilled piers or slurry walls. The bottom of the excavation should also be watertight, and this may be more difficult to achieve. In some cases an extensive stiff alluvial deposit may be thick enough and have sufficiently low permeability to provide a water barrier for the bottom of the excavation, which then may be completed in the dry. However, at most of the station locations, the soils at the base of the excavation may not be able to provide effective water barriers. At locations where there is no impermeable layer, the excavation would have to be conducted underwater by clamshell or dredging techniques and the bottom reinforced concrete slab poured underwater by tremie methods. The enclosed concrete structure would then be dewatered. In some cases tie-downs may be required to compensate for uplift on the bottom slab and buoyancy of the structure.

Slurry wall construction is considered a viable alternative to support the station walls. A properly braced slurry wall may limit settlement of adjacent buildings and may also provide an effective groundwater cut-off. The walls would be constructed in a salt water environment, which could affect the gel properties of the bentonite slurry. The presence of loose to very loose sands at shallow depths may still present excavation difficulties as will the hard coral reef rock. Large voids in the coral-algal deposits could cause sudden loss of the bentonite slurry with accompanying trench collapse and adjacent surface settlement.

Construction Techniques

In traditional subway construction, two types of running or line tunnel construction are typically considered; cut-and-cover tunnels and mined tunnels. The construction method differentiates the two types of tunnels, with each method having advantages and disadvantages dependent upon the site-specific conditions that are encountered.

Mined Tunnels

In general, mined-tunnel construction refers to excavation techniques that are performed below grade, thereby minimizing disruption of surface activities. Numerous mining methods have been devised over the years to cope with a multitude of tunneling environments. Mined tunnels have been constructed in materials ranging from extremely hard rock to very soft clays and silt, all with varying exposures of hydrostatic head, and each with unique geological profiles requiring unique design solutions. Mined tunnels are attractive because they are unobtrusive to surface activities during construction and service operations. They generally function unnoticed for decades and require a minimal amount of maintenance effort. In addition, the capital cost of a mined tunnel may be a significant advantage over other tunneling techniques, particularly when excavations are deep or surface disruption becomes prohibitive.

The tunneling environment encountered along the Kapiolani/Waikiki Subway route suggests that a Tunnel Boring Machine (TBM), utilizing Slurry Shield or Earth Pressure Balance (EPB) Shield technology may be selected as an appropriate construction method.

The Slurry Shield is a TBM designed to work in soft-ground below the water table. It is a closed face, fully enclosed TBM. As the Slurry Shield is forced ahead into the ground by jacks, the rotating cutter head, fitted with cutting tools, cuts, grinds, and excavates the ground materials. As the TBM advances, a slurry of bentonite is automatically mixed with the ground just ahead of the cutter head. This bentonite slurry enters the ground materials under an appropriately designed pressure and forms an impervious "cake" that resists the groundwater pressure.

The Slurry Shield TBM is highly mechanized and typically computerized. Because the men never see the ground, they must rely on instruments to determine the amount of material being excavated; too much material excavated per foot of advance would result in excessive settlement at the ground surface. Bentonite slurry is expensive, therefore, it is separated and recycled for continued use. Bentonite reclamation facilities are located on the ground surface at regular intervals along the route for this purpose.

The Earth Pressure Balance (EPB) Shield is a variation of the slurry shield. The men work inside the protection of the EPB shield, operating the TBM and erecting the support system. The rotating EPB cutter head, fitted with appropriate cutters, is jacked into the ground and excavates it. However, instead of using a slurry made of bentonite to resist the groundwater, a slurry made of the earth and water actually encountered at the face is mixed inside a pressurized chamber. This mixture of the earth and water is carefully monitored by various instruments, and is kept at the necessary pressure and density inside the pressurized chamber to resist the outside soil and groundwater pressure. The material is discharged without loss of pressure by a screw conveyor, which is synchronized to the advance of the shield. No cleaning and/or recycling of the earth mixture is needed.

The excavated volume and the discharge volume must be the same. To achieve this, the advance of the EPB shield is controlled either by monitoring the discharged muck volume, and/or by monitoring the earth pressure of the face. Earth pressure within the pressure chamber is controlled by observing the thrust of the shield jacks, torque, and revolving speed of the cutter frame and the torque and revolving speed of the screw conveyor.

Both shield machines are well suited to work below the water table along the Kapiolani/Waikiki Subway alignment. However, should either TBM encounter large subsurface voids in the coral-algal deposits, the slurry could be lost. An accompanying inflow of water would endanger the workers and result in subsurface settlement. These potential problems are generally addressed during preliminary and final tunnel design stages.

Cut-and-Cover Tunnels

Cut-and-cover tunneling is the traditional method of underground construction and as such is utilized daily, albeit on a small scale, for the construction of underground utilities. It is a relatively straightforward method, familiar to many general contractors, utilizing readily available technology.

In cut-and-cover tunneling, a temporary earth retaining system is first installed from the ground surface. The retaining system might consist of steel sheet piles, soldier piles, and lagging or a concrete slurry wall. The choice of system would be dependent upon the depth of excavation, geotechnical conditions, structure configuration, and proximity of surrounding structures.

The earth between the retaining walls is progressively removed and struts are placed between the walls to support the excavation. Once the desired elevation is reached, the structure is constructed within the excavation, the excavation backfilled, and the temporary retaining system removed or abandoned in place.

Construction is complicated by the presence of a high water table and permeable soils. Such a condition requires the installation and operation of dewatering equipment to allow the construction to progress without the potential for water infiltration and/or ground destabilization. If the soil consists of soft clays or silts, the lateral loads on the retaining walls will be sizeable, especially for a deep excavation as required for subway construction.

As the Kapiolani/Waikiki Subway alignment runs through permeable soils, completely below the water table, it will be necessary to dewater the site ahead of the excavation. Once the lowest excavation elevation is reached, the tunnel base slab is constructed, stabilizing the bottom of the retaining walls. Then, inner walls and the roof slab are constructed. Waterproofing, if required, is placed prior to construction of the respective box-section elements. In progressive order, working upward, the excavation is backfilled and intermediate struts are removed. Once the backfilling is completed, the street surface is restored and opened to traffic.

An inherent disadvantage of cut-and-cover tunnels is the extent of surface disruption caused by the required open excavation, which is usually situated along street rights-of-way. Various methods, such as "top-down" construction, have been developed and utilized in an effort to minimize surface disruptions. However, present day activities in the urban areas surrounding Kapiolani Boulevard, Kalakaua Avenue, and Kuhio Avenue, preclude even the "top-down" construction method, which would be too disruptive. In addition, the feasibility of cut-and-cover line tunnel construction is also diminished by specific dewatering complications discussed under Station Structures.

Stations Structures

The eight aerial stations associated with Option "A," are replaced with seven underground passenger stations for Options "B" and "C." In general, two methods of providing an underground space for construction of a station are typically available; cut-and-cover excavation or mined-cavern excavation.

Several modern subway systems have passenger stations constructed with mined-cavern excavation techniques. The construction of these stations is often complex; however, the benefit associated with minimized surface disruptions generally exceed the negative aspects associated with mining underground station caverns. However, mined-cavern excavations are extremely expensive even in the best geological conditions.

The geological conditions along the Kapiolani/Waikiki Subway alignment are not favorable for the construction of mined-cavern subway stations. The geology is composed of soft ground and pervious corals with voids, well below the water table. The groundwater would have to be controlled with compressed air or by dewatering with deep wells. Therefore, cut-and-cover passenger station construction will be assumed for this preliminary assessment of providing a subway system from Downtown Honolulu through Waikiki.

Cut-and-cover station construction would be performed using techniques identical to those described for line tunnels. The extent of surface disruption would be limited to actual station locations, and additional isolated areas dedicated for special trackwork or ancillary structures.

It is anticipated that any cut-and-cover excavation along the guideway alignment would be accomplished using concrete slurry walls as the earth retaining structure. A slurry wall is beneficial in that it can be used to limit deflections of adjacent buildings more effectively than other systems. The second advantage of the slurry wall is that it can be used to isolate the excavation (a cut-off wall) so that dewatering efforts within the excavation will not draw down the surrounding water table, thereby causing additional settlement of adjacent buildings.

For a slurry wall to be as effective as a cut-off wall during dewatering, the local geology must have a measure of permeability that restricts the volume of groundwater inflow, particularly through the exposed invert during station excavation and construction. Recent exploratory tests at the proposed Civic Center Station site have indicated that the local soil conditions are not sufficiently impervious to withstand the expected hydrostatic head at the invert elevation of the station cavern. In addition, tests at this site indicate that during excavation the infiltration rate may exceed the feasible capacity of standard dewatering devices. Consequently, construction of this station would probably be performed using a dredging operation, followed by underwater construction of a tremie slab. The tremie slab would be designed to seal the station invert from continued water inflow. Such construction is expensive, disruptive, and time-consuming.

Currently ten subsurface exploratory borings have been obtained within the study limits of the Kapiolani/Waikiki Subway. Based on this information, an estimate has been prepared that identifies six stations that may require dredging and underwater construction using methods similar to those described for the Civic Center Station. An initial assessment has identified the following stations as candidates for the dredging and underwater construction technique:

Neal Blaisdell Center
Ala Moana Center
Kalakaua/Kapiolani
McCully
Nahua
Kapahulu

Similar to the Hotel Street Subway, all underground stations will require provisions for emergency exits, ancillary areas, and ventilation structures.

Building Protection

Subway construction invariably results in ground disturbance and some surface settlement generated by the excavation. Settlement caused by tunneling through open country will generally go unnoticed with no objection or adverse consequence. In urban areas, the settlement trough or zone of influence may extend below buildings, and the resulting displacements can cause architectural or structural damage.

Settlement of surrounding structures can be minimized by proper design and careful construction of earth retaining, bracing, or lining systems combined with a diligent ground movement monitoring program and building protection plan. However, even with the most careful planning and construction, some settlement of existing structures can be expected. The goal should be to limit such settlement to an acceptable minimum.

Some types of buildings, such as those founded on end-bearing piles in a stratum not affected by tunneling, will not be damaged by the settlement trough and the resulting differential settlement. Buildings on friction piles or mat foundations may be distorted by the settlement trough and suffer varying degrees of distress.

Important utilities may be affected. Historic buildings and monuments, especially those made of brick, are sensitive to differential settlement, as are older buildings of poor construction.

Tunnel designs typically include building protection schemes designed to mitigate potential settlement-related distress to existing structures. Typical building protection techniques include ground stabilization, jet grouting, chemical grouting, pin piles, and extensive underpinning of existing structures. During construction, remedial measures, such as compaction grouting, are available should excessive settlement or other hazardous ground movements evolve.

For purposes of this preliminary assessment, a conceptual estimate of building protection requirements has been prepared. It is assumed that no extraordinary protection measures will be required from Station 764+50 to Station 836+00, which encompasses the alignment along Kapiolani Boulevard. However beginning at Station 4+00, Koko Head of the Kalakaua/Kapiolani Station, extending to Station 88+40 at the termination of the Waikiki Line, a moderate amount of building protection is anticipated. Within these limits, a building protection effort comparable to that for the Hotel Street Subway alignment has been assumed which includes ground stabilization, jet grouting, chemical grouting, pin piles, and possibly extensive underpinning of existing structures.

Environmental Comparison

Short-Term Impacts

Traffic. Although there would be significant traffic disruption with any option, subway construction (Options "B" and "C") would impact traffic less severely than aerial construction (Option "A") because much of the tunnel would be bored. In the areas of cut-and-cover construction for the subway alignment, however, the disruption to traffic during construction would be significant. Portions of the alignment within the study limits that would require cut-and-cover comprise approximately 22 percent of the alignment with Option "B" and approximately 25 percent of the alignment with Option "C."

Business Disruption. The construction of Options "B" and "C" would disrupt business somewhat less than Option "A" because large portions of these subway constructions would be bored tunnel construction, allowing businesses to remain open at grade with minimal disturbance. In the areas of the subway that would be cut-and-cover construction (station locations), however, there would be considerable disruption during construction.

Generally, construction of the aerial guideway would take approximately one and one-half years and the area of pier construction would take approximately six months. The tunnel construction would take two to three years, while each cut-and-cover station would take approximately two and one half years, of which 18 months would be disruptive to the general public.

Specific construction practices that could reduce impacts on businesses include:

- reducing noise and dust near businesses;
- adhering to scheduling so that merchants could plan sales and other retail events around construction;
- using information programs to highlight alternative street approaches and parking locations; and
- coordinating the temporary location of loading zones during construction to help ensure that all business delivery entrances are less than one block away from relocated loading zones.

Noise and Vibration. Except in the areas of cut-and-cover construction (station locations), noise would be significantly less with the subway options (Option "B" and "C") than with the aerial alignment (Option "A") because the construction would be carried out below grade, below the line of sight and covered. Areas surrounding cut-and-cover construction would experience the most noise in the beginning of construction; however, the noise would decrease as the excavation deepened. Vibration would be perceptible at some locations during construction; however, final design solutions would exclude the potential of any structural damage. Option "A", the aerial option, could have more severe impacts as compared to options "B" and "C" due to the equipment used for construction of the pier columns.

Noise control during construction would primarily be accomplished by including noise specifications in construction criteria, such as limiting the hours of construction. Also, the contractor would comply with the Community Noise Control requirements of the State of Hawaii.

Specific structures adjacent to construction operations would require monitoring for vibration during construction. A preventive program would be established through contract specification. Additional detailed studies would be required later in this design phase.

Visual. Because much of the subway construction (Options "B" and "C") would be below grade, it would create less visual impact than the aerial option. Cut-and Cover station construction along Kuhio Avenue and Kapiolani Boulevard would cause severe visual impacts. The view along Kapiolani Boulevard, Kuhio Avenue, the Kalakaua Avenue Bridge, and the Ala Wai Canal are the areas of greatest concern regarding visual impact with the aerial option (Option "A").

Historic/Archaeological. Fewer historic resources would be affected (proximity) by the subway alignment (Options "B" and "C") than the aerial alignment because subway construction would be below grade with any of the alternatives. In addition, the historic mahogany trees on Kalakaua Avenue would be removed or significantly pruned during construction of Option "A".

There is the potential for archaeological finds during the construction of either subway option (Options "B" or "C") or the aerial option (Option"A"); particularly in the area of pier column construction. In terms of areas of potential finds by square footage Options "B" and "C" are only slightly greater.

Parklands. The aerial alignment would take a small mauka portion of Princess Kaiulani Park for a station location with Option "A." However, a reconfiguration of the park to include a portion of Kaiulani Avenue would mitigate this impact. There would be minimal disruption to the Ala Wai Clubhouse and Field during construction of any of the options.

Hazardous Waste. There could be areas of hazardous waste concern with any option selected; however, the extensive excavation required by either subway option (Option "B" and "C") would increase the likelihood that a subway option would have the greatest impact.

Long-Term Impacts

Traffic. Long-term traffic impacts would be much less severe for Options "B" and "C" than Option "A," particularly in the Waikiki area. Once the tunnel and station construction were completed, traffic circulation would be similar to what it is today. With the aerial alignment, there would be substantial long-term changes in traffic flow due to the introduction of supporting columns in the street right-of-way, especially in Kuhio Avenue.

Business Displacement. Initial estimates of business displacements indicate that the displacements as a result of the construction of the subway options (Option "B" and "C") would be less than the aerial option (Option "A"). The subway alignment Option "B" would not require any business displacements between Waimanu and Dreier Streets to the terminus in Waikiki. The subway alignment Option "C" would require approximately six business displacements between Waimanu and Dreier Streets to the terminus in Waikiki. The six businesses are Korean Senior Center, Blue Jeans and Bikinis, University Bicycle, In Sam Barbeque, Chio Yakiniku and Club Rock-Za. In addition, Options "B" and "C" would displace 14 businesses (Al Phillips the Cleaner, Rent-A-Center, Kapiolani Market, Pacific Island Estate Jewelry Corporation, Shirubachi, Pub 1901, Domino's Pizza, Suruya Group Hawaii International, Inc., Polo Tours, Super Cuts, True-Value Hardware, Hawaiian Eyeland, Kapiolani Massage Specialists, Inc., and Mitsuko International Hana, Inc.) at Kapiolani Plaza along the makai side of Kapiolani Boulevard at the portal.

The aerial alignment (Option "A") between the subway portal near Waimanu and Dreier Streets to the Honolulu Convention Center would require approximately 24 business displacements.

Residential Displacement. There would not be any residential displacement with Option "A." With Options "B" and "C," there would be 22 residences displaced in three apartment buildings, near the portal structure at Kapiolani Boulevard and Pumehana Street.

Noise and Vibration. Although noise and vibration impacts will be determined by the selection of a technology, generally the potential for adverse airborne noise impacts would be eliminated with the subway alternatives (Option "B" and "C"). Noise and vibration impacts from the aerial guideway (Option "A") would be most noticeable in residences and hotels along the alignment in Waikiki, particularly those rooms located nearest to and at the same elevations as the alignment. Some vibration could be experienced at some of the buildings closest to the aerial structure. For a steel wheel/steel rail system, vibration levels are expected to be acceptable for residential structures beyond 25 to 30 feet and commercial structures at 10 to 20 feet. For other technologies, the vibration levels are acceptable at 15 to 20 feet for residential structures and 10 to 20 feet for commercial structures (Wilson, Ihrig and Associates, Inc. 1989).

If a Waikiki subway is chosen and a steel wheel/steel rail system is selected, groundborne noise and vibration would be audible within small buildings along the alignment (Wilson, Ihrig and Associates, Inc. 1989). Within large commercial structures or hotel buildings, the groundborne noise and vibration from subway options would not be audible for any of the rapid transit vehicle technologies.

Visual. Options "B" and "C" would not have significant visual impacts on the streetscape because the guideway would be below grade. The addition of an aerial guideway, particularly along Kuhio Avenue, would be a significant visual addition to the environment. The visual impacts to the Kuhio Theater, Conrad Apartments, Ala Wai Canal, the Kalakaua Bridge, and the Kalakaua Avenue mahogany trees with the addition of an aerial guideway, particularly the columns, to the streetscape would be of particular concern.

Historic/Archaeological. An aerial option (Option "A") could affect the setting of several historic resources (Kuhio Theater, Kalakaua Bridge, and the Ala Wai Canal) along the alignment. The historic mahogany trees would be removed or, depending on design adjustments, significantly pruned. None of these historic resources would be affected for the long term with Options "B" and "C."

Once construction was completed there would not be any additional potential impacts to archaeological resources as a result of any of the options selected.

Flood Plain Impacts. The Federal Emergency Management Agency (FEMA) Flood Insurance Rate maps indicate that a large portion of the Waikiki options would be in one of the largest 100 year floodplains. The floodplain includes the 100-year base floodplains associated with Manoa-Palolo Stream and the Ala Wai Canal; it also includes an area inundated by worst-case hurricane conditions (AA/DEIS).

All the Options would be in the 100-year floodplain beginning at approximately Ward Avenue and going Koko Head to the terminus in Waikiki, with a small exception on Kuhio Avenue between Kaiulani Avenue and Kapuni Street which is outside the floodplain. The alignment along Kapiolani Boulevard also is in the 100 year floodplain until it turns mauka onto University Avenue.

Parklands. Although Princess Kaiulani Park would be reconfigured during construction with Option "A," there would not be any long-term loss of parklands with any of the Waikiki options.

Conclusion

In conclusion, subway options (Options "B" and "C") would result in less visual impact; however, the subway alternative would have a greater impact on traffic during construction and the potential of hazardous waste finds during construction, vibration from passing trains, residential displacement, and business disruption in the areas of cut-and-cover construction.

Construction Cost Estimate

An order-of-magnitude cost estimate has been prepared for Option "A" and the two Kapiolani/Waikiki Subway configurations defined as Options "B" and "C." The definition documents in Attachment 1 were used in preparation of the subway estimates. In addition, generic information has been extrapolated from the Hotel Street Subway Study and applied to appropriate line items.

The following estimate includes all costs for the Kapiolani/Waikiki Subway within the study limits including, procurement, contract, and other costs to the City so that a valid comparison may be reached. The Other Costs To The City include station finishes, landscaping, right-of-way, private utility relocations, and engineering and management. Costs not included are those associated with the System Vendor procurement.

This estimate specifically includes the following items:

1. Demolition
2. Utility relocation
3. Street modifications
4. Underpinning
5. Subway construction
6. Aerial guideway construction
7. Passenger stations
8. Landscaping
9. Engineering and management

10. Contingency
11. Right-of-way

The following items are cost exclusions:

1. System vendor items
2. Preliminary engineering
3. Owner (City) cost for financing and preoperating expense
4. Operating cost
6. Project reserve for change orders and scope enhancements.

The Koko Head portal for the Hotel Street Subway is outside the study limits for this feasibility assessment, and therefore is not included in the estimate. However, there is a land acquisition savings associated with Options "B" and "C" due to the elimination of the portal structure for those schemes. The estimated savings is approximately $29 million. This savings is not applicable to the supplemental subway variations (portal connection, independent operation, mechanical transfer) that were analyzed as a part of this feasibility assessment.

A cost summary for each option is presented on the following table.

ICF KAISER ENGINEERS, INC.
KAPIOLANI/WAIKIKI SUBWAY
JOB NO. 91184 (REV 1)

DATE: 03-Oct-91

COMPARISON OF ALTERNATIVES: KAPIOLANI/WAIKIKI SUBWAY STUDY

(NOTE: ALL COSTS IN $1,000's)

DESCRIPTION	UNIT	OPTION "A"		OPTION "B"		OPTION "C"	
		QUANTITY	COST	QUANTITY	COST	QUANTITY	COST
SYSTEM DATA:							
ROUTE LENGTH	RF	24480		25372	0	25525	0
TRACK LENGTH	TF			53037	0	53037	0
NUMBER OF STATIONS	EA	11		10	0	10	0
CONSTRUCTION COSTS:							
SITE MODIFICATIONS							
DEMOLITION	LS			6	1473	6	1473
UTILITY RELOCATION	RF			24330	35889	24330	35889
STREET MODIFICATIONS	SY			24330	6046	24330	6046
UNDERPINNING	LS			3	20468	3	20468
AERIAL GUIDEWAY	RF			7482	23291	7480	24902
SUBWAY GUIDEWAY							
TWIN TUNNEL	RF			11480	186469	10840	186469
CUT & COVER, SGL CELL	RF			180	3575	180	3575
CUT & COVER, DBL CELL	RF			1300	42890	1300	42890
CUT & COVER, TPL CELL	RF			960	28800	960	28800
GDWAY RETAINED CUT	RF			330	1980	330	1980
STATIONS - AERIAL							
SIDE PLATFORM, 100 FT	EA			0	0	2	6200
SIDE PLATFORM, 240 FT	EA			2	9000	0	0
CENTER PLATFORM, 100 FT	EA			0	0	1	4300
CENTER PLATFORM, 240 FT	EA			1	5600	0	0
STATIONS - SUBWAY							
CUT & COVER, 100'	EA			1	18342	0	0
CUT & COVER, 100' W/TREMIE	EA			3	60360	0	0
CUT & COVER, 320' W/TREMIE	EA			3	118523	6	210431
CUT & COVER, 320'	EA			0	0	1	27527
JET GROUTING	LS			1	9069	1	9069
Subtotal CONSTRUCTION COSTS:			$212,934		$571,775		$610,019
CONTINGENCY			15,970		171,533		183,006
TOTAL CONSTRUCTION COSTS:			$228,904		$743,308		$793,025
OTHER COSTS TO THE CITY:							
STATION FINISHES	LS	1	62094	1	62094	1	62094
PRIVATE UTILITIES	LS	1	16478	1	16478	1	16478
RIGHT OF WAY & AGREEMENTS	LS	1	63233	1	63233	1	63233
Subtotal OTHER COSTS TO THE CITY:			$141,805		$141,805		$141,805
CONTINGENCY			10635		10635		10635
TOTAL OTHER COSTS TO THE CITY:			$152,440		$152,440		$152,440
TOTAL CONSTR & OTHER COSTS			$381,344		$895,748		$945,465
ENGR & MGMT (GEC + OWNER COST)			26694		62702		66183
ESCALATION:							
ESCALATION			0		0		0
PROJECT RESERVE:							
PROJECT RESERVE			0		0		0
TOTAL:			$408,038		$958,450		$1,011,648

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CONCLUSION

The preliminary assessment of the Kapiolani/Waikiki Subway indicates that a feasible underground solution does exist.

Option "B" is considered to be a fairly representative solution, with features that characterize a typical subway configuration for the Honolulu Rapid Transit Program. The premium or increased capital expenditure associated with this solution is $550 million, relative to the base system (Option "A"), in 1991 dollars.

Option "C" was developed as an optimum subway configuration to be used primarily as a gauge to measure the variation of cost between alternative subway solutions. The premium associated with this solution is $604 million relative to Option "A."

The cost differential between Options "B" and "C" is relatively small in comparison with premiums associated with the base system. Other subway variations do exist. However, cost differentials relative to the evaluated subway options are likely to be insignificant when judging the economic viability of a subway system for Waikiki.