A HISTORY OF THE EXPANSION OF THE RECLAIMED AREAS AND SOME ENVIRONMENTAL PROBLEMS IN HIROSHIMA, WESTERN JAPAN

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Abstract The present Hiroshima lowland has experienced two processes of reclamation since the 17th Century. Before the 19th Century, the expansion of the deltaic lowland mainly depended on reclamation by drainage, but since the earlier part of the 20th Century, it has only depended on reclamation by modern advanced technology. Present reclamation is being carried out in the deeper sea off the outer slope of the delta, therefore requiring plenty of materials and two types of sand which are composed of terrestrial and marine sand. In this paper, the volume, composition and spatial flow of materials for reclamation are illustrated by the example given of the newest reclaimed area in Hiroshima, the "*Seibu* (Western)-*Kaihatsu* (Development)".

1. Introduction

It might be said that whatever the period in history an example of land transformation can be found. Land utilization is the historical result of the spatial aspect of human activity and daily life, and is subject to change according to man's attitude towards his environment. When man needs residential land or fields for cultivation he always chooses or intends to choose the most suitable land within the given area. Therefore, the compositive ratio of landform units, or mountains, piedmont slopes, river or marine terraces and alluvial plains etc. strongly influences the land use system. In the case of Hiroshima city, they have always sought the flatter lowland, because Hiroshima city is situated facing the Seto Inland Sea, and is surrounded by mountains and hills composed of weathered granitic rocks which rise upsheer from the sea, thus creating narrow alluvial and coastal plains.

Recently geographers and related scholars have paid attention to the human impact on land (Kadomura, 1980; Kadomura and Takeuchi, 1983). The human agent in land transformation is one of the important geomorphic processes. We should discuss geomorphic problems concerning not only the volume and rate of materials moved by man, but also the way of movement, especially the spatial aspect of the movement of materials.

Direct anthropogenic landforming processes are characterized by constructional, excavational and hydrological interference (Haigh, 1978; Goudie, 1981, p. 189). According to the anthropogenic process, a process quite different to that which occurs under natural conditions, there occurs, for example, reversed and inverted movement from a lower level to

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an upper level (or from a lower stream to an upper stream), and from one organized space to another organized space (or from one drainage basin to another drainage basin). We should look for the equilibrium and the harmony between anthropogenic land-forming processes and the natural geomorphic processes.

In this paper, firstly the history of the expansion of the delta strongly influenced by anthropogenic landforming processes is described, and secondly, the modern reclamation focusing on the volume and geographical movement of materials for reclamation in Hiroshima.

2. A History of the Expansion of the Delta under Anthropogenic Landforming Processes

A History of the expansion of the Hiroshima Delta

The Hiroshima Delta is a typical arcuate delta formed by the Ohta River. The Ohta River originates in the Chugoku Mountains, and the drainage area is 1,690 km^2. This delta is surrounded by mountains and hills (400 to 500 meters in relative height) on three sides.

The historical change of the Hiroshima Delta has been studied by Kuwashiro (1972) as shown in Fig. 1 (newly reclaimed areas are added by the author, Hori, 1982). According to Kuwashiro's study, the historical processes of the delta are divided into the following five periods:

I ··· Before 1589, or before the construction of Hiroshima Castle. This area shows the initial delta without disturbances by anthropogenic landforming processes.

II ··· 1590 to 1700. The period is subdivided into three periods as shown in the figure. These areas were produced by reclamation by drainage.

III ··· 1701 to 1867. The latter half of the *Tokugawa* (or the *Edo*) period is also sub-

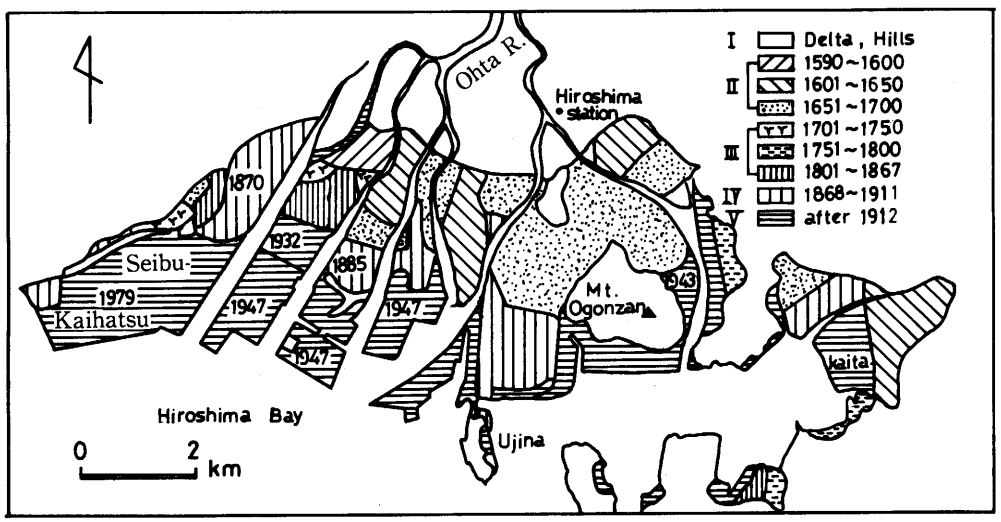


Fig. 1 The history of the expansion of Hiroshima Delta due to the reclamation by drainage and filling.

Table 1 Reclaimed area and volume of reclaimed materials in the Hiroshima Delta

Period or name of reclaimed district	Reclaimed area (km^2)	Volume of reclaimed materials ($\times 10^6 m^3$)	Reclaimed depth per unit area (m)	Efficiency of reclamation (km^2/km^3)	Remarks***
I (Before 1589)	11.44	–	–	–	–
II (1590–1700)	10.37	10.37–20.74	1–2	500–1,000	R.D.
III (1701–1867)	2.70	2.70–5.40	1–2	500–1,000	R.D.
IV (1868–1911)	4.91	4.91–9.82	1–2	500–1,000	R.D.
V (After 1912)	6.29	25.2–37.7	4–6	167–250	R.F.
Seibu-Kaihatsu	3.52	16.25	4–5	222.1	R.F.
(1966–1982)		ca. 31.50*	8.9*	111.7*	
Kaita	18.3		10	100	R.F.
(1978–1984)					
Kobe Port Island	4.36	80	18.3**	54.5	R.F.

Note: * This value shows the finally consumed materials for reclamation. It is about twice that of the calculated value based on the map.

** Including filled materials for loading.

*** R.D.: Reclamation by drainage, R.F.: Reclamation by filling.

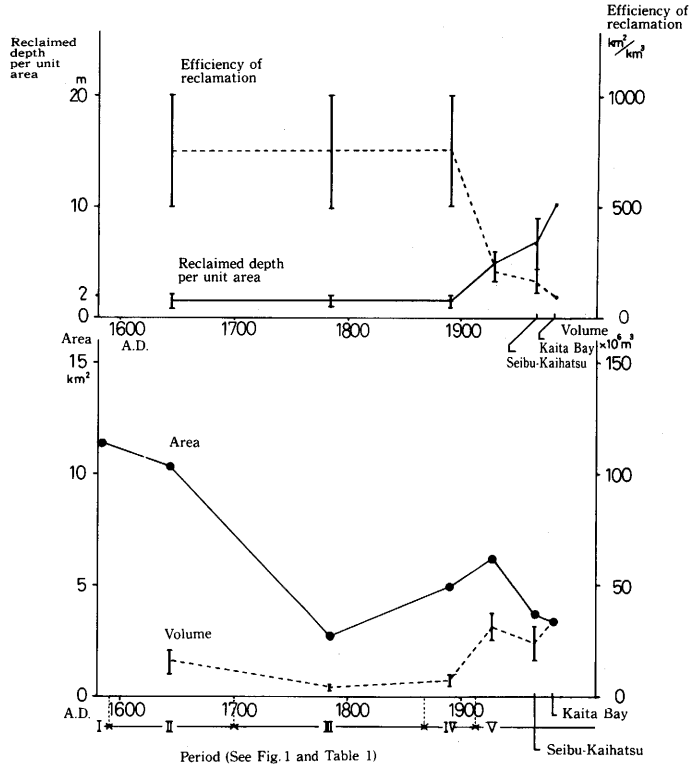


Fig. 2 The historical change on volume of reclaimed materials, on area of reclaimed land, and on efficiency of reclamation.

divided into three periods shown in the figure. These areas were produced mainly by reclamation by drainage.

IV . . . 1868 to 1911, or from the *Meiji Ishin* (Meiji Restoration) to the *Taisho* period. Reclamation by drainage was still an effective method.

V . . . After 1912, or the *Showa* period. This area has been changed by filling since the Second World War. The reclaimed area in 1979 is the *Seibu-Kaihatsu* (Western-Development) area. The *Seibu-Kaihatsu* will be mentioned in the later chapter. The *Kaita* area in the eastern part of the Hiroshima Bay has been under construction since 1978.

The historical change of reclaimed area and the volume of reclaimed materials are calculated and shown in Table 1 and Fig. 2.

In the above figure and table, reclaimed depth per unit area is calculated by the following formula:

$$\text{Reclaimed depth per unit area (m)} = \frac{\text{Volume of reclaimed materials}}{\text{Reclaimed area}}$$

and the efficiency of reclamation is calculated by the following formula:

$$\text{Efficiency of reclamation } (km^2/km^3) = \frac{\text{Reclaimed area}}{\text{Volume of reclaimed materials}}$$

Judging from Table 1 and Fig. 1, it can be clearly said that higher efficiency of reclamation appeared before the 20th Century. This fact shows that the expansion of reclaimed land using the upper surface of the natural delta was carried out by reclamation by drainage during periods II, III and IV. The lower efficiency of reclamation which occurred after period V results from reclamation on or off the outer slope of delta.

The relationship between deltaic deposits and reclaimed land and riparian environments

The micro-relief on the present delta harmonizes well with each reclaimed process. The land produced by drainage almost corresponds to the sea level lowland, or "zero-meter area" (Nakano, 1963). On the other hand, the land produced by filling appears in the southern fringe area of delta (Fig. 1).

The geological and topographical cross sections in Fig. 3 are prepared for understanding the relationship between deltaic deposits and reclaimed areas, and between inner lowland and riparian environments represented by bridges and banks. Fig. 3-1 is the location map of cross sections (Fig. 3-2 to 3-5). Some features are briefly summarized by Fig. 3.

In Fig. 3, the profile of the lowest ground between Sohtoku Junior High School and the Hiroshima Prefectural Playground is shown by the line descending gently toward the seaside. This line has been adjusted to the original surface of delta which harmonizes with the stratigraphy and composition of deposits communicating the Holocene sea level changes. The above zone corresponds to the land changed by drainage since the 17th Century. On the other hand, the fringe area of the delta is occupied by the land changed by filling. Hiroshima Airport is located on this surface. The land reclaimed from the sea is generally characterized by the slightly undulating surface and unstable soft ground. Moreover, the muddy and silty layers become thicker toward the fringe area of the delta. Therefore, reclaimed ground located on the fringe area of the delta is confronted with complicated problems on not only its defence against storm surge and other coastal erosion, but also counterplans against soft and unstable ground.

One of the typical problems in coastal lowland and reclaimed land from the sea is the counterplan against storm surge. Strong and high bridges and high banks constructed along rivers are symbolic facilities of urban riparian landscape as shown in Fig. 3-3, 3-4 and 3-5.

3. Spatial flow and composition of reclaimed materials: an example of the Seibu-Kaihatsu district

The reclaimed area from the sea, the Seibu-Kaihatsu (*seibu,* western: *kaihatsu,* development) was carried out as the biggest reclamation work by the municipal authorities of Hiroshima. The Seibu-Kaihatsu is located seven kilometers to the west of the city center. This reclamation work started in 1966, and continued until 1982, and required about 94,600,000,000 yen. The reclaimed area is 3.516 km^2.

In this chapter, the Seibu-Kaihatsu is mentioned as an example of modern reclamation

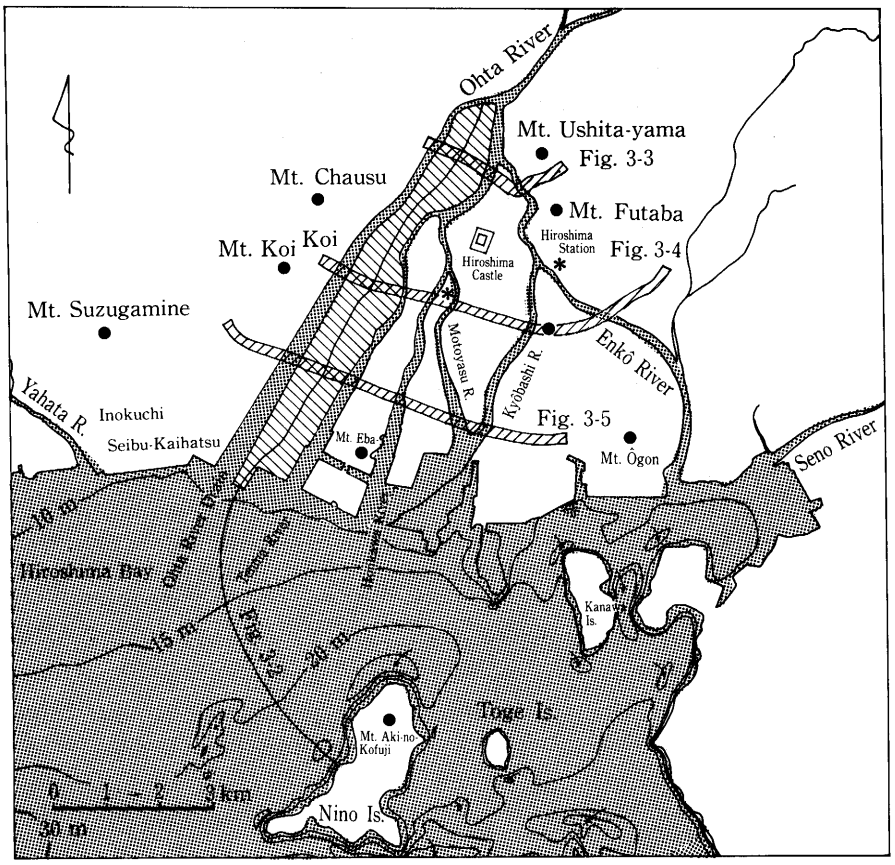


Fig. 3-1 The location map of cross-sections.

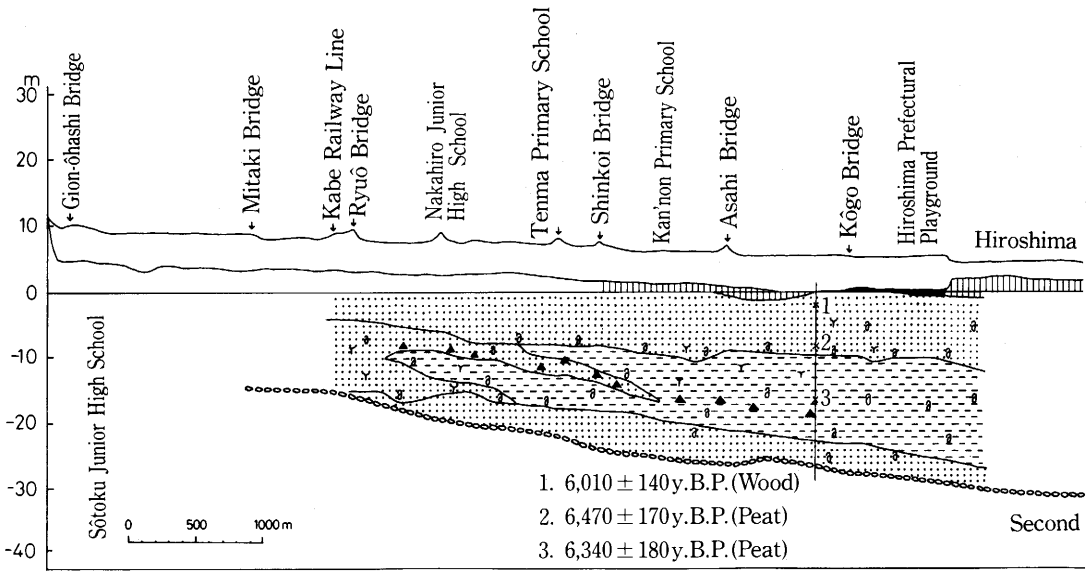


Fig. 3-2 The cross-section from north to south.

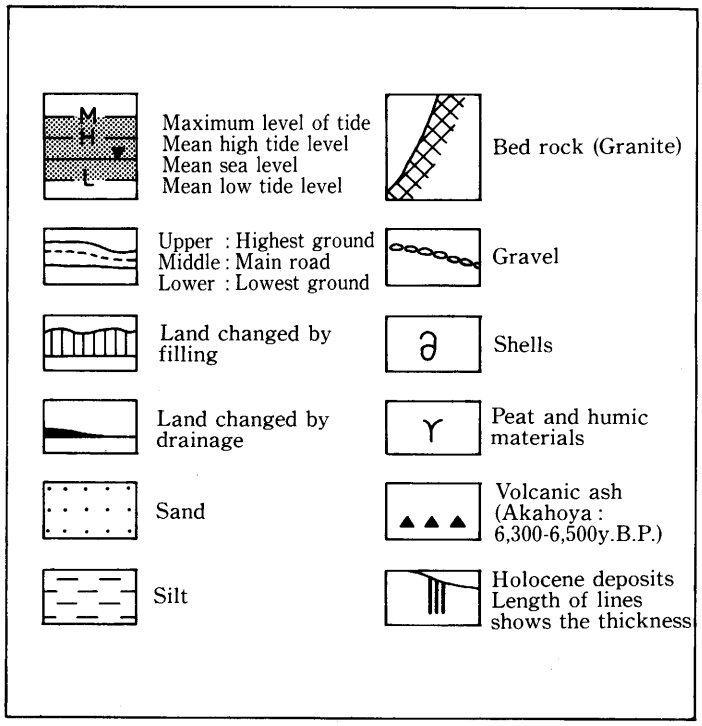
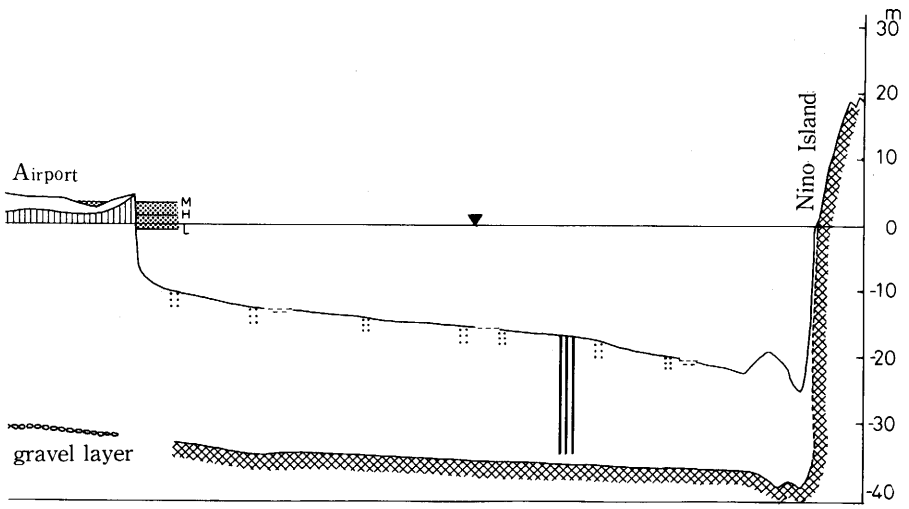


Fig. 3 The topographical and geological cross section.



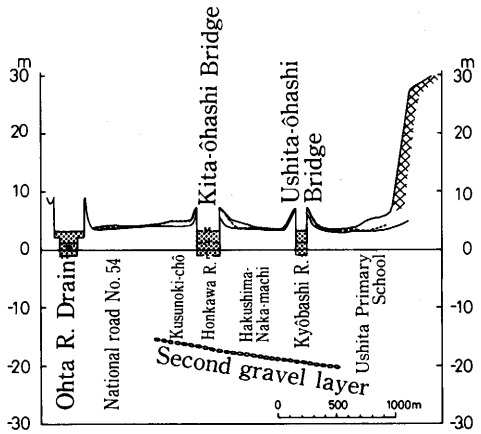
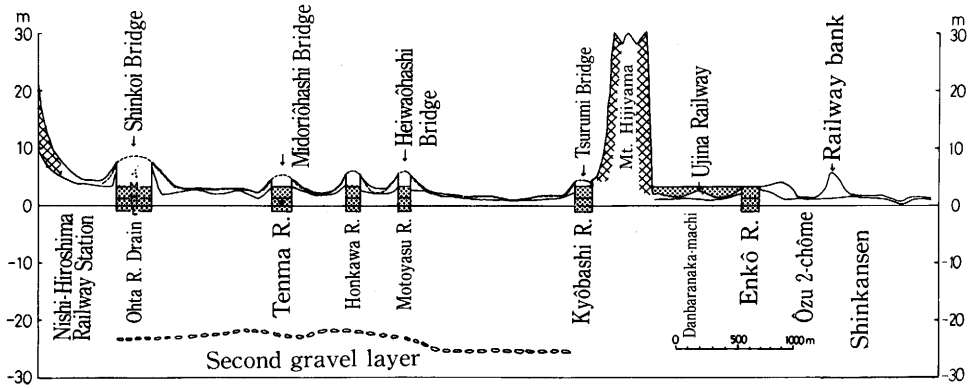
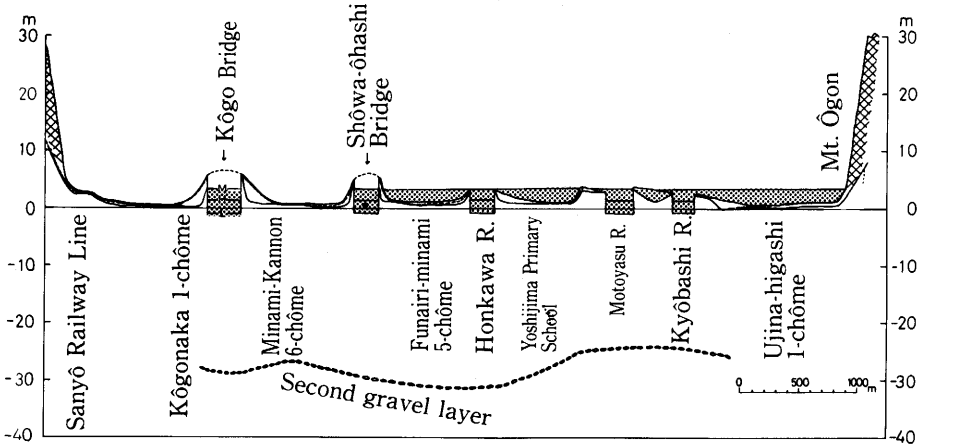


Fig. 3-3 The cross-section from east to west (The northern part of the Delta).

Fig. 3-4 The cross-section from east to west (The central part of the Delta).

Fig. 3-5 The cross-section from east to west (The southern part of the Delta).





work sustained by the advanced technology of civil engineering. The stratigraphical structure and the volume of reclaimed materials and the spatial flow between sources of supply and the reclamation site are shown in Fig. 4 and Table 2.

It is obvious that recent reclamation by filling needs voluminous materials, which have to be collected from widely distributed burrow pits located not only in the urban area and urban fringe area, but also from islands and the sea bottom some distance away (Fig. 4 and Table 2). Most of the materials for filling were obtained from Mt. Suzugaminé just behind the reclaimed site, the Seibu-Kaihatsu. The remaining burrow pits were graded for use as residential sites. It is finally expected that two thousand two hundred houses will be built and about eight thousand people will live in these areas.

The component ratio of reclaimed materials is as follows: 83% for terrestrial materials, 16% for marine sands and 1% for others (dredging). Terrestrial materials are mainly sandy materials derived from the upper part of weathered granitic rocks, so called *masa* in Japanese. Terrestrial materials are called *yama* (mountain)-*tsuchi* (soil), and are derived from

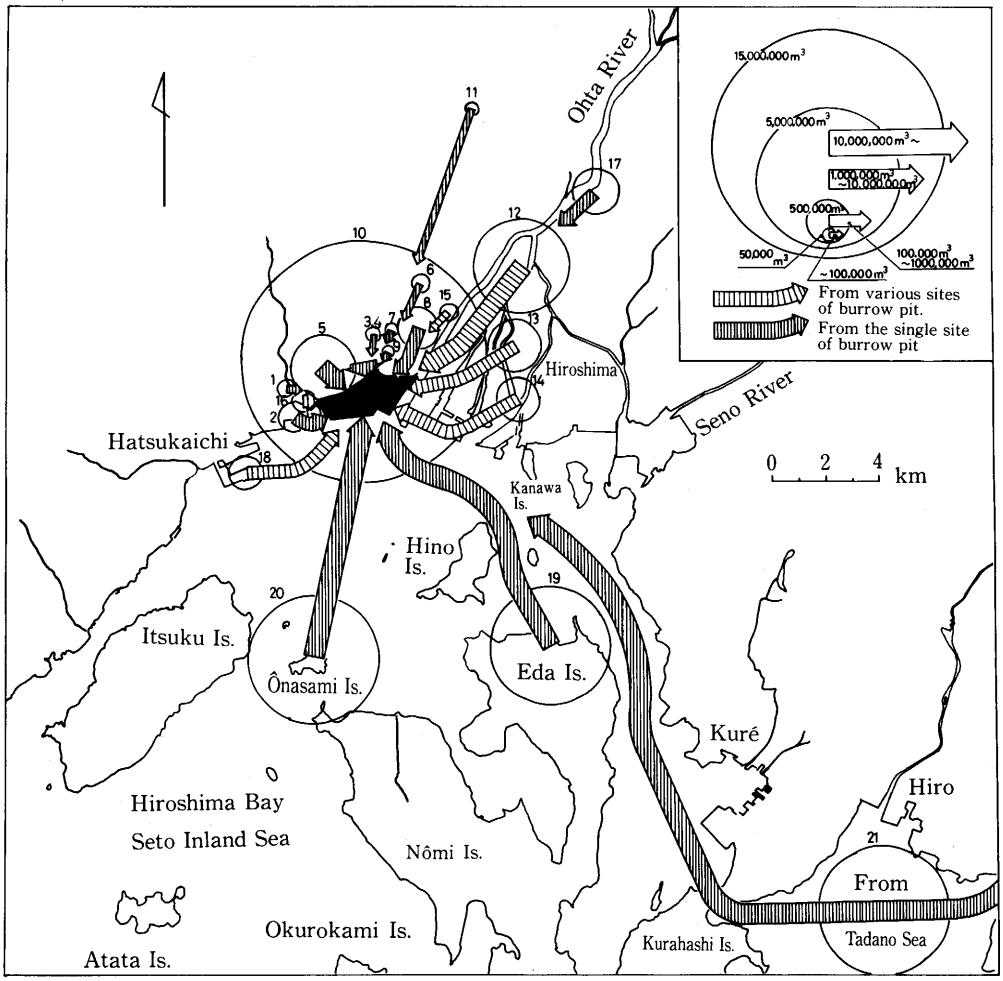


Fig. 4 The spatial flow of reclaimed materials taken place by the Seibu-Kaihatsu reclamation work.

Mt. Suzugaminé (43%) and islands (22%, consisting of 10% for Eta-Jima and 12% for Nasami-jima) and other sandy materials collected as remains due to development by public authorities and private enterprise.

Marine sand is transported from the sea bottom near Takehara town, called Tadano-umi. Marine sand is one of the important stratigraphical units in the filled-up strata for draining the water which oozes through the upper layers and through existing muddy layers in the

Table 2 The composition of materials collected for the reclamation work of the Seibu-Kaihatsu

Category of materials	Purpose of use	Volume, m^3 (% to total materials)	Place name of burrow pit	No. in Fig. 4
Marine sand	Sheeted sand Sand pile Loading earth	6,162,200 (16%)	Tadano-umi	21
Terrestrial material (Sandy materials of weathered granitic rocks: Yama-tsuchi)	Bottom-fill earth Loading earth Loading earth (Band protection) Total	3,107,300 786,100 119,800 4,013,200 (10%)	Eda Island	19
	Bottom-fill earth Loading earth Loading earth (Bank protection) Total	4,494,700 263,700 11,700 4,770,100 (12%)	Ônasami Island	20
	Earth fill	16,500,000 (43%)	Mt. Suzugaminé	10
	Remaining earth from other developments Earth fill Total	304,500 480,000 50,000 100,000 100,000 1,200,000 52,000 36,300 6,000 51,700 2,380,500 (6%)	Minaga Higashi-furué Yasufuruichi Itsukaichi Koi-uemachi Inokuchi Furué Furué Tagata Tagata	2 8 11 1 6 5 7 9 3 4
	Remaining earth of public development Total	77,000 151,000 569,000 797,000 (2%)	Koi (Nat. Rail ways) Itsukaichi (Min. Constr.) Kôyô water purifing plant (Waterworks Bureau)	15 16 17
	Remaining earth appeared in the city area Earth fill Total	2,475,500 789,000 522,200 3,786,700 (10%)	City area (Private developer) City area (Prefecture)	12 13 14
Others	Dredge, Earth fill	290,900 (1%)		18
	The grand total	38,700,600(100%)		

Note: This table is made up as of September 3, 1982.

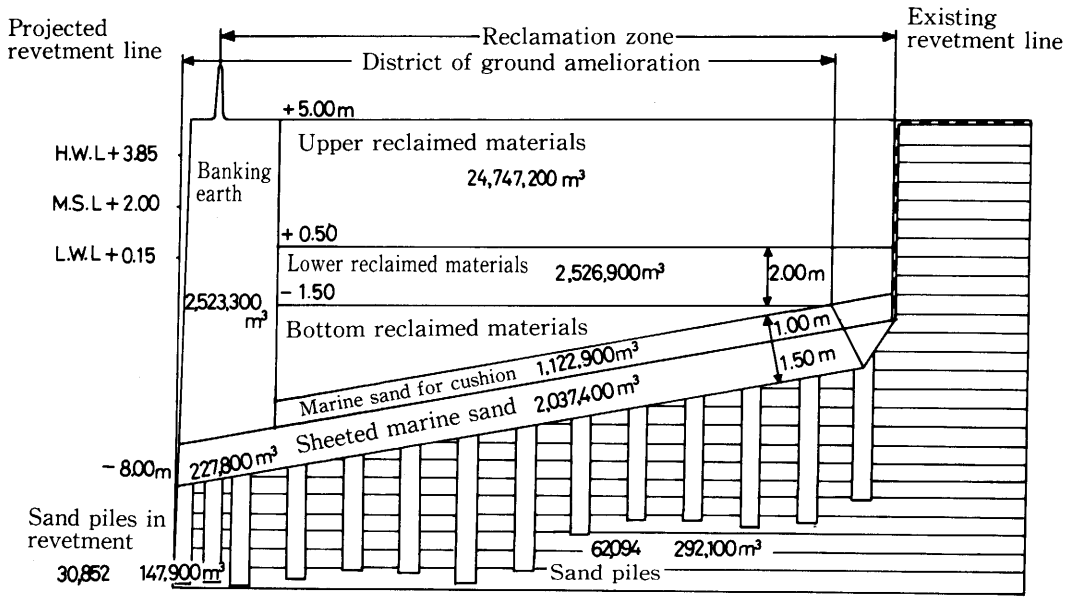


Fig. 5 The structure and stratigraphy of the land changed by filling, the Seibu-Kaihatsu.

delta deposits.

Several decades ago, reclamation work by filling was carried out only by dumping various kinds of materials composed of not only sand and gravel, but also refuse and industrial waste. Consequently, land produced by the above-mentioned filling is very soft and unstable ground, and restricts the possibility of land use. On the other hand, recently reclaimed land is created by using selected materials, and has a well organized stratigraphy as shown in Fig. 5.

Fig. 5 shows the stratigraphy and the structure of the reclaimed land of the Seibu-Kaihatsu. According to Fig. 5, the upper layers consist of terrestrial sandy materials, and the lower layers consist of marine sand except sand for sand pile in the existing sea bottom layer. There are a total of 92,946 sand piles. Many sand piles exist in order to drain away water oozing from the existing sea bottom layer composed of silt and mud. This silt and mud bottom layer is compacted by the above filled-up layers, thus the water oozes away into sand piles, and moves to the sheeted marine sand layer. Finally the water oozes away from it into the sea.

4. Concluding Remarks

The present Hiroshima Delta consists of not only naturally advanced alluvial plains, but also anthropogenic landforms due to reclamation by drainage and filling. The land changed by drainage was made mainly between the 17th Century and the 19th Century (Fig. 1). Though reclamation by drainage was carried out at an intertidal zone and on a very shallow sea floor, that is the upper surface of the delta, reclamation by filling was carried out at a

deeper part of the marginal delta (Fig. 3). Recent reclamation by filling is large in scale, and needs plenty of reclaimed materials composed of terrestrial sandy materials and marine sand (Table 1 and Fig. 2), and collected from many burrow pits and other sites (Fig. 4 and Table 2). Remaining burrow pits are often used as residential sites. The geology of mountains and hills around Hiroshima consists of weathered granitic rocks. Most of the recent development for residential sites take place in this area. Slopes appeared by cutting and filling in residential sites are thus easily eroded by slope failure or other surface processes.

On the other hand, remaining burrow pits in the sea change to depositional places, and the marine sand moves by tidal current in order to fill them up until attaining the next dynamic equilibrium of marine erosion. The redistribution of marine sand on the sea floor and on the surrounding sandy beaches creates a severe impact on the marine ecosystems of fish, shell and other marine organisms.

Reclaimed land by filling itself disturbs marine ecosystems by taking away the intertidal zones of beaches and the shallow sea floor. Water oozing out from the reclaimed materials and from the existing deltaic deposits sometimes creates problems of sea water pollution. Oyster and laver cultivation in Hiroshima Bay and inland sea fishing play a significant role in local industry. As a consequence of the gradual disappearance of shallow sea floor due to reclamation such industries have been forced to shift further out to sea.

The expansion of the Hiroshima Delta brought about other environmental problems concerning the defence against storm surge, flooding and other marine erosion. The present surface of the delta is not a simple flat surface, and is completely occupied by various artificial facilities. Higher and stronger bridges and riparian and coastal banks exist as symbols of defence against the catastrophic phenomena of nature between water and land. The inhabitants who live near those high banks and bridges have chosen to live there for reasons of safety and accordingly have chosen to forgo their former more aesthetically pleasing environment.

The expansion of the delta by reclamation achieved by advanced technological means is yet another symbol of man's progress. However, there is the danger that the more man alters his environment through technological means, the more he will be forced to rely on his own resources to check any possible counter-reaction by nature – thus accelerating the size of the gap separating man and nature. In the case of Hiroshima Bay, the existing balance between what is desirable for both man and the environment is barely being maintained and perhaps now is the time for serious reflection before it is too late.

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