TENDER IDEAS

WORKS FOR THE PROTECTION OF THE HAVANA MALECON

OCTOBER 93

SUMMARY OF THE PROPOSED SOLUTION

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I.- BACKGROUND

The original city of Havana was situated on the inner shores of the bay, sheltered from the violent storms that frequently occur on the northern coast of the island. The city began to expand gradually towards the north coast at the end of the 1800s and, above all, during the first half of this century.

The first city planning, dating from before the fifties (Forestier, Febles Valdés, etc.), proposed "soft" solutions for the coastal area, characterized by the intense application of green belts and unbuilt zones, respecting absolutely the original coastline.

The widespread speculation prevailing in the city in the fifties led to a radical transformation of these initial planning criteria. The magnificent coast road designed by the engineer and Minister of Public Works, Manuel Febles Valdés, along the lines of a boulevard, with wide sidewalks, parks and gardens, was replaced with the road as it exists at present. A noteworthy example of the situation at the time is the construction of the Hotel Riviera, the promoter of which was none other than the infamous gangster, Lucky Luciano, on land destined for use as a public park. In consequence, the seafront of Havana now takes the brunt of the storms approaching from the north.

Contact between the present roadway and the sea was resolved by constructing the wall of the Malecón, a considerable section of which overlies land reclaimed from the sea, which involved filling in and building up the level of the coast, thus leaving many inland areas depressed and readily susceptible to flooding.

The Malecón, therefore, acts as a bulwark against the onslaught of the waves but also as a retaining wall for the afore-mentioned filling materials. Its situation on a higher level with respect to the adjacent inland terrain converts it, in turn, into a dike, restricting the natural return of floodwater towards the sea

Despite the above, the unquestionable urban values of the Havana seafront have made it one of the most popular areas in the city among the local residents.

As a consequence of the weather and pressure conditions at the coast as well as the transformations that have taken place along the shore, at certain times during the winter the waves break over the wall and penetrate violently into the urban areas, causing extensive flooding and disrupting traffic, affecting everyday life in the city and increasing economic hardship for the population.

For the above reasons, the Cuban authorities have considered it convenient to announce the present competition, in their quest for imaginative solutions to resolve satisfactorily the

problems in hand in a manner compatible with the values of the environmental and urban heritage to be upheld.

II.- CHARACTERISTICS OF THE PROBLEM IN HAND

The most relevant factors causing th storm-related vulnerability of the waterfront of the city of Havana are as follows:

II.1.- INSUFFICIENCY OF THE MALECON TO DETAIN THE OCEAN-WAVES IN THE COURSE OF STORMS

The present elevation and layout of the Malecón render it an inadequate bulwark against flooding caused by violent ocean-storms.

A relatively low estructure, considering the height of the crown, the Malecón is an important feature of the landscape, allowing an uninterrupted view of the open sea along the entire avenue. Its fundamental disadvantage. however, is its manifest insufficiency to detain storm waves. Its insufficient elevation above sea-level renders it readily surmountable by storm-induced waves in two circumstances:

a.- **When the incoming waves have a long characteristic period. These waves have been, generated by wind fields situated at a great distance from the coast.** This type of waves increase considerably in height upon reaching shallow waters at the coast, they have a great surmounting capacity and sweep over the wall along several sections.

b.- **When the storm-generating wind field reaches the coast**. In these cases the wind drags the surface water, raising the level of the sea due to the accumulation of water against the shore and the sea - wal. This raised level is further increased when the low atmospheric pressure centre forming the nucleus of the storm or cyclone passes over the coast.

Obviously, the most unfavourable setting in this regard is high tide. It is also thought that waters circulation patterns found in the Gulf of Mexico which are apparentthy associated with the phenomenon named "El Niño" periodically cause an elevation of the sea-level along the coast, with a corresponding increase in the vulnerability of the Malecón. As a consequence of the afore-mentioned phenomena, the sea-level has occasionally been observed to reach the level of the crown of the sea - wall, the crests of the waves sweeping freely over the wall.

The Malecón runs parallel to the coast and therefore receives the impact of the waves perpendicularly along the greater part of the route, which is the most unfavourable position with regard to overtopping

Moreover, the topography of the submerged coastal platform allows sizeable waves to reach the proximity of the wall unbroken. The 10-metre isobath runs at a distance of between 60 and

200 m. from the shore. Detailed depth-charts examined frequently record a depth of 3 m. at low tide close to the Malecón, reaching 5 m. at the base of the wall, in the area opposite the Calixto García monument.
At those sections of the wall where the impact of the waves is perpendicular and the topography of the sea floor is unfavourable, the overtopping caused by storm waves are very significant and the problem of preventing it is not an easy one to resolve. These particularly problematic sections are located between the mouth of the River Almendares and the José Martí Stadium, and between the tower of San Lázaro and the Castillo de la Punta.

Contrarily, at the section of the wall between the José Martí Stadium and the San Lázaro tower, the incidence of the storm waves on the sea wall is notably oblique because of the NE orientation of the coastline, thus favouring the hydraulic efficiency of the wall such that the overflows are comparatively smaller.

II.2.- INEFFICIENCY OF THE DRAINAGE SYSTEM ALONG THE ENTIRE COASTLINE

II.2.1.- Unfavourable topographic conditions.

From the topographic point of view, the coastline is relatively low and with little slope to facilitate drainage, the adjacent land thus being susceptible to flooding. An added factor is the existence in this area of another unfavourable feature, depressions, readily transformed into lagoons, drainage of which is particularly difficult. Buildings in this area are frequently damaged despite being situated some distance from the coast and not subject to direct impact by overtopping waves

Flooding of the urban coastal areas is not caused by sea-water only. An important contributing factor are the torrential rains that frequently accompany the storms. The water from both sources accumulates in the depressions causing extensive flooding due to the inefficiency of the drainage system, which will be discussed below

II.2.2.- Difficulties of seaward drainage.

The return to the sea of water flowing over the sea wall is hindered by the wall itself due to the insufficient number of evacuation points for rapid return of overspills. In this respect, the Malecón acts like a dam, retaining the water, which quickly flows inland, at times over a distance of 500 metres.

The drainage by way of the underground collectors with outlets in the sea at the foot of the wall is also problematic. The mouths of the outlets face directly seawards, almost perpendicular to the shore and totally unprotected from the waves, with the sole exceptions of those at Caleta de San Lázaro.

At those sections of the wall where the incoming wave crests arrive parallel to de wall, the water enters the collectors directly, not only hindering drainage but causing the collectors to operate inversely, permitting the passage of water towards the interior of the city. The force of the water can be such that it removes the manhole lids in the streets, the water fountaining in

two metre-high columns.

The deficiencies of the sewage network in this part of the city have led to sewage pipes being clandestinely connected to the rainwater drainage system. When flooding occurs in the manner described immediately above, the waste from the overtaxed sewage system makes its way upwards through the sanitary ware in the lower storeys of the buildings in the areas susceptible to flooding.

II.2.3.- Problems in the River Almendares.

Drainage is directed towards the Bay of Havana and the River Almendares from the surrounding urban areas. In principle, this is a favourable situation since the waste does not reach the open sea. But while the Bay of Havana is protected from storms because of its conformation, the situation at the river mouth is different This river enters the sea at a wide estuary, the east bank of which is completely open to the action of the waves.

The waves approaching the river mouth from the sea find a wide entrance channel with depths of up to 20 metres at the centre that allow the passage of large waves.

As a consequence of the storm waves travelling landwards, aggravated by the accumulation of sea water dragged by the wind, the river ceases to drain efficiently towards the sea and, in addition, the added volume of the water raises the level of the river, hindering the correct drainage of the tributary areas. Moreover, the waves inundate large areas of the east margin along the final stretch of the river, flooding the adjacent low-lying land at the José Antonio Echevarria Stadium. Flooding quite frequently affects the Quinta Avenida tunnel, cutting off communication by road between the banks.

III.- SET OF MEASURES PROPOSED

III.1.- TYPE OF COASTAL DEFENCE IN FRONT OF THE MALECON

The critical importance of this chapter was stressed in the announcement of the competition, for reasons that are not only functional but also urbanistic, historical and environmental, and it will therefore be presented in greater detail.

As indicated earlier, the efficiency of the Malecón as a defence system must be considerably augmented, particularly of those coastal sections where its alignment is markedly perpendicular to the direction of approaching storm waves. The conditions of this competition stipulate that this objective must be achieved within the context comprised of the following premises:

a.- A positive contribution must be made to the recreational character of this coastal area of the city.

b.- The emblematic image of the Malecón must not be deteriorated.

c - The protective works must not surpass sea-level.

The above premises reflect the decisions to consolidate the recreational use presently made of this particular coastal area of Havana and to reaffirm the importance of the seafront to the inhabitants of the city.

After studying the different possibilities offered by presently available technology, we have reached the conclusion that the types of defence system wich would satisfy the double decision indicated above with a high degree of efficacy are incompatible with the literal interpretation of the third premise specified in this competition, that is, that the protective works must not surpass sea-level, although the solution proposed by us is totally compatible with the spirit of the said premise, which we identify as a deep concern for the aesthetics of the proposed solution from the standpoint of scenic conservation.

The conveners must also have arrived at the same conclusion since those participating in the competition have been recently informed by the UNAIC of the decision to allow the jury to assess eventually emerging proposals. Probably they have finally considered that it would not be advisable to impose such restrictions on the creativity of the designer of the project. In the chapter containing the assessment report on the impact on the landscape and city heritage, the reasons prompting us to adopt an emerged solution are discussed in greater detail.

We have discarded the options of submerged works because, in order to be acceptably efficient, they would imply the grave ecological deterioration of the coastal waters and/or the radical elimination of the principal recreational activity in the Malecón area, sea-bathing, once the problems posed by pollution have been resolved.

The said options should basically consist of a submerged berm situated at the Malecón, eventually completed with a very wide submerged breakwater located at a certain distance, its crown close to sea-level.

This type of solutions poses the following problems:

- The large submerged outer breakwater would cause stalling of the waters between the dike and the Malecón. In storm-free times, waves would be dispersed on passing over the wide crown of the dike and would arrive at the other side without the capacity to renew or oxygenate the areas close to the shore.

- The submerged berm situated at the Malecón would make bathing impossible because the proximity of the crown of the work (made up of concrete or quarry rocks blocks) to the surface of the sea together with its great width would make it impracticable for bathers to swim over the berm or gain access to the open sea beyond.

- An insufficiently controlled large-scale dumping of quarry stones could also cause a considerable ecological impact on the marine environment. One of the worst enemies of coral formations are fine arid materials, inasmuch as they signify the instant death of the algae that constitute the basic nourishment of this ecosystem, because the layer of lime they form deprives the algae of the light necessary for their development.

We have opted for a coastal defence system based on works placed against the actual Malecón, situated at a mean level of two metres below the surface of the Avenue and designed to increase decisively the defensive capacity of the wall and, at the same time, to potentiate the recreational use of the seashore, contribute to an attractive landscape at the seafront of the city and respect to the utmost degree the present appearance of the Malecón.

The defence system has been conceived as an application to the seafront of Havana of "sinusoidal defences". The peculiarity of sinusoidal defence consists in performing the function of dissipating the energy of a wave by means of a morphology wich promotes intensive lateral interaction of flows, such as dividing wave crests and channelling them in series of paired flows that end colliding with each other.

Among the advantages of this form of action, one in particular qualifies this type of works to achieve fine hydraulic efficacy in conjunction with the Malecón: they cause directional dispersion of flows, improving the capacity of the wall to reflect them. As stated above, the Malecón is performing deficiently in those sections where the impact of the waves is perpendicular to its alignment.

In regard to the urbanistic and landscaping value of this type of defence systems, which proves to be of interest in the case of the Havana seafront, two main aspects can be indicated as follows.

- The crown of the structures is terraced with a flat surface, and can be constructed in concrete Its configuration and dimensions are suitable throughout for use by the public as a seafront solarium, place for bathing and walkway.

- The form of these structures presents oscillations in plant and profile. The rhythmic morphology of the defence system, in contrast with the straight-line uniformity of the Malecón, constitutes a whole the attractive appearance of which would not detract from the present beauty of the city`s shoreline.

It has been deemed advantageous to supplement the sinusoidal defence system built against the Malecón with a series of exterior sinusoidal dikes, situated at a certain distance in the open sea. This first line of defences is not continuous but spaced out in order to permit the passage of sufficient waves and currents to renew and oxygenate the sheltered waters.

In a spot of such value to the tourist industry, opposite the Hotel Cohiba, one of the exterior dikes has been joined to the coast and has been designed for use as a landing stage, providing a further recreational facility to enrich the seafront of Havana at little additional cost. During violent storms, the pier will not be in service and boats will be sheltered in the Bay, but one of the lines of landing points will provide sufficient protection for boats in moderately stormy weather. In high-magnitude storms, the works function as a particularly effective coastal defence system.

Because of the different bathymetric and urbanistic factors conditioning the entire seafront, the shoreline provided with the sinusoidal defence system has not been treated with total

homogeneity. The variants proposed in the different zones can be observed in the plans.

At that section of the coast where the inciding storm waves make oblique contact with the Malecón sea wall, the sinusoidal defence has been substituted by a series of curved breakwaters, situated at the drainage collector outlets. These breakwaters have been integrated as a part of the shoreline walk and can also be used by bathers to gain ready access to the sea and as a waterfront solarium.

III.2.- MEASURES IN THE MARITIME AVENUE

The defence system proposed in the foregoing chapter will greatly decrease flooding over the Malecón but will not eradicate the problem completely in all foreseeable future storm situations. A negative factor with respect to future prospects is the existing uncertainty about global climatic changes.

Considering the characteristics of the cyclones and storms that affect the coast at Havana, and those of the submerged shoreline topography, a totally effective protective barrier would involve works of such dimensions that the environmental and scenic impact would be colossal and, moreover, such works would prove economically unfeasible.

Therefore, the Avenida del Malecón has been considered a reserve in which supplementary measures are proposed to detain the water flowing over the sea wall during exceptionally violent storms, ensuring that such floodwater does not travel farther into the city. During high-magnitude storms, road traffic will be diverted to the alternative route represented on the maps adjoining this proposal. The diverted traffic will use the road connections through the tunnels that cross the Bay of Havana and the River Almendares since specific measures are proposed to protect both tunnels integrally in the event of floods.

The proposed measures are as follows:

- **Barriers on the Avenue.** It is proposed to deploy a series of low-lying linear shields, situated along the sidewalk bordering the Malecón and on the footpath in the centre of the carriageway, taking the form of concrete walls of different heights which will also serve as seating facilities, containers for plants, etc. Their function is to check the advance of the water, and they are discontinuous in order to facilitate the water returning into the sea once it has been stalled.

The first of these barriers is a succession of wall-bench segments, situated behind the entrances of the coastal protection built against the shore wall, at which point the water penetrating will concentrate.

The remainder are arranged on the central footpath proposed for the carriageway, and form the edges of the plant containers.

- **Anti-flooding Barrier.** This is composed of dismountable stakes -that would be used by Civilian Protection to close off the streets perpendicular to the Malecón- and walls (reinforced

and extended) for closing off the sites facing the Malecon, complemented with ornamental walls having structural functions, situated at strategic points, where the topographic conditions of the sea floor do not favour the installation of the outer dike.
This barrier would act as a regulating deposit or controlled dam, preventing the progress of the water towards the more low-lying areas farther inland from the Malecón, thus minimizing the effects of flooding similar to those caused on previous occasions and affording a reasonable degree of "control" over any water that might penetrate.

This defence system would be complemented with the following measures for civilian protection to be implemented on land:

- **Permeabilization of the Malecón.** Openings are made in the Malecón to allow the return to the sea of water overflowing onto the avenue during high-magnitude storms, and which, after being stalled by the barriers on the avenue, is finally halted by the anti-flooding barrier situated along the inner border of the avenue.

The openings are shaped such that they act like a valve, allowing the outward flow of floodwater and preventing entrance of wave generated flow. The valve-works are also provided with steps built into the resistent structure, permitting access to the shore.

This solution is indispensable for the efficacy of the above-mentioned "regulating deposit", being the only method to ensure rapid emptying. In some cases, the apertures provide access for pedestrians and cyclists to the sinusoidal defence built against the wall, while in others they function only as water outlets.

- **Waterproofing of the buildings** in the flood-prone coastal areas by means of the widespread use of dismountable devices for sealing doors and windows in the event of flooding of public spaces. Frames are mounted over the existing woodwork, into which tongue and groove boards similar to those employed to close off the streets at the anti-flood barrier are slotted.

- **Construction of a supplementary drainage system** at those points in the city where the unfavourable topography favours flooding caused by torrential rainfall.

The collector outlets draining into the open sea to the north are protected against penetration by the sea by means of a system that rechannels sewage and rainwater towards a position favourable to the marine current, while preventing the waste from returning by ensuring that the outlets are not directed frontally towards the oncoming waves. These systems are channelled in the interior of the defence constructed against the sea wall.

Along the remainder of the open coast, where the incidence of storm waves at the shore is notably oblique, the mouths of the waste outlets are sheltered by curved groynes.

- **Floodproofing of reserve deposits of fresh water for domestic use** by sealing off with surrounding walls.
- **Establishing an auxiliary public lighting system** to facilitate civilian protection.

- **Implementation of an early warning system of sirens** with which the Meteorological Service and Civilian Protection can notify the public immediately a potentially dangerous oncoming storm is detected. The fact that the March 1993 event was detected at a late hour on the previous night, when the majority of the public had switched off television and wireless sets prior to retiring, made it impossible to alert the general public. This warning system, together with the auxiliary street lighting, must, logically, be connected to an emergency electricity network to ensure their correct functioning at all times.

- **Planning an alternative route should the Malecón** become impassable, ensuring permanent and fluid communication between east and west Havana. Anti-flood measures must be adopted at the Bay, Quinta Avenida and Línea tunnels.

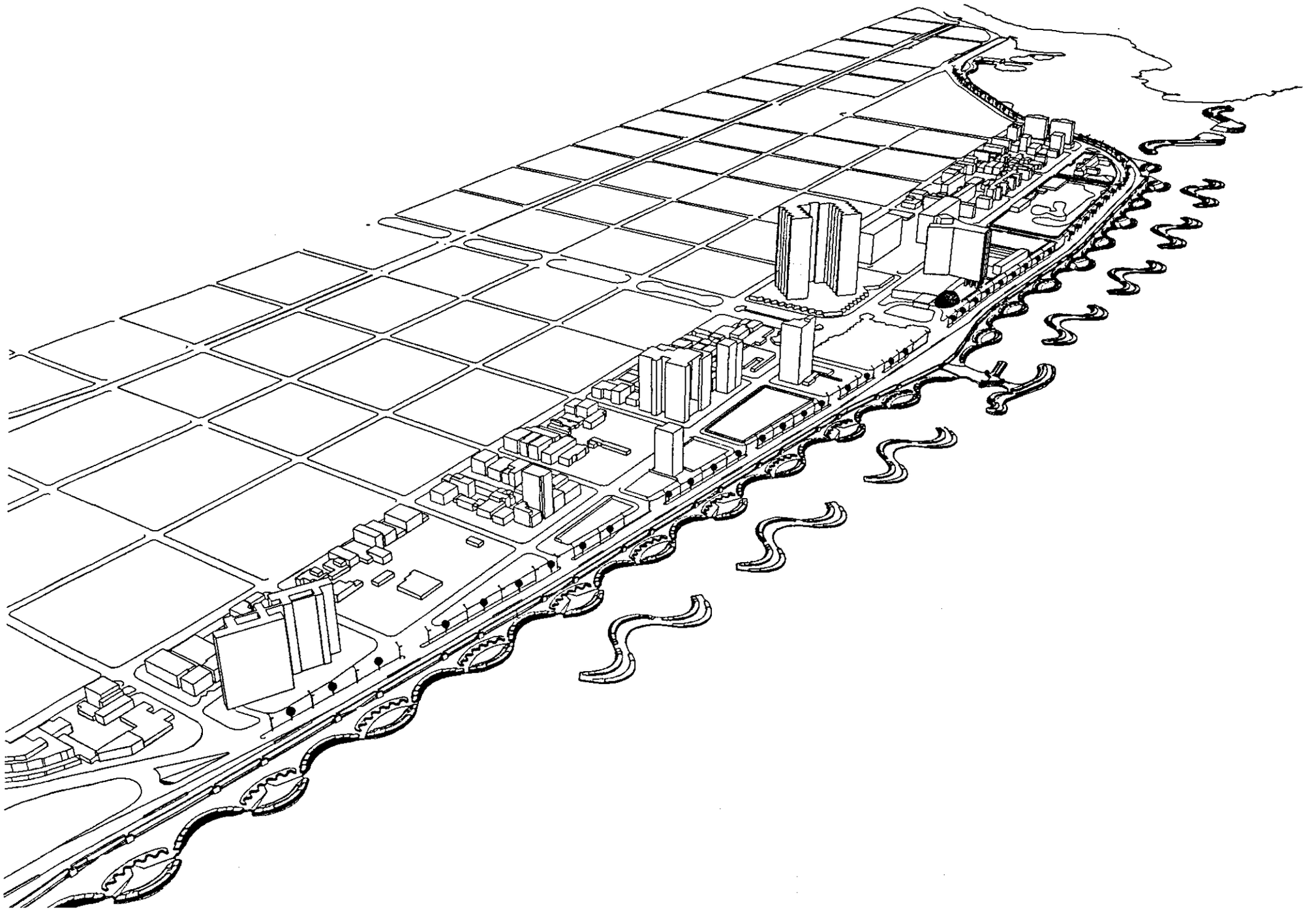
- **Central footpath for public safety and to carry the public lighting system and ornamental vegetation**. This central footpath will be constructed along the entire Avenida del Malecón. The trees planted will be autochthonous species capable of living in the proximity of the sea such as Coccoloba uvifera (Uva caleta) and Casuarina

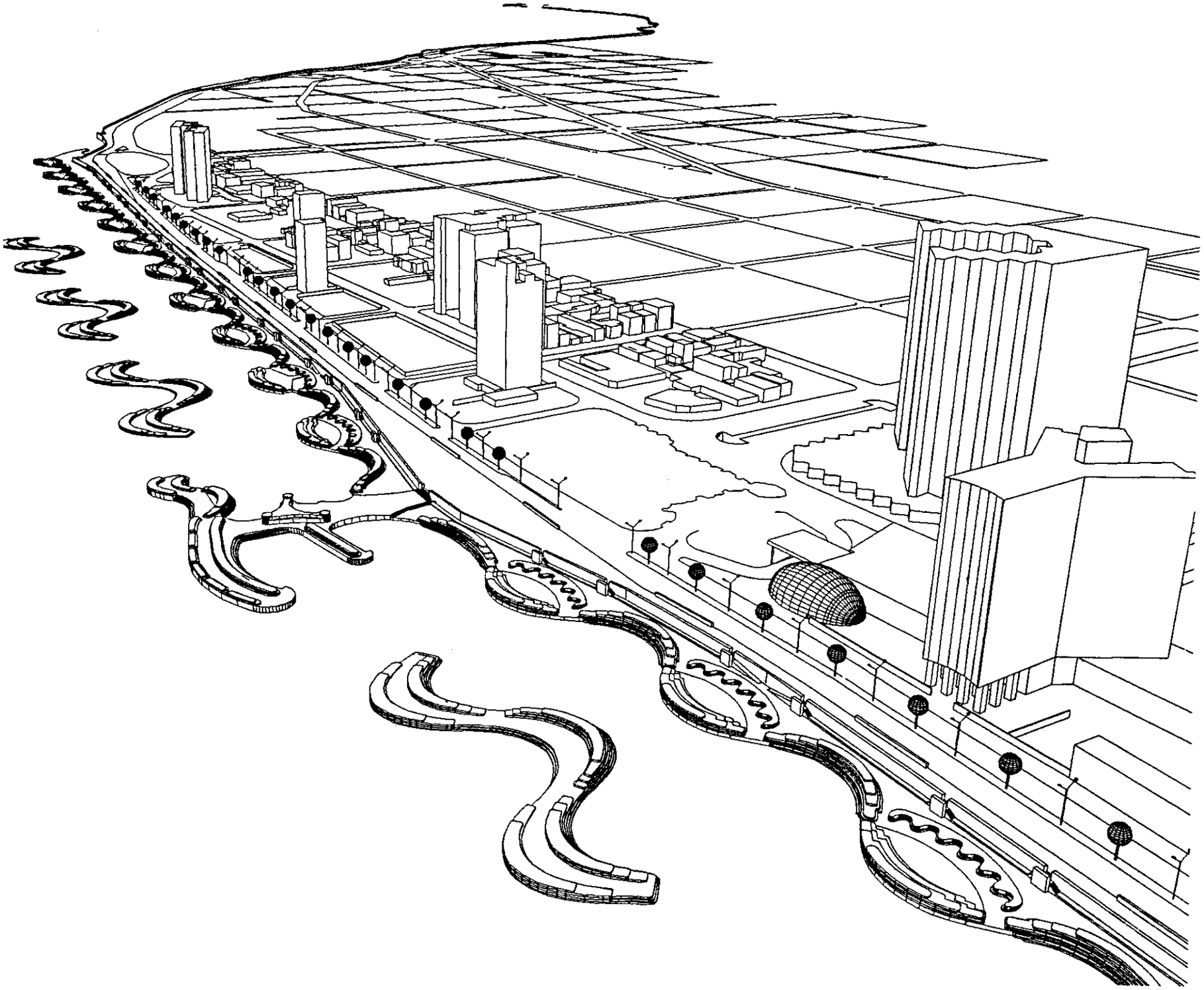
III.3.- PROTECTION OF THE MOUTH OF THE RIVER ALMENDARES

A fundamental aspect of the overall protection of the Havana waterfront is to prevent penetration of the River Almendares by storm waves, for the reasons put forward in chapter II.2.3. The protection of the river mouth will impede flooding of the important tunnel that crosses the Almendares and of large areas on its east bank, permitting, moreover, the drainage systems of the extensive urban and industrial areas that currently flow into the river to function properly.

In view of the width and depths existing at the river mouth, the defence system will have to be of considerable dimensions and therefore costly. Two dikes have been designed in the form of two symmetric wings with a space between them. The greater part of the river water flowing seawards will pass through the central aperture, where the depth is such that very few waves will have broken when they arrive at that point, even during violent storms, the broken waves being precisely those that hinder the water from flowing into the sea. These proposed works will also greatly decrease the volume of water carried upriver by storm winds. The waves travelling in through the central opening will be progressively dampened - off by radial dispersion.

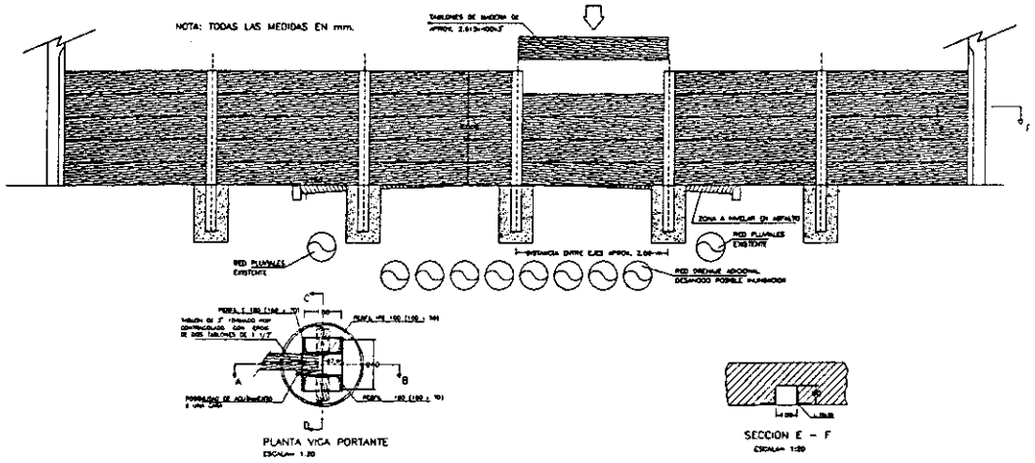
These protective works have also been designed with adjoined landing stages for use by the general public. This complementary function is intended to stimulate the urbanistic recovery of the area, which has deteriorated over the years Plans developed by the Cuban administration for the regeneration of the waters of the River Almendares are to be put into effect and are a necessary complementary measure to achieve the objective described.





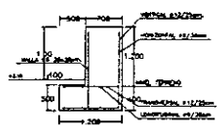
BARRERA ANTI–INUNDACION: EMPALIZADA DESMONTABLE PARA CERRAMIENTO DE CALLES

ANTI–FLOOD TEMPORARY BARRIES

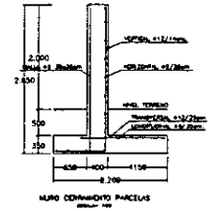


PLANTA VIGA PORTANTE

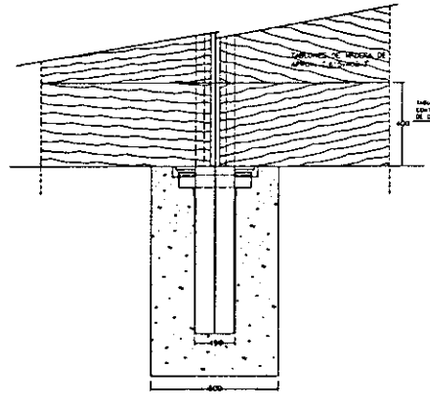
SECCION E – F



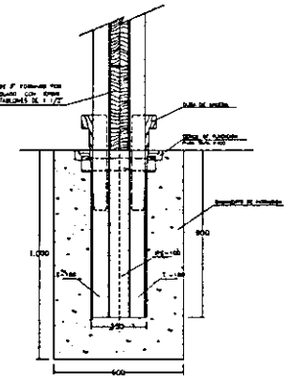
MURO PROTECCION EN ACERA DEL MALECON



MURO CERRAMIENTO PARCELAS



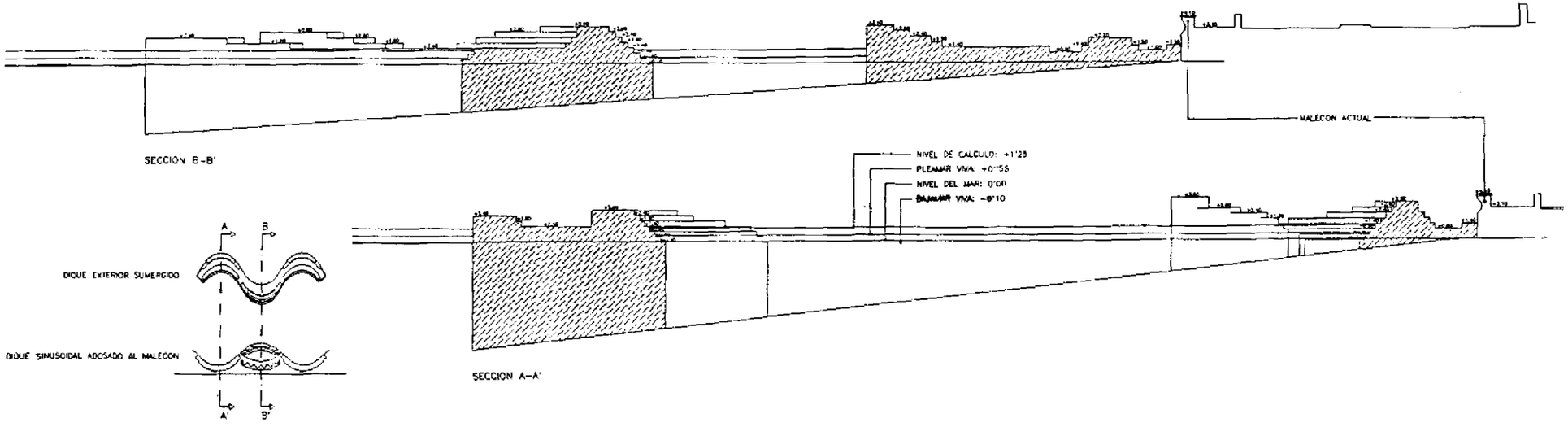
SECCION A – B
BARRERA ANTI–INUNDACION



SECCION C – D
BARRERA ANTI–INUNDACION

SECCIONES OBRA MARITIMA

SEA DEFENCE SECTIONS



DRAFT

COMMUNIQUE TO THE DECENNIAL SYMPOSIUM ON NATURAL DISASTERS REDUCTION.

The Geographical Institute of the Science Academy of Cuba and the Spanish consultancy winner of the International Competition on Protection of Havanna Malecon, having jointly studied the recent series of floods caused by sea penetration in the City of Havanna, hereby propose their Conclusions and Recommendations to be presented at the **Decennial Symposium on Natural Disaster Reduction** to be held in Yokohama, May 1994.

CONCLUSIONS

*1.- The recurrent sea penetration in Havanna presents two different sorts of problems. One is the **SEA PENETRATION IN ITSELF** as a consequence of the limitations of the Malecon as an effective barrier under the studied circunstances. The other the **FLOODING OF THE SEA FRONT OF HAVANNA** that follows the penetration as a result of different combined factors:*

- *The existing Malecon, once unable to halt the penetration of the sea waters, acts as a dam that prevents them returning to the ocean.*

- *The depressed topography of large city areas with respect to the sea front Avenue favours the flooding of such areas.*

- *The insufficient hydraulic section of the existing sewers and lack of protection at their sea ends makes them unable to evacuate the invading waters.*

2.- Considering the underwater topography as well as the characteristics of the tropical cyclones and storms that affect the Havanna coast, the building of a totally efficient sea barrier would require such enormous dimensions, height in particular, that it would present a colossal negative environmental impact, apart from being economically unsound.

*3.- **The Sinousoidal Barriers** here proposed will significantly reduce the sea penetration over the Malecon, but would not be capable to avoid it completely in the event of greater storms. Therefore complementary in-land defence measures will be necessary.*

In view of the precedent Conclusions the following Recommendations are presented:

RECOMENDATIONS

1.- Due to the recurrence of the sea penetration phenomena - last march 1994 for the third consecutive year - it would be wise and opportune in terms of cost and time, whatever the engineering solution at sea, to tackle a set of urgent and complementary in-land defence

works to control the flood and reduce the demage to population and historical heritage alike.

2.- A system of permanent and temporary barriers, the reinforcement of the sewerage system at strategic spots of the City and other additional protection means as outlined in the adjoined panels are all proposed as urgent works to be carried out at a moderate estimated cost of 4.5 million U.S dollars, therefore permitting a significant immediate protection of both population and heritage until resources for the main defence works, estimated at a minimun of 22 million U.S. dollars, are available

3.- A reduce scale model test of these ***anti-flood barriers*** *is considered a* ***main priority,*** *since in case of positive results its simplicity and reduced costs would permit that in less than a year the City of Havanna would be in a much better condition to cope with the flood disasters, if not avoid the sea penetration altogether.*

Eventually the same solutions could be extended to other parts of the Island.

4.- Equally urgent is the reduced scale testing of the ***sinousoidal barriers system.*** *It is assumed that apart from its specifical hydraulic efficiency that is to be tested the system would present the added value, with reference to other engineering proposals, of its capacity to incorporate leisure elements and landscape friendly solutions that could equally be of great interest for other areas of the cuban coast.*

Havanna, May 6 th 1994