

5.4.3.6 The SI was carried in phases to cover the areas of KTAC, KTTS and Hoi Sham. **Table 5.5** summarizes the sampling locations for the SI.

Table 5.5 Locations of Sampling Points for the SI

Location	Sampling Point
Kai Tak Approach Channel	AC1, AC2, AC3, AC4, AC5, AC6 and AC7
Kwun Tong Typhoon Shelter and the Proposed Typhoon Shelter	KT1, KT2, KT3 and KT4
Hoi Sham	KB1, KB2, KB3, KB4, KB5, KB6 and KB7

Collection of Sediment Samples

5.4.3.7 Vibrocore samples were collected at the sampling points. The vibrocore penetrated into the unconsolidated mud layer until the more compact consolidated sand layer was encountered. This could easily be distinguished by the different penetration rates of the two different layers during vibrocore. The sediment depth was further checked by visual observation of the collected vibrocore sample.

5.4.3.8 Vertical profile of the sediment core was taken at each sampling point. Three sediment samples were collected at the top 1 m layer, middle 1 m layer and bottom 1 m layer of each vibrocore sample when the sediment length was greater than 3 m. For sediment length between 900 mm and 3 m, three equal sections were divided from the top of the vibrocore samples. For sediment length less than 900 mm, three equal sections of 300 mm were divided from the top of vibrocore samples. Each sample was split into aliquots for both inorganic and organic analyses. The size of aliquots collected for inorganic and organic analyses was as follows:

Metals and metalloid: 0.5 litre
Organic: 0.5 litre

Laboratory Analysis of Sediment

5.4.3.9 The collected vibrocore samples were analyzed for the following parameters:

- Total organic carbon (TOC), sediment oxygen demand (SOD), total sulphide and acid volatile sulphide (AVS);
- Heavy metals and metalloid including cadmium (Cd), chromium (Cr), copper (Cu), mercury (Hg), nickel (Ni), lead (Pb), zinc (Zn), silver (Ag) and arsenic (As); and
- Organic micro-pollutants including polychlorinated biphenyls (PCB), tributyltin (TBT) and polyaromatic hydrocarbons (PAHs).

5.4.3.10 In order to estimate the percentage of biodegradable TOC, three grab samples of the upper layer sediment collected at the KTAC were analyzed for carbon compound fractionation using Gas Chromatography – Flame Ionization Detector (GC-FID).

5.4.3.11 Analytical methods in accordance with the *Standards Methods for the Examination of Water and Wastewater by APHA* and relevant testing methods (e.g. USEPA) were adopted in analyzing the above listed parameters.

5.5 Identification, Prediction and Evaluation of Potential Impacts

5.5.1 Sediment Contamination

5.5.1.1 The chemical characteristics of the sediments collected at KTAC, KTTS and Hoi Sham were determined for the SI. The average depths of the contaminated sediments in the KTAC, KTTS, Hoi Sham and near Cha Kwo Ling were 2.9m, 1.63m, 1.81m, 3.75m respectively. The

average depth for each reclamation area was calculated by averaging the sediment depths at all the individual sampling points. The sediment depth at each sampling point was determined during the vibrocore sampling. The vibrocore penetrated into the sediment layer until the consolidated sand layer was encountered. The sediment depth was further checked by visual observation of the collected vibrocore sample to ensure that the vibrocore sample covered the whole depth of the contaminated sediments. Since the reclamation will commence after end of 2001, criteria stipulated in *WBTC No. 3/2000* were used for the classification of sediment.

- 5.5.1.2 Analytical results of the sediments including the parameters of cadmium, chromium, copper, mercury, nickel, lead, silver, zinc, arsenic, polycyclic aromatic hydrocarbons, polychlorinated biphenyls and tributyltin, are summarized in **Tables 5.6 to 5.8**. The results of the KTAC sediments showed that concentrations of most of the tested parameters were very high. The only exception was arsenic. All the arsenic concentrations in the sediments collected from the KTAC were below the LCEL of 12 mg/kg (dry weight). The sediments in the KTAC were considered seriously contaminated. High heavy metal contents found in the area would be related to the wastewater discharges from polluting industries in the past.
- 5.5.1.3 The contamination in the KTAC sediments was dominated by copper, silver, chromium, nickel, zinc and to a lesser extent by lead, mercury and cadmium. The sediments at sampling points AC1 to AC5 located near the entrance of Kai Tak Nullah showed higher contamination levels. The contamination levels at sampling points AC6 and AC7 located farther away from the entrance of Kai Tak Nullah were comparatively lower. The organic micro-pollutants (PCBs, PAHs and TBT) were generally high in concentrations especially the PCB levels at AC2 and AC5. The TBT levels at AC6 and AC7 were found to be higher than that of the other sampling points in the KTAC. **Drawing Nos. 22936/EN/046 to 051** show the concentration distributions of the selected heavy metals in KTAC.
- 5.5.1.4 As presented in **Table 5.7**, the contamination in the KTTS sediments (KT1 and KT2) showed similar characteristics as that in the KTAC. The copper concentrations in the sediments were the highest. The contamination was dominated to a lesser extent by lead, chromium, zinc, cadmium and nickel. Some of the silver and mercury contents were several times higher than their LCELS. The arsenic levels at all the sampling points were below the LCEL except the lower sediment layer (1.49–2.05m) at KT2. The measured organic micro-pollutant concentrations (PCBs, PAHs and TBT) were high at KT1 and KT2. The contamination levels were found to be higher mostly in the upper and middle layers of the sediments. The sediments collected at sampling points KT3 and KT4 located near the exit of Tsui Ping Nullah were found to be less contaminated.
- 5.5.1.5 The analytical results of the sediments collected in Hoi Sham showed that the copper concentrations were the highest amongst the other tested heavy metals, in particular at KB6 and KB7. The concentrations of other heavy metals were also found to be high and mostly exceeded the LCEL. Elevated levels of lead, chromium and zinc were recorded in most of the sampling points. The arsenic concentrations were in general below the LCEL except in the lower sediment layer at KB5. Some of the PCB and PAH levels in the sediments collected from Hoi Sham were exceptionally high. The highest PCB and PAH levels were found at KB6. The analytical results indicated that the entire depth at KB6 (0-1.9m) was seriously contaminated. Not only high PAH and PCB levels were observed at KB6, the concentrations of other tested parameters were also high at the same location. The TBT levels in the Hoi Sham area were comparatively higher than that recorded in the KTAC and KTTS. **Drawing Nos. 22936/EN/095 to 100** show the concentration distributions of the selected heavy metals in Hoi Sham.
- 5.5.1.6 The sediments in the upper, middle and lower layers collected at all the sampling points in the KTAC were in the Class C category according to *TC No. 1-1-92*. Comparisons with the sediment classification stipulated in the *WBTC No. 3/2000* showed that all the sediments were Category H material. In addition, at least one layer of sediments at sampling points AC1 to

- AC6 showed contaminant levels 10 times higher than the LCEL. In accordance with the *WBTC No. 3/2000*, Tier III screening test would be required to determine the disposal option for these sediments.
- 5.5.1.7 All the sediments collected in KTTS were classified as Category H material (and in the Class C category according to *TC No. 1-1-92*). The upper and middle sediment layers at KT1 and KT2 and the lower sediment layer at KT4 showed contaminant levels 10 higher than the LCEL. The remaining layers at these sampling points and all three layers at KT3 showed contaminant levels below 10 x LCEL.
- 5.5.1.8 The sediments in Hoi Sham were Category H material except that the sediments in the middle layer at KB2 would be Category M material. With reference to the *TC No. 1-1-92*, all these sediments were also classified as Class C material. The contaminant levels in all layers of sediments at KB5, KB6 and KB7 exceeded 10 x LCEL. In addition, at least one layer of sediments at the remaining sampling points (KB1 to KB4) showed contaminant levels 10 times higher than the LCEL. Tier III screening test would be required to determine the disposal option for these sediments.
- 5.5.1.9 Total sulphide and AVS results are presented in **Table 5.9**. Total sulphide concentrations measured in the three layers at most of the sampling stations were below 1 mg/kg (dry weight). The highest total sulphide level (147 mg/kg (dry weight)) was found in the upper layer (0.1 – 1.1m) at AC1 located nearest to the entrance of Kai Tak Nullah. The laboratory analysis of total sulphide was based on 1:5 sediment/water extraction. The total sulphide results represented the portion of water extractable sulphide and would be comparatively lower than the extraction using acid. The results of AVS concentrations as shown in **Table 5.9** were much higher than the total sulphide concentrations. The range of AVS concentrations in the KTAC sediments was from 557 to 6689 mg/kg (dry weight). The sediments at sampling points AC2 to AC4 contained higher AVS concentrations at the upper and middle layers. High AVS concentrations were also found in the middle and lower layer at the other sampling points. The high AVS concentrations in the area indicate that odorous hydrogen sulphide gas is likely to be generated. This is a result of the reaction $\text{SO}_4^{2-} \rightarrow \text{HS}^-$ or H_2S . It is obvious that the sediments with high AVS concentrations are the major source of odour in the KTAC.
- 5.5.1.10 The highest total sulphide concentration of 126 mg/kg (dry weight) was recorded in the upper layer at KB1. Most of the results at the other sampling points were below 1 mg/kg (dry weight). Elevated AVS results were mostly found in the upper layer of the sediments (KB1, KB4, KB6 and KB7) with the highest level of 1987 mg/kg (dry weight) at KB4. The overall AVS concentrations recorded in Hoi Sham were much lower than that recorded in the KTAC.
- 5.5.1.11 Total sulphide concentrations at sampling points KT1 to KT4 were mostly below 1 mg/kg (dry weight). No high peak of total sulphide was found and the highest total sulphide concentration recorded in the middle layer at KT2 was 3 mg/kg (dry weight). The AVS concentrations recorded at KT1 and KT2 were in general higher than that recorded at AC6 and AC7. This would be related to the discharge of pollutants from the box culvert at KTTS.

Table 5.6 Sediment Chemical Quality Results – Kai Tak Approach Channel

Location	Depth (m)	Coordinates		Sediment Chemical Quality													Sediment Classification TC No. 1-1-92	Sediment Classification WBTC No.3/2000
		Easting	Northing	Ag (mg/kg)	As (mg/kg)	Cd (mg/kg)	Cr (mg/kg)	Cu (mg/kg)	Ni (mg/kg)	Pb (mg/kg)	Zn (mg/kg)	Hg (mg/kg)	Low molecular wt. PAHs (µg/kg)	High molecular wt. PAHs (µg/kg)	Total PCBs (µg/kg)	TBT (µgSn/kg)		
AC1	0.10-1.10	838804.86	820146.79	<u>16.10</u>	5.4	2.96	218	529	66.7	123	987	1.24	1306	4398	150	17 (< 0.015)	Class C	Category H
AC1	1.10-2.10	838804.86	820146.79	6.59	7.6	4.50	<u>1081</u>	<u>3670</u>	192	156	1129	3.69	2830	3973	140	8	Class C	Category H
AC1	2.10-3.10	838804.86	820146.79	7.07	5.3	2.89	<u>938</u>	<u>1599</u>	137	103	611	1.08	1141	2135	170	8	Class C	Category H
AC2	0.00-1.00	838924.24	819940.24	6.20	3.9	2.02	550	<u>824</u>	99.6	123	667	1.34	742	2814	<u>270</u>	3	Class C	Category H
AC2	1.00-2.00	838924.24	819940.24	6.95	5.4	3.30	<u>929</u>	<u>1267</u>	149	204	975	2.81	2380	4975	<u>340</u>	4	Class C	Category H
AC2	2.00-3.00	838924.24	819940.24	2.08	4.2	1.31	219	243	53	126	344	0.85	1354	5915	<u>560</u>	3	Class C	Category H
AC3	0.20-1.20	839082.41	819958.33	7.63	6.1	2.60	537	<u>1743</u>	111	163	840	1.87	1501	3776	190	7	Class C	Category H
AC3	1.20-2.20	839082.41	819958.33	3.53	4.9	1.70	287	423	67.8	144	542	1.51	1066	2006	220	4	Class C	Category H
AC3	2.20-3.20	839082.41	819958.33	3.31	5.2	1.44	318	385	67.2	133	456	1.54	783	1419	<u>300</u>	5	Class C	Category H
AC4	0.25-1.25	839202.72	819766.02	4.95	2.5	0.80	61.5	150	20.5	102	633	0.68	835	1846	47	2 (< 0.015)	Class C	Category H
AC4	1.45-2.45	839202.72	819766.02	4.10	3.7	4.76	198	<u>822</u>	62.4	125	656	1.19	668	1132	52	5	Class C	Category H
AC4	2.65-3.65	839202.72	819766.02	1.99	4.3	0.91	171	<u>233</u>	44.1	383	339	1.02	735	1290	180	7	Class C	Category H
AC5	0.00-0.75	839315.26	819565.15	5.36	6.0	2.21	537	<u>890</u>	112	142	681	1.88	742	1683	<u>390</u>	4	Class C	Category H
AC5	0.75-1.50	839315.26	819565.15	2.63	4.5	1.23	270	339	47.1	114	402	1.24	915	1665	<u>310</u>	3	Class C	Category H
AC5	1.50-2.25	839315.26	819565.15	5.47	6.1	2.87	692	<u>717</u>	154	188	702	2.71	1699	2600	<u>820</u>	7	Class C	Category H
AC6	0.25-0.85	839478.85	819577.05	0.72	2.1	0.35	32.4	165	11.5	58.6	133	0.27	89	443	35	7	Class C	Category H
AC6	0.85-1.45	839478.85	819577.05	3.29	5.8	1.86	289	<u>847</u>	67.1	129	445	0.88	225	1016	87	27	Class C	Category H
AC6	1.45-2.05	839478.85	819577.05	1.55	4.1	0.70	120	203	32.3	90.2	204	0.70	111	655	120	6	Class C	Category H
AC7	0.65-1.45	839599.62	819393.66	1.00	3.0	0.40	45	202	14.1	46.8	108	0.87	95	454	26	9 (0.017)	Class C	Category H
AC7	1.45-2.25	839599.62	819393.66	3.34	5.2	1.52	268	623	59	108	307	0.93	200	827	160	30	Class C	Category H
AC7	2.25-3.05	839599.62	819393.66	2.49	4.5	0.89	172	266	41.4	81.7	234	0.78	179	995	160	10	Class C	Category H

- Notes:
1. The underlined number means that the concentration is 10 times higher than the Lower Chemical Exceedance Level;
 2. The sample volume of vibrocore sediments was not sufficient for carrying out TBT analysis in interstitial water. Surface grab samples were collected at selected sampling points and pore water tests were conducted. The numbers in brackets are the TBT results in µg TBT/L from pore water tests.

Table 5.7 Sediment Chemical Quality Results – Kwun Tong Typhoon Shelter

Location	Depth (m)	Coordinates		Sediment Chemical Quality													Sediment Classification TC No. 1-1-92	Sediment Classification WBTC No.3/2000
		Easting	Northing	Ag (mg/kg)	As (mg/kg)	Cd (mg/kg)	Cr (mg/kg)	Cu (mg/kg)	Ni (mg/kg)	Pb (mg/kg)	Zn (mg/kg)	Hg (mg/kg)	Low molecular wt. PAHs (µg/kg)	High molecular wt. PAHs (µg/kg)	Total PCBs (µg/kg)	TBT (µgSn/kg)		
KT1	0.30-0.60	839914.66	819393.56	4.24	6.0	2.68	369	<u>1600</u>	81.3	224	449	1.33	166	1397	<u>340</u>	55 (<0.015)	Class C	Category H
KT1	0.60-0.90	839914.66	819393.56	3.62	6.3	2.85	361	<u>1570</u>	84.3	159	493	1.29	197	1381	<u>430</u>	48	Class C	Category H
KT1	0.90-1.20	839914.66	819393.56	2.02	6.1	1.35	98.3	382	29.8	94.2	213	1.02	90	668	100	12	Class C	Category H
KT2	0.35-0.92	840073.08	819241.19	4.79	5.9	3.59	567	<u>2959</u>	136	180	589	1.37	315	1883	<u>270</u>	35 (<0.015)	Class C	Category H
KT2	0.92-1.49	840073.08	819241.19	5.18	4.8	6.37	645	<u>1104</u>	87.7	398	502	1.77	305	1858	<u>1600</u>	28	Class C	Category H
KT2	1.49-2.05	840073.08	819241.19	0.35	11.9	0.13	27.1	39.3	17.8	129	177	2.62	200	1191	11	<0.5	Class C	Category H
KT3	0.10-1.10	841064.83	818296.58	3.49	5.9	1.08	108	436	26.9	76.8	267	0.69	209	1499	22	47	Class C	Category H
KT3	1.40-2.40	841064.83	818296.58	2.20	4.5	1.62	113	587	26.9	80.3	193	0.68	84	142	94	28	Class C	Category H
KT3	2.70-3.70	841064.83	818296.58	2.67	4.8	3.01	134	628	30.5	102	226	0.93	47	55	110	13	Class C	Category H
KT4	0.00-1.00	840912.49	818138.16	1.59	3.4	0.34	33.9	117	9.92	64.7	82.2	0.22	50	247	14	11 (<0.015)	Class C	Category H
KT4	1.40-2.40	840912.49	818138.16	1.31	4.0	0.73	101	234	28	59.5	157	0.70	132	1270	130	18	Class C	Category H
KT4	2.80-3.80	840912.49	818138.16	2.10	6.0	0.54	142	187	30.8	76.6	208	1.02	132	1056	<u>360</u>	11	Class C	Category H

- Notes:
1. The underlined number means that the concentration is 10 times higher than the Lower Chemical Exceedance Level;
 2. The sample volume of vibrocore sediments was not sufficient for carrying out TBT analysis in interstitial water. Surface grab samples were collected at selected sampling points and pore water tests were conducted. The numbers in brackets are the TBT results in µg TBT/L from pore water tests.

Table 5.8 Sediment Chemical Quality Results – Hoi Sham/Kowloon Bay

Location	Depth (m)	Coordinates		Sediment Chemical Quality													Sediment Classification TC No. 1-1-92	Sediment Classification WBTC No.3/2000
		Easting	Northing	Ag (mg/kg)	As (mg/kg)	Cd (mg/kg)	Cr (mg/kg)	Cu (mg/kg)	Ni (mg/kg)	Pb (mg/kg)	Zn (mg/kg)	Hg (mg/kg)	Low molecular wt. PAHs (µg/kg)	High molecular wt. PAHs (µg/kg)	Total PCBs (µg/kg)	TBT (µgSn/kg)		
KB1	0.00-0.90	837972.72	818966.22	6.06	6.4	1.18	114	556	35.6	88.5	373	1.09	81	542	49	64 (<0.015)	Class C	Category H
KB1	0.90-1.80	837972.72	818966.22	4.56	7.0	1.18	136	896	47.8	123	259	1.25	528	3309	48	51	Class C	Category H
KB1	1.80-2.70	837972.72	818966.22	4.31	6.9	1.41	204	1428	62.5	124	351	1.99	429	2891	69	20	Class C	Category H
KB2	0.00-0.74	838048.56	819357.17	1.61	5.0	0.43	68.5	164	16.6	78.4	150	0.95	418	3968	110	2	Class C	Category H
KB2	0.74-1.48	838048.56	819357.17	0.63	2.0	0.17	25.5	97.4	7.23	32.5	50.5	0.34	40	197	48	7	Class C	Category M
KB2	1.48-2.22	838048.56	819357.17	3.14	6.9	3.20	124	229	37.9	93.7	389	1.52	2960	22410	390	9	Class C	Category H
KB3	0.05-0.51	838045.89	819656.72	0.20	4.3	0.13	29.8	33.8	18.6	27.8	78	1.82	519	2555	40	60	Class C	Category H
KB3	0.51-0.97	838045.89	819656.72	3.95	6.1	1.14	145	775	42.1	112	310	0.26	6970	50430	300	38	Class C	Category H
KB3	0.97-1.43	838045.89	819656.72	3.41	5.0	0.94	124	614	33.4	91.1	266	0.20	54	296	2	1	Class C	Category H
KB4	0.10-0.63	838450.29	819374.58	6.68	7.1	0.84	103	531	29.1	73.9	248	0.85	81	298	47	141	Class C	Category H
KB4	0.63-1.16	838450.29	819374.58	3.98	6.3	0.89	122	723	32.9	171	221	1.06	305	2643	38	57	Class C	Category H
KB4	1.16-1.69	838450.29	819374.58	3.16	6.6	0.94	115	651	34	78.8	174	0.98	470	2277	210	46	Class C	Category H
KB5	0.10-0.43	838271.87	819591.33	4.02	6.9	1.03	158	1189	41.9	125	277	1.50	182	1695	81	83 (<0.015)	Class C	Category H
KB5	0.43-0.76	838271.87	819591.33	3.80	6.6	0.90	124	917	41.1	109	212	1.14	175	1646	100	49	Class C	Category H
KB5	0.76-1.09	838271.87	819591.33	1.33	9.9	1.54	61	127	20.4	188	253	0.97	1576	28580	210	5	Class C	Category H
KB6	0.10-0.70	838350.72	819973.01	3.18	6.5	<0.02	265	4222	188	489	480	6.45	5880	41720	120	88	Class C	Category H
KB6	0.70-1.30	838350.72	819973.01	2.95	7.5	<0.02	511	9898	349	770	825	6.08	29080	93710	320	73	Class C	Category H
KB6	1.30-1.90	838350.72	819973.01	5.95	7.5	3.05	458	790	104	228	868	3.61	30000	178000	1500	24	Class C	Category H
KB7	0.00-0.55	838659.40	819678.09	3.84	7.6	1.81	277	2538	86.9	204	355	3.03	98	1098	120	76 (<0.015)	Class C	Category H
KB7	0.55-1.10	838659.40	819678.09	3.52	7.2	1.23	232	1025	52.8	131	352	1.89	920	11020	290	26	Class C	Category H
KB7	1.10-1.65	838659.40	819678.09	3.16	8.0	1.77	173	263	42.7	133	450	3.17	1846	44870	1000	12	Class C	Category H

- Notes:
1. The underlined number means that the concentration is 10 times higher than the Lower Chemical Exceedance Level;
 2. The sample volume of vibrocore sediments was not sufficient for carrying out TBT analysis in interstitial water. Surface grab samples were collected at selected sampling points and pore water tests were conducted. The numbers in brackets are the TBT results in µg TBT/L from pore water tests.

Table 5.9 Laboratory Results of Total Sulphide and Acid Volatile Sulphide

Vibrocore Station	Depth below Seabed (m)	Total Sulphide (mg/kg, dry weight)	AVS (mg/kg, dry weight)
AC1	0.10-1.10	147	2206
AC1	1.10-2.10	4	4567
AC1	2.10-3.10	<1	4424
AC2	0.00-1.00	<1	4943
AC2	1.00-2.00	4	4597
AC2	2.00-3.00	<1	1153
AC3	0.20-1.20	<1	6689
AC3	1.20-2.20	<1	6013
AC3	2.20-3.20	<1	3625
AC4	0.25-1.25	7	4661
AC4	1.45-2.45	4	4156
AC4	2.65-3.65	<1	1331
AC5	0.00-0.75	<1	3938
AC5	0.75-1.50	<1	1803
AC5	1.50-2.25	<1	4172
AC6	0.25-0.85	<1	1184
AC6	0.85-1.45	<1	1543
AC6	1.45-2.05	<1	1559
AC7	0.65-1.45	<1	822
AC7	1.45-2.25	<1	2072
AC7	2.25-3.05	<1	557
KB1	0.00-0.90	126	1977
KB1	0.90-1.80	<1	149
KB1	1.80-2.70	<1	129
KB2	0.00-0.74	<1	61
KB2	0.74-1.48	<1	36
KB2	1.48-2.22	<1	118
KB3	0.05-0.51	<1	331
KB3	0.51-0.97	<1	29
KB3	0.97-1.43	<1	<4
KB4	0.10-0.63	6	1987
KB4	0.63-1.16	<1	547
KB4	1.16-1.69	<1	23
KB5	0.10-0.43	<1	307
KB5	0.43-0.76	<1	79
KB5	0.76-1.09	<1	175
KB6	0.10-0.70	<1	1375
KB6	0.70-1.30	<1	1073
KB6	1.30-1.90	<1	314
KB7	0.00-0.55	<1	1007
KB7	0.55-1.10	<1	320
KB7	1.10-1.65	<1	154
KT1	0.30-0.60	2	2272
KT1	0.60-0.90	<1	1902
KT1	0.90-1.20	<1	880
KT2	0.35-0.92	<1	3968
KT2	0.92-1.49	3	5433
KT2	1.49-2.05	<1	9
KT3	0.10-1.10	<1	1265
KT3	1.40-2.40	<1	614
KT3	2.70-3.70	<1	144
KT4	0.00-1.00	<1	282
KT4	1.40-2.40	<1	339
KT4	2.80-3.80	<1	821

5.5.2 **Biogas Generation**

- 5.5.2.1 The vibrocore samples collected in the KTAC, KTTS and Hoi Sham were analyzed for TOC and SOD. The incubation period for the SOD test was selected to be 20 days. **Table 5.10** presents the TOC and SOD results for the SI.
- 5.5.2.2 **Drawing Nos. 22936/EN/052 to 055** show the TOC and SOD distributions in KTAC. The analytical results for the KTAC show that there was a decreasing trend of TOC concentrations from AC1 to AC7. This indicates that the inner part of KTAC contained higher concentrations of organic matter. The range of TOC results varied from 0.45 to 13.2% (dry weight). The overall depth-averaged TOC in the KTAC sediments was 4.4 % (dry weight).
- 5.5.2.3 The SOD levels in the sediments collected at AC1 to AC5 were higher than those at AC6 and AC7. This was consistent with the TOC measurements. The overall depth-averaged SOD in the KTAC sediments was 9376 mg/kg (dry weight).
- 5.5.2.4 The sampling points KT1 and KT2 are located near the exit of the KTAC. The TOC and SOD results in the sediments collected at these two sampling points were found to be higher than those recorded at AC6 and AC7. The pollutants discharged from the nearby box culvert may contribute to the high concentrations of TOC and SOD at KT1 and KT2. The overall depth-averaged TOC and SOD results are 2.9% (dry weight) and 6017 mg/kg (dry weight) respectively.
- 5.5.2.5 The SOD and TOC levels in the sediments collected at KT1 and KT2 were higher than those collected at KT3 and KT4. The sediments in the inner part of KTTS appeared to be more seriously contaminated. The SOD results ranged between 1060 and 8840 mg/kg (dry weight) and the TOC results ranged between 1.03 and 5.57 % (dry weight). The overall depth-averaged SOD and TOC levels were 6017 mg/kg (dry weight) and 2.9 % (dry weight) respectively.
- 5.5.2.6 **Drawing Nos. 22936/EN/101 to 104** show the TOC and SOD distributions in Hoi Sham. The sediments collected in Hoi Sham contained lower SOD and TOC levels when compared to the other two reclamation areas. The SOD results ranged between 570 and 9750 mg/kg (dry weight) whilst the TOC results ranged between 0.49 and 5.27 % (dry weight). The overall depth-averaged SOD and TOC levels were 2744 mg/kg (dry weight) and 2.2 % (dry weight) respectively.

Table 5.10 Total Organic Carbon and Sediment Oxygen Demand Results for the Site Investigation

Vibrocore Station	Depth below Seabed (m)	Moisture Content %	TOC (% dry wt.)	SOD (mg/kg dry wt)
AC1	0.10-1.10	86.4	13.2	7770
AC1	1.10-2.10	74.6	11.2	14100
AC1	2.10-3.10	57.5	4.59	13300
AC2	0.00-1.00	47.6	4.77	15600
AC2	1.00-2.00	49.1	11.3	19400
AC2	2.00-3.00	39.9	2.41	5720
AC3	0.20-1.20	70.1	7.53	11200
AC3	1.20-2.20	55.1	3.90	11800
AC3	2.20-3.20	48.6	3.21	11300
AC4	0.25-1.25	56.3	5.15	10200
AC4	1.45-2.45	52.5	4.11	15000
AC4	2.65-3.65	40.5	1.93	6410
AC5	0.00-0.75	51.5	4.02	12000
AC5	0.75-1.50	40.1	2.84	6540
AC5	1.50-2.25	48.7	4.78	17400
AC6	0.25-0.85	33.3	0.45	2550
AC6	0.85-1.45	47.1	1.89	4810
AC6	1.45-2.05	33.6	1.13	3210
AC7	0.65-1.45	37.0	0.56	2070
AC7	1.45-2.25	39.0	1.72	3630
AC7	2.25-3.05	33.6	1.73	2880
KB1	0.00-0.90	69.8	2.48	4400
KB1	0.90-1.80	54.5	1.98	3430
KB1	1.80-2.70	52.1	1.88	1590
KB2	0.00-0.74	37.2	1.19	1560
KB2	0.74-1.48	19.1	0.49	1280
KB2	1.48-2.22	43.0	1.67	1450
KB3	0.05-0.51	48.6	1.85	1710
KB3	0.51-0.97	47.4	2.09	2490
KB3	0.97-1.43	25.7	0.81	570
KB4	0.10-0.63	69.2	1.95	3370
KB4	0.63-1.16	60.7	1.65	1030
KB4	1.16-1.69	53.1	2.35	1960
KB5	0.10-0.43	57.0	1.74	3840
KB5	0.43-0.76	54.6	1.43	1290
KB5	0.76-1.09	39.5	1.40	1140
KB6	0.10-0.70	64.8	3.84	3760
KB6	0.70-1.30	63.0	5.27	9750
KB6	1.30-1.90	57.9	4.63	4370
KB7	0.00-0.55	58.6	2.29	3320
KB7	0.55-1.10	56.0	2.50	1930
KB7	1.10-1.65	55.2	2.68	3380
KT1	0.30-0.60	50.7	2.03	8010
KT1	0.60-0.90	48.2	3.51	6470
KT1	0.90-1.20	41.6	1.03	2960
KT2	0.35-0.92	50.6	5.57	8760
KT2	0.92-1.49	61.9	3.67	8840
KT2	1.49-2.05	43.5	1.59	1060
KT3	0.10-1.10	52.1	1.67	3960
KT3	1.40-2.40	38.3	1.13	3390
KT3	2.70-3.70	41.7	1.37	3400
KT4	0.00-1.00	30.8	1.16	1290
KT4	1.40-2.40	37.7	3.21	3540
KT4	2.80-3.80	45.9	1.66	2430

Estimation of Methane Generation Potential Based on TOC

- 5.5.2.7 Under anaerobic conditions, degradation of organic matter would generate methane and carbon dioxide. The ratio of methane to carbon dioxide was assumed to be 50% : 50% based on the reaction $2C_6H_{12}O_6 \rightarrow 6CH_4 + 6CO_2$. The ratio of mass of methane to mass of TOC was approximately 0.67 in the sediments.
- 5.5.2.8 In the previous *Feasibility Study for South East Kowloon Development* and study in *Tsuen Wan Bay Further Reclamation - Biogas Risk Assessment*, the adopted peak annual methane potential based on half-life cycles of ½ year and 5 years were between 13% and 75%. In considering that almost 90-95% of the organic matter would have been degraded after two years of reclamation based on a half-life of ½ year, this higher flux rate would not be significant for the future developments. The methane flux would be reduced to a rate much lower than that of the peak annual methane potential based on a half-life of 5 years after the same time. For a short half-life cycle of decay, the decomposition rate of biodegradable organic matter would be high. To cover a reasonable range of half-life cycles, the half-life cycles of 2 years and 5 years were considered for estimation of potential methane emission in this study.
- 5.5.2.9 The KTAC reclamation covers an area of approximately 29.7ha. Within this area, all sediments were heavily polluted and contained high concentrations of organic matter. The average sediment depth in this area was 2.9m. **Table 5.11** presents the calculation of total methane potential from the reclamation area of KTAC. The estimated total methane potential were 1.95×10^7 kg or 2.74×10^7 m³.

Table 5.11 Calculation of Total Methane Potential Based on TOC – KTAC

Area of Reclamation (m ²)	2.97x10 ⁵
Average depth of sediment (m)	2.90
Volume of sediment to be left in situ (m ³)	86x10 ⁴
Assumed density of sediment (kg/m ³)	1529
Average dry matter of the undredged area (% w/w)	50.38
Mass of dry matter (kg per each m ³)	770
Average TOC level of the undredged area (%)	4.40
Mass of TOC (kg/m ³)	33.89
CH ₄ potential (kg/m ³)	22.71
Total CH ₄ potential (kg)	1.95x10 ⁷
Total CH ₄ potential (m ³)	2.74x10 ⁷

Note: Mass of methane potential is equal to 0.67 times of the mass of TOC in the sediments.

- 5.5.2.10 The annual and daily methane fluxes from the KTAC reclamation for different year intervals based on half-life cycles of 2 and 5 years are presented in **Tables 5.12** and **5.13** respectively. The potential daily methane flux decreases with time as the decay of organic matter. The results based on a half-life cycle of 2 years showed higher methane fluxes for the first several years after the reclamation. The methane flux after two years of reclamation would be 68.8 L/m²/day. After 8 years following reclamation, the methane flux would fall below the maximum safe rate of gas emission.
- 5.5.2.11 For a decay rate of 5 years, the daily methane flux would be 24.95 L/m²/d after a two-year period. This value was still much higher than the maximum safe rate of gas emission (10 L/m²/d). Based on the calculation, the daily methane flux would fall below the maximum safe rate of gas emission after 9 years following reclamation. It is obvious that if the sediments were left in place and no further treatment of the sediments were taken prior to reclamation, the risk of methane emission to the development is likely to be high.

Table 5.12 Annual and Daily Methane Fluxes Based on TOC (Half-life Cycle = 2 years) – KTAC

Year After Sediment Becomes Anaerobic	Remaining Methane Generation Potential (m ³)	Methane produced (m ³ /yr)	Methane Flux (L/m ² -yr)	Methane Flux (L/m ² -day)
0.5	23054225	12525360	42228	115.69
1	19386928	10532918	35511	97.29
2	13709637	7448446	25112	68.80
3	9694891	5267234	17758	48.65
4	6855828	3724771	12558	34.40
5	4848159	2634005	8880	24.33
6	3428418	1862660	6280	17.21
7	2424436	1317196	4441	12.17
8	1714462	931467	3140	8.60
9	1212397	658695	2221	6.08
10	857357	465802	1570	4.30
11	606288	329396	1111	3.04
12	428742	232935	785	2.15
13	303188	164722	555	1.52
14	214402	116485	393	1.08
15	151617	82373	278	0.76

Table 5.13 Annual and Daily Methane Fluxes Based on TOC (Half-life Cycle = 5 years) – KTAC

Year After Sediment Becomes Anaerobic	Remaining Methane Generation Potential (m ³)	Methane produced (m ³ /yr)	Methane Flux (L/m ² -yr)	Methane Flux (L/m ² -day)
0.5	25579700	3325361	11211	30.72
1	23867055	3102717	10461	28.66
2	20778090	2701152	9107	24.95
3	18088910	2351558	7928	21.72
4	15747774	2047211	6902	18.91
5	13709637	1782253	6009	16.46
6	11935284	1551587	5231	14.33
7	10390574	1350775	4554	12.48
8	9045786	1175952	3965	10.86
9	7875046	1023756	3452	9.46
10	6855828	891258	3005	8.23
11	5968520	775908	2616	7.17
12	5196052	675487	2277	6.24
13	4523559	588063	1983	5.43
14	3938103	511953	1726	4.73
15	3428418	445694	1503	4.12

5.5.2.12 The area of KTTS reclamation is approximately 35ha. The sediments in this area were also heavily polluted with high concentrations of organic matter in the past. The average sediment depth in this area is 1.63m. **Table 5.14** presents the calculation of total methane potential from the reclamation area of KTTS. The estimated total methane potential is 8.61×10^6 kg or 1.21×10^7 m³.

Table 5.14 Calculation of Total Methane Potential Based on TOC – KTTS

Area of Reclamation (m ²)	3.5x10 ⁵
Average depth of sediment (m)	1.63
Volume of sediment to be left in situ (m ³)	57x10 ⁴
Assumed density of sediment (kg/m ³)	1529
Average dry matter of the undredged area (% w/w)	50.58
Mass of dry matter (kg per each m ³)	773

Average TOC level of the undredged area (%)	2.90
Mass of TOC (kg/m ³)	22.43
CH ₄ potential (kg/m ³)	15.03
Total CH ₄ potential (kg)	8.61x10 ⁶
Total CH ₄ potential (m ³)	1.21x10 ⁷

Note: Mass of methane potential is equal to 0.67 times of the mass of TOC in the sediments.

5.5.2.13 The calculation of annual and daily methane fluxes from the KTTS reclamation for different year intervals based on half-lives of 2 and 5 years is presented in **Tables 5.15** and **5.16**. After two years following reclamation, the daily methane flux based on a half-life of 2 years would be 25.59 L/m²/d, which is much higher than the maximum safe rate of gas emission. The estimated methane flux based on a half-life of 5 years would be 9.28 L/m²/d, which is just below the maximum safe rate of gas emission (10 L/m²/d). Even the methane flux would continue to decrease with time, the emission rate of methane would be high especially for first several years after reclamation. The potential methane emission from the future developments should not be overlooked.

Table 5.15 Annual and Daily Methane Fluxes Based on TOC (Half-life Cycle = 2 years) – KTTS

Year After Sediment Becomes Anaerobic	Remaining Methane Generation Potential (m ³)	Methane produced (m ³ /yr)	Methane Flux (L/m ² -yr)	Methane Flux (L/m ² -day)
0.5	10158325	5519018	15706	43.03
1	8542413	4641093	13207	36.18
2	6040843	3281990	9340	25.59
3	4271835	2320888	6605	18.10
4	3020866	1641236	4671	12.80
5	2136232	1160615	3303	9.05
6	1510655	820739	2336	6.40
7	1068273	580393	1652	4.53
8	755439	410430	1168	3.20
9	534215	290239	826	2.26
10	377775	205245	584	1.60
11	267147	145141	413	1.13
12	188915	102638	292	0.80
13	133593	72581	207	0.57
14	94472	51326	146	0.40
15	66806	36296	103	0.28

Table 5.16 Annual and Daily Methane Fluxes Based on TOC (Half-life Cycle = 5 years) – KTTS

Year After Sediment Becomes Anaerobic	Remaining Methane Generation Potential (m ³)	Methane produced (m ³ /yr)	Methane Flux (L/m ² -yr)	Methane Flux (L/m ² -day)
0.5	11271118	1465245	4170	11.42
1	10516480	1367142	3891	10.66
2	9155397	1190202	3387	9.28
3	7970470	1036161	2949	8.08
4	6938902	902057	2567	7.03
5	6040843	785310	2235	6.12
6	5259014	683672	1946	5.33
7	4578372	595188	1694	4.64
8	3985822	518157	1475	4.04
9	3469962	451095	1284	3.52
10	3020866	392713	1118	3.06
11	2629894	341886	973	2.67
12	2289523	297638	847	2.32
13	1993204	259117	737	2.02

Year After Sediment Becomes Anaerobic	Remaining Methane Generation Potential (m ³)	Methane produced (m ³ /yr)	Methane Flux (L/m ² -yr)	Methane Flux (L/m ² -day)
14	1735236	225581	642	1.76
15	1510655	196385	559	1.53

5.5.2.14 The area of Hoi Sham reclamation is approximately 59ha. The average sediment depth in this area is 1.81m. **Table 5.17** presents the calculation of total methane potential from the reclamation area of Hoi Sham. The estimated total methane potential is 1.15×10^7 kg or 1.62×10^7 m³.

Table 5.17 Calculation of Total Methane Potential Based on TOC – Hoi Sham

Area of reclamation (m ²)	5.9x10 ⁵
Average depth of sediment (m)	1.81
Volume of sediment to be left in situ (m ³)	106x10 ⁴
Assumed density of sediment (kg/m ³)	1529
Average dry matter of the undredged area (% w/w)	48.24
Mass of dry matter (kg per each m ³)	738
Average TOC level of the undredged area (%)	2.20
Mass of TOC (kg/m ³)	16.23
CH ₄ potential (kg/m ³)	10.87
Total CH ₄ potential (kg)	1.15x10 ⁷
Total CH ₄ potential (m ³)	1.62x10 ⁷

5.5.2.15 **Tables 5.18** and **5.19** present the annual and daily methane fluxes that would be generated from the Hoi Sham reclamation for different year intervals based on half-lives of 2 years and 5 years. The daily methane fluxes would be 20.56 L/m²/d (half-life of 2 years) and 7.46 L/m²/d (half-life of 5 years) after two years following reclamation. The estimated methane fluxes based on a half-life of 2 years are higher than the estimated fluxes based on a half-life of 5 years for the first six consecutive years. The methane fluxes would be lower than the maximum safe rate of gas emission after 4 years following reclamation based on the conservative estimation.

Table 5.18 Annual and Daily Methane Fluxes Based on TOC (Half-life Cycle = 2 years) – Hoi Sham

Year After Sediment Becomes Anaerobic	Remaining Methane Generation Potential (m ³)	Methane produced (m ³ /yr)	Methane Flux (L/m ² -yr)	Methane Flux (L/m ² -day)
0.5	13604317	7391226	12618	34.57
1	11440243	6215484	10611	29.07
2	8090068	4395334	7504	20.56
3	5720963	3108199	5306	14.54
4	4045630	2197991	3752	10.28
5	2860903	1554328	2654	7.27
6	2023113	1099157	1876	5.14
7	1430662	777279	1327	3.64
8	1011705	549659	938	2.57
9	715436	388697	664	1.82
10	505927	274870	469	1.29
11	357771	194377	332	0.91
12	253001	137455	235	0.64
13	178912	97203	166	0.45
14	126519	68738	117	0.32
15	89469	48609	83	0.23

Table 5.19 Annual and Daily Methane Fluxes Based on TOC (Half-life Cycle = 5 years) – Hoi Sham

Year After Sediment Becomes Anaerobic	Remaining Methane Generation Potential (m ³)	Methane produced (m ³ /yr)	Methane Flux (L/m ² -yr)	Methane Flux (L/m ² -day)
0.5	15094602	1962298	3350	9.18
1	14083969	1830916	3126	8.56
2	12261168	1593952	2721	7.46
3	10674281	1387657	2369	6.49

Year After Sediment Becomes Anaerobic	Remaining Methane Generation Potential (m ³)	Methane produced (m ³ /yr)	Methane Flux (L/m ² -yr)	Methane Flux (L/m ² -day)
4	9292775	1208061	2062	5.65
5	8090068	1051709	1795	4.92
6	7043021	915593	1563	4.28
7	6131486	797093	1361	3.73
8	5337926	693930	1185	3.25
9	4647071	604119	1031	2.83
10	4045630	525932	898	2.46
11	3522029	457864	782	2.14
12	3066194	398605	681	1.86
13	2669356	347016	592	1.62
14	2323878	302104	516	1.41
15	2023113	263005	449	1.23

5.5.2.16 In order to estimate the percentage of biodegradable TOC, 3 grab samples of the upper layer sediments collected at AC1, AC4 and AC7 were analyzed for carbon compound fractionation using Gas Chromatography – Flame Ionization Detector. The analytical results of carbon compound fractionation are presented in **Table 5.20**. **Figure 5B** presents graphically the distribution of carbon compounds.

Table 5.20 Results of Carbon Compound Fractionation

Carbon No.	AC1		AC4		AC7	
	%	Cumulative %	%	Cumulative %	%	Cumulative %
11	0.70	0.70	0.65	0.65	0.79	0.79
12	1.08	1.78	1.05	1.69	1.22	2.00
13	1.73	3.52	4.55	6.25	1.64	3.64
14	2.23	5.74	2.15	8.40	2.21	5.85
15	2.76	8.50	2.49	10.89	2.36	8.21
16	5.58	14.08	3.35	14.24	3.48	11.69
17	8.98	23.07	5.43	19.67	5.96	17.66
18	5.93	29.00	3.86	23.53	4.08	21.74
19	3.49	32.49	3.58	27.11	3.54	25.28
20	2.76	35.25	3.63	30.75	3.63	28.91
21	3.21	38.46	4.03	34.78	3.71	32.62
22	3.12	41.57	3.73	38.50	3.83	36.44
23	3.40	44.97	3.82	42.32	4.08	40.52
24	3.61	48.58	4.21	46.53	4.10	44.62
25	4.39	52.97	6.08	52.61	5.08	49.70
26	4.25	57.22	4.50	57.10	4.85	54.54
27	4.88	62.10	5.05	62.16	5.32	59.86
28	4.71	66.81	5.22	67.37	5.51	65.37
29	4.89	71.71	5.43	72.80	5.63	71.00
30	4.10	75.81	4.46	77.26	4.86	75.86
31	4.98	80.79	5.52	82.77	5.25	81.11
32	5.42	86.20	5.55	88.33	4.83	85.94
33	4.60	90.80	4.80	93.13	4.55	90.49
34	4.05	94.85	4.23	97.36	3.82	94.31
35	3.09	97.94	3.35	100.71	3.20	97.51
36	2.06	100.00	2.29	103.00	2.49	100.00

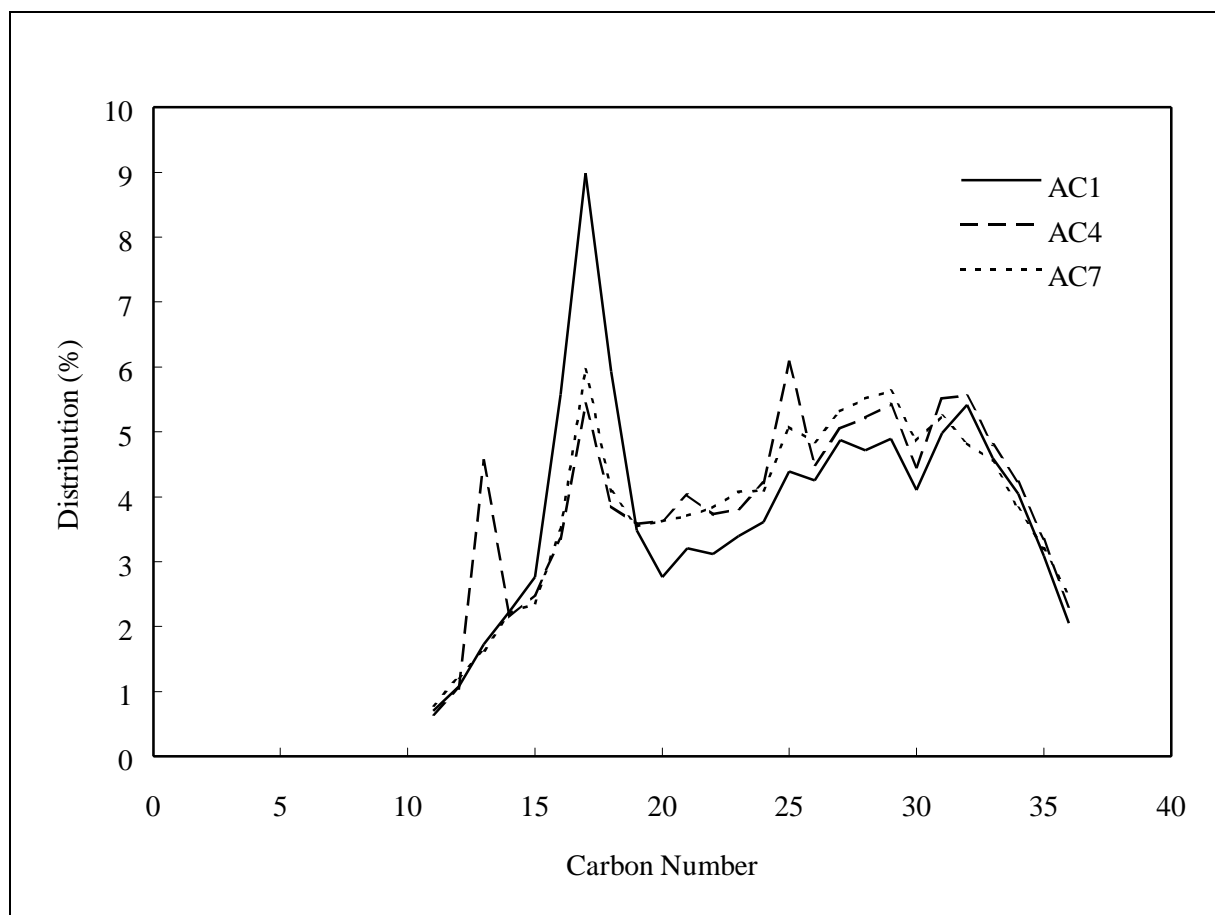


Figure 5B Distribution of Carbon Compounds

5.5.2.17 The biodegradable TOC value suggested in the previous *Feasibility Study for South East Kowloon Development* was 15%. A higher percentage of 50% based on carbon compounds less than 30 carbon atoms was suggested in the study *In-situ Treatment of Kai Tak Nullah Approach Channel Sediments – Future Methane Generation Potential*. As indicated in **Table 5.20**, approximately 50% of carbon compounds had 25 or less carbon atoms and 75% of carbon compounds had 30 or less carbon atoms. In considering that the material with molecules containing less than 30 carbon atoms is more easily degraded, the percentage of 75% would be used to estimate the removal of the biodegradable fraction of the KTAC, KTTS and Hoi Sham sediments after application of chemical treatment.

Estimation of Methane Generation Potential Based on SOD

5.5.2.18 Organic matter can be converted to carbon dioxide and methane under anaerobic conditions and to carbon dioxide and water under aerobic conditions. Methane generation based on SOD is to estimate the required oxygen concentrations for conversion of organic matter to carbon dioxide and water under aerobic conditions. This is a result from the reaction $C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O$.

5.5.2.19 The ratio of the methane generation to unit mass of SOD (Mass of CH_4 / Mass of SOD) is equal to 0.25. The volume of methane generated equivalent to 1 kg of SOD was calculated as:
 Equivalent methane volume = $0.25 \text{ kg} \times 10^3 \text{ g/kg} \times 1 \text{ mol}/16\text{g} \times 22.4 \text{ L/mol} \times 10^{-3} \text{ m}^3/\text{l}$
 = 0.35 m^3

5.5.2.20 The above calculation indicates that 0.35 m^3 of methane would be generated per kg of SOD.

5.5.2.21 **Table 5.21** presents the calculation of total methane generation potential based on SOD for the reclamation in KTAC. The total methane generation potential was $2.17 \times 10^6 \text{ m}^3$. This

value was much lower than the value calculated based on TOC. The reason is that the total organic carbon used for estimation of TOC may not all be biodegradable. Therefore, the methane generation potential calculated based on TOC provides the higher end results whereas the estimation based on SOD gives the lower end results.

Table 5.21 Calculation of Total Methane Generation Potential Based on SOD – KTAC

Area of Reclamation (m ²)	2.97x10 ⁵
Average depth of sediment (m)	2.9
Volume of sediment to be left in situ (m ³)	8.6x10 ⁵
Assumed density of sediment (kg/m ³)	1529
Average dry matter of the undredged area (% w/w)	50.38
Mass of dry matter (kg/m ³)	770
Total dry matter of sediment (kg)	6.63x10 ⁸
Average SOD of the undredged area (mg/kg dry wt)	9376
CH ₄ potential (m ³ CH ₄ /kg dry weight of sediment)	3.3x10 ⁻³
Total CH ₄ potential (m ³)	2.17x10 ⁶

5.5.2.22 The annual and daily methane fluxes for different year intervals based on 2-year and 5-year decay rates were calculated and presented in **Tables 5.22** and **5.23** respectively. Comparing with the results obtained based on TOC, the results presented in these two tables were much lower. The daily methane fluxes after the first two years of reclamation were estimated to be 5.46 L/m²/d (half-life of 2 years) and 1.98 L/m²/d (half-life of 5 years), which were within the maximum safe rate of gas emission (10 L/m²/d).

Table 5.22 Annual and Daily Methane Fluxes Based on SOD (Half-life = 2 years) – KTAC

Year After Sediment Becomes Anaerobic	Remaining Methane Generation Potential (m ³)	Methane produced (m ³ /yr)	Methane Flux (L/m ² -yr)	Methane Flux (L/m ² -day)
0.5	1828494	993421	3349	9.18
1	1537631	835395	2816	7.72
2	1087349	590757	1992	5.46
3	768929	417759	1408	3.86
4	543755	295422	996	2.73
5	384521	208910	704	1.93
6	271917	147733	498	1.36
7	192289	104470	352	0.96
8	135979	73877	249	0.68
9	96159	52243	176	0.48
10	67999	36944	125	0.34
11	48086	26125	88	0.24
12	34005	18475	62	0.17
13	24047	13065	44	0.12
14	17005	9239	31	0.09
15	12025	6533	22	0.06

Table 5.23 Annual and Daily Methane Fluxes Based on SOD (Half-life = 5 years) – KTAC

Year After Sediment Becomes Anaerobic	Remaining Methane Generation Potential (m ³)	Methane produced (m ³ /yr)	Methane Flux (L/m ² -yr)	Methane Flux (L/m ² -day)
0.5	2028796	263744	889	2.44
1	1892962	246085	830	2.27
2	1647968	214236	722	1.98
3	1434681	186509	629	1.72
4	1248999	162370	547	1.50
5	1087349	141355	477	1.31
6	946620	123061	415	1.14
7	824105	107134	361	0.99
8	717446	93268	314	0.86

Year After Sediment Becomes Anaerobic	Remaining Methane Generation Potential (m ³)	Methane produced (m ³ /yr)	Methane Flux (L/m ² -yr)	Methane Flux (L/m ² -day)
9	624592	81197	274	0.75
10	543755	70688	238	0.65
11	473380	61539	207	0.57
12	412113	53575	181	0.49
13	358776	46641	157	0.43
14	312342	40604	137	0.38
15	271917	35349	119	0.33

- 5.5.2.23 Estimation of methane generation potential based on SOD provided the lower end results. The daily methane fluxes for the KTAC reclamation were within the maximum safe rate. However, the higher end results estimated based on TOC exceeded the maximum safe rate considerably. The range of the daily methane fluxes calculated from the two methods represented the upper and lower bounds of the methane emission in the future reclaimed land.
- 5.5.2.24 The application of chemical treatment would remove the biodegradable fraction of the sediments. In considering that the material with molecules containing less than 30 carbon atoms is more easily degraded, the percentage of 75% biodegradable carbon in the sediments obtained from the SI has been used to estimate the TOC contents in the KTAC sediments. A reduction of TOC content would be from 4.4% (dry weight) to 1.1% (dry weight). The daily methane flux based on a half-life of 5 years would be below the assessment criteria of 10 L/m²/d. For a half-life cycle of 2 years, the daily methane flux falls below the assessment criteria after 4 years following reclamation. Similarly, a 75% reduction would result in a SOD content of 2344 mg/kg (dry weight) in the KTAC sediments. The estimated daily methane fluxes based on half-lives of 2 and 5 years would be 2.29 and 0.61 L/m²/d respectively. These values are much lower than the assessment criteria. The higher end result based on TOC with a half-life cycle of 2 years represents the worst case scenario. The application of suitable sediment treatment techniques is likely to reduce the methane potential to acceptable levels before the reclamation.
- 5.5.2.25 **Figures 5C and 5D** show graphically the methane production rates based on TOC and SOD for half-life cycles of 2 years and 5 years respectively for the KTAC reclamation. The estimated landfill gas production rate (~10x10³ m³/hr) of the WENT Landfill after operating for 75 years and the maximum safe rate of gas emission were included in the figures for comparison. In order to compare with the landfill gas production rate (in unit of m³/hr), the methane production rates (in unit of L/m²/d) estimated based on TOC and SOD were multiplied by the total reclamation area of the KTAC and converted to the unit of m³/hr. The maximum safe rate of gas emission (10L/m²/d) was also modified in a similar way for comparison in the figures.
- 5.5.2.26 The methane production rates estimated based on TOC and SOD were significantly lower than the landfill gas production rate of the WENT Landfill. The two problems are very much different in magnitude. However, the biogas assessment indicated that high methane generation potential (based on TOC) would last for about 8 to 9 years following reclamation before dropping below the maximum safe rate of gas emission. Potential methane emission in the future reclaimed land is a concern and cannot be overlooked. The estimation based on TOC could be considered as the worst case scenario. Mitigation measures and monitoring of methane emission should be undertaken to minimize the potential hazards to the future developments.

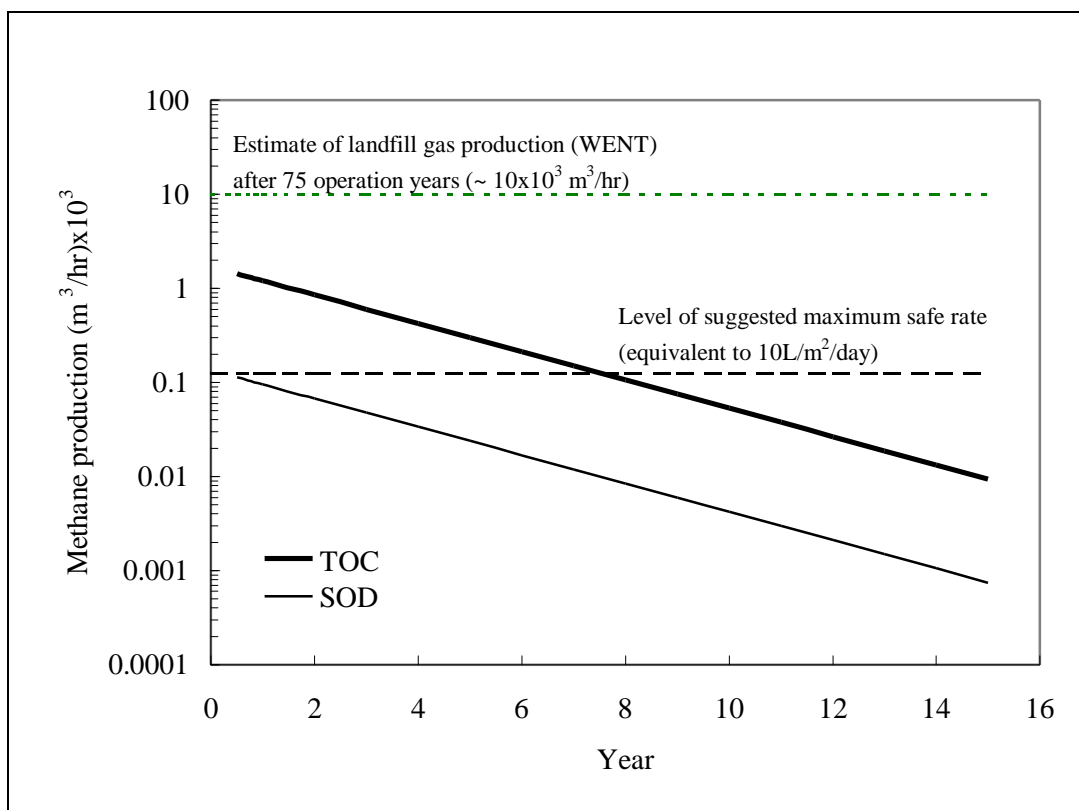


Figure 5C Methane generation potential for a Half-life Cycle of 2 years - KTAC

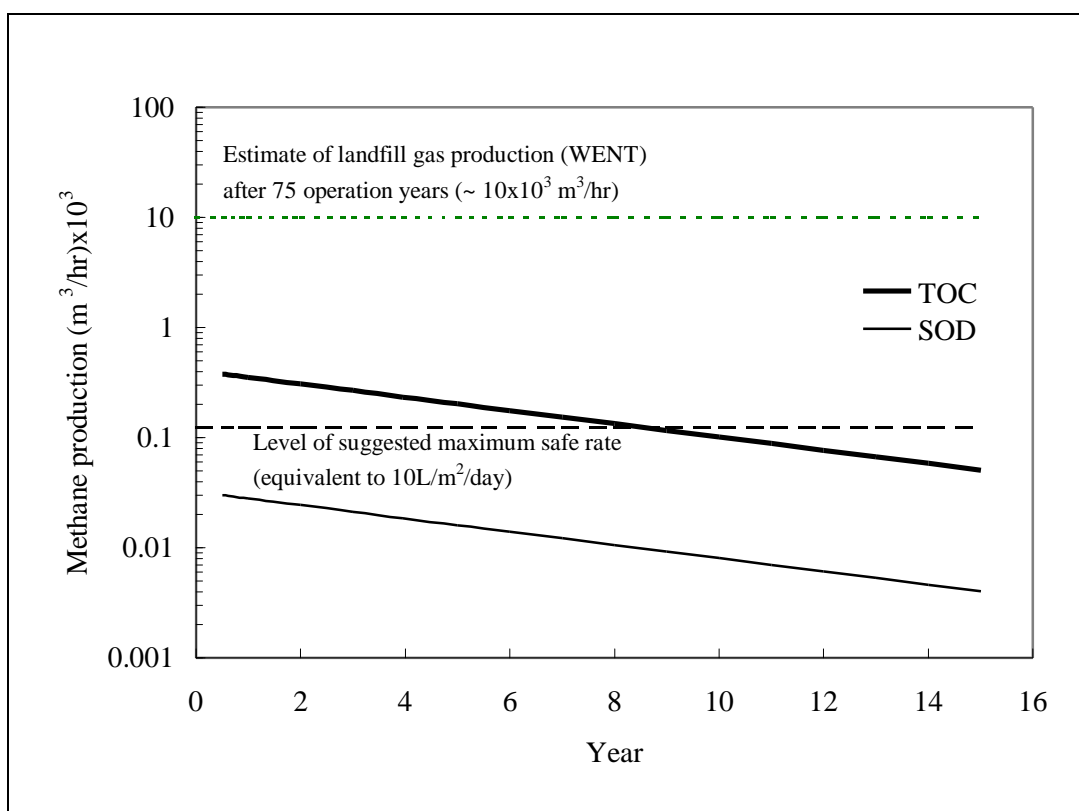


Figure 5D Methane generation potential for a Half-life Cycle of 5 years – KTAC

5.5.2.27 **Table 5.24** presents the calculation of total methane generation potential based on SOD for the reclamation in KTTS. The total methane generation was estimated to be 9.33×10^5 . This result represented the lower end of the methane generation potential and was much lower than the value calculated based on TOC.

Table 5.24 Calculation of Total Methane Generation Potential Based on SOD – KTTS

Area of Reclamation (m ²)	35x10 ⁴
Average depth of sediment (m)	1.63
Volume of sediment to be left in situ (m ³)	57x10 ⁴
Assumed density of sediment (kg/m ³)	1529
Average dry matter of the undredged area (% w/w)	50.58
Mass of dry matter (kg/m ³)	773
Total dry matter of sediment (kg)	4.43x10 ⁸
Average SOD of the undredged area (mg/kg dry wt)	6017
CH ₄ potential (m ³ CH ₄ /kg dry weight of sediment)	2.1x10 ⁻³
Total CH ₄ potential (m ³)	9.33x10 ⁵

5.5.2.28 **Tables 5.25** and **5.26** presents the calculation of the daily methane fluxes for different year intervals based on 2-year and 5-year decay rates. The daily methane fluxes after the first two years of reclamation in KTTS would be 1.98 l/ (2-year decay rate) m²/d and 0.72 L/m²/d (5-year decay rate). The estimated results were well below the maximum safe rate of gas emission (10 L/m²/d).

Table 5.25 Annual and Daily Methane Fluxes Based on SOD (Half-life = 2 years) – KTTS

Year After Sediment Becomes Anaerobic	Remaining Methane Generation Potential (m ³)	Methane produced (m ³ /yr)	Methane Flux (1/m ² -yr)	Methane Flux (1/m ² -day)
0.5	784481	426208	1213	3.32
1	659691	358410	1020	2.79
2	466506	253453	721	1.98
3	329894	179231	510	1.40
4	233288	126745	361	0.99
5	164971	89629	255	0.70
6	116661	63382	180	0.49
7	82498	44821	128	0.35
8	58339	31696	90	0.25
9	41255	22414	64	0.17
10	29174	15850	45	0.12
11	20631	11209	32	0.09
12	14589	7926	23	0.06
13	10317	5605	16	0.04
14	7296	3964	11	0.03
15	5159	2803	8	0.02

Table 5.26 Annual and Daily Methane Fluxes Based on SOD (Half-life = 5 years) – KTTS

Year After Sediment Becomes Anaerobic	Remaining Methane Generation Potential (m ³)	Methane produced (m ³ /yr)	Methane Flux (1/m ² -yr)	Methane Flux (1/m ² -day)
0.5	870417	113154	322	0.88
1	812139	105578	300	0.82
2	707029	91914	262	0.72
3	615523	80018	228	0.62
4	535859	69662	198	0.54
5	466506	60646	173	0.47
6	406129	52797	150	0.41
7	353567	45964	131	0.36
8	307807	40015	114	0.31
9	267969	34836	99	0.27
10	233288	30327	86	0.24
11	203095	26402	75	0.21
12	176809	22985	65	0.18
13	153926	20010	57	0.16
14	134004	17421	50	0.14
15	116661	15166	43	0.12

5.5.2.29 **Figures 5E and 5F** show graphically the methane production rates based on TOC and SOD for half-life cycles of 2 years and 5 years respectively for the KTTS reclamation. The methane production rates were much lower than the landfill gas production rate of the WENT Landfill. The biogas assessment indicated that high methane generation potential (based on TOC) would last for about 5 years following reclamation before dropping below the maximum safe rate of gas emission.

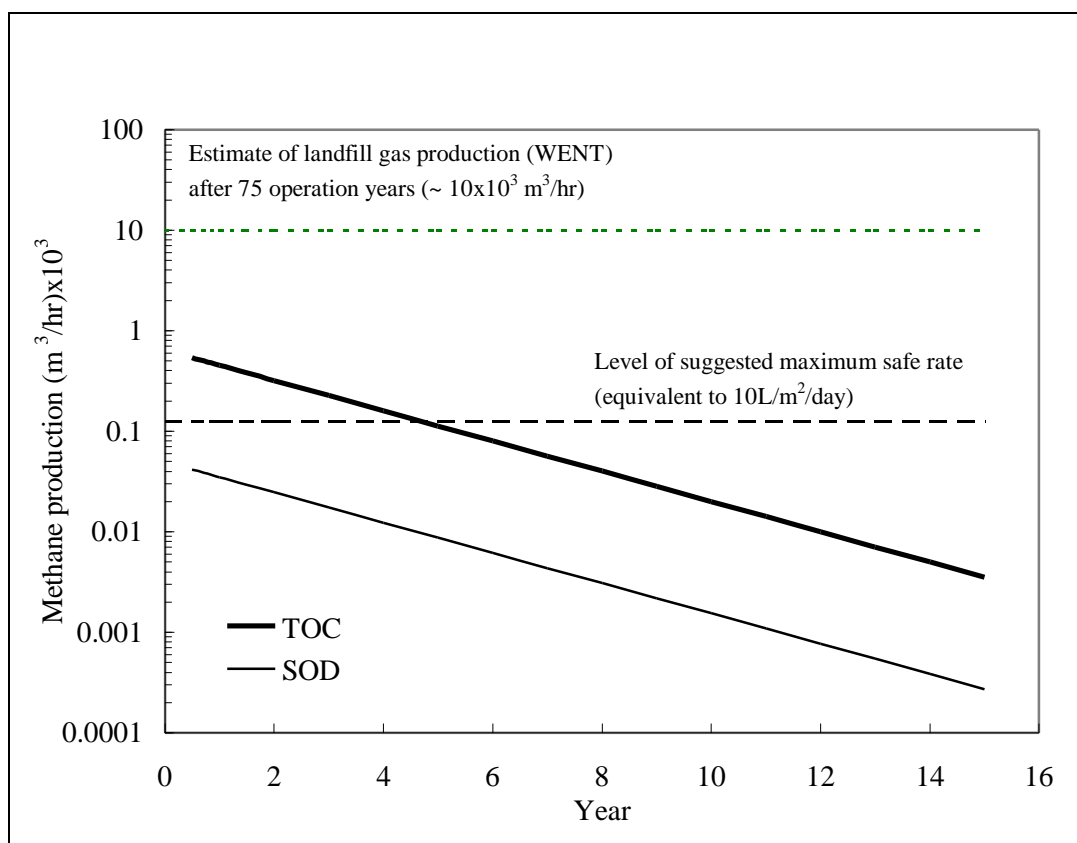


Figure 5E Methane generation potential for a Half-life Cycle of 2 years – KTTS

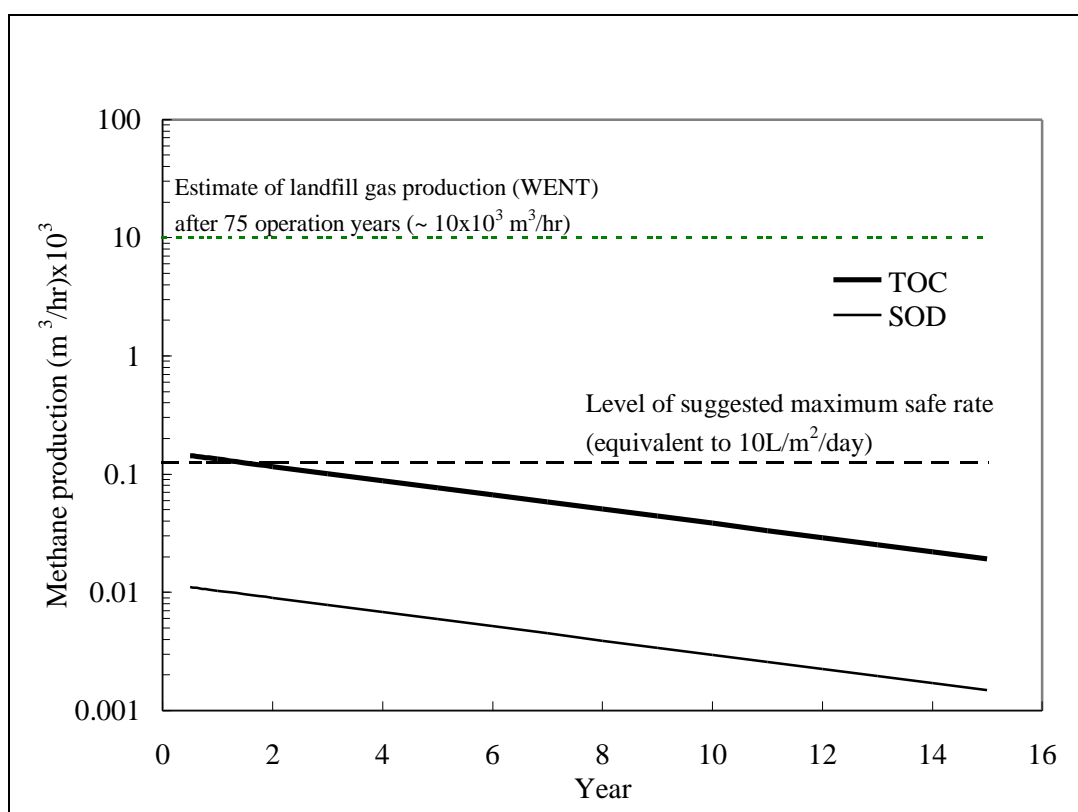


Figure 5F Methane generation potential for a Half-life Cycle of 5 years - KTTS

5.5.2.30 The calculation of total methane generation potential based on SOD for the reclamation in Hoi Sham is presented in **Table 5.27**. The total methane generation was $7.51 \times 10^5 \text{ m}^3$. This estimated value was the lowest when compared to the results of total methane generation potential for the KTAC and KTTS. The potential methane emission is likely to be lower.

Table 5.27 Calculation of Total Methane Generation Potential Based on SOD – Hoi Sham

Area of Reclamation (m ²)	5.9x10 ⁵
Average depth of sediment (m)	1.81
Volume of sediment to be left in situ (m ³)	106x10 ⁴
Assumed density of sediment (kg/m ³)	1529
Average dry matter of the undredged area (% w/w)	48.24
Mass of dry matter (kg/m ³)	738
Total dry matter of sediment (kg)	7.82x10 ⁸
Average SOD of the undredged area (mg/kg dry wt)	2744
CH ₄ potential (m ³ CH ₄ /kg dry weight of sediment)	9.6x10 ⁻⁴
Total CH ₄ potential (m ³)	7.51x10 ⁵

5.5.2.31 The annual and daily methane fluxes for different year intervals based on 2-year and 5-year decay rates are presented in **Tables 5.28** and **5.29**. The estimated daily methane fluxes after two years of reclamation were 0.95 L/m²/d (2-year decay rate) and 0.35 L/m²/d (5-year decay rate). This emission rate is much lower than the assessment criteria. As the daily methane fluxes estimated based on TOC and SOD were within acceptable range, it is likely that the potential risk of methane emission to the reclamation in Hoi Sham would be relatively low. However, mitigation measures should be implemented to avoid accumulation of methane gas in confined areas so as to avoid the risk to the future developments in Hoi Sham.

Table 5.28 Annual and Daily Methane Fluxes Based on SOD (Half-life = 2 years) – Hoi Sham

Year After Sediment Becomes Anaerobic	Remaining Methane Generation Potential (m ³)	Methane produced (m ³ /yr)	Methane Flux (1/m ² -yr)	Methane Flux (1/m ² -day)
0.5	631516	343103	586	1.60
1	531059	288525	493	1.35
2	375543	204033	348	0.95
3	265569	144284	246	0.67
4	187799	102031	174	0.48
5	132804	72152	123	0.34
6	93913	51023	87	0.24
7	66412	36082	62	0.17
8	46964	25515	44	0.12
9	33211	18043	31	0.08
10	23485	12760	22	0.06
11	16608	9023	15	0.04
12	11744	6381	11	0.03
13	8305	4512	8	0.02
14	5873	3191	5	0.01
15	4153	2256	4	0.01

Table 5.29 Annual and Daily Methane Fluxes Based on SOD (Half-life = 5 years) – Hoi Sham

Year After Sediment Becomes Anaerobic	Remaining Methane Generation Potential (m ³)	Methane produced (m ³ /yr)	Methane Flux (L/m ² -yr)	Methane Flux (L/m ² -day)
0.5	700696	91090	156	0.43
1	653782	84992	145	0.40
2	569167	73992	126	0.35
3	495503	64415	110	0.30
4	431373	56079	96	0.26
5	375543	48821	83	0.23
6	326939	42502	73	0.20
7	284625	37001	63	0.17
8	247788	32212	55	0.15
9	215718	28043	48	0.13
10	187799	24414	42	0.11
11	163494	21254	36	0.10
12	142334	18503	32	0.09
13	123912	16109	28	0.08
14	107875	14024	24	0.07
15	93913	12209	21	0.06

5.5.2.32 **Figures 5G** and **5H** show graphically the methane production rates based on TOC and SOD for half-life cycles of 2 years and 5 years respectively for the Hoi Sham reclamation. The methane production rates were lower than those for the KTAC and KTTS reclamation. It was estimated that high methane generation potential (based on TOC) would last for about 4 years following reclamation before dropping below the maximum safe rate of gas emission.

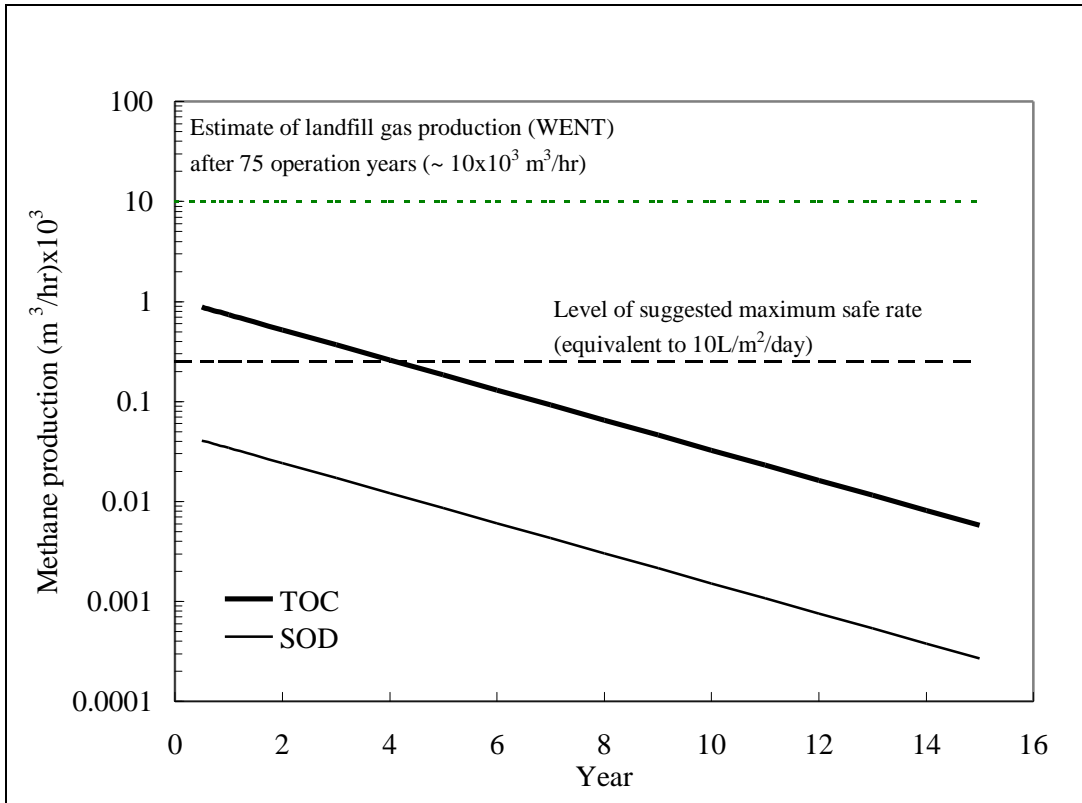


Figure 5G Methane generation potential for a Half-life Cycle of 2 years – Hoi Sham

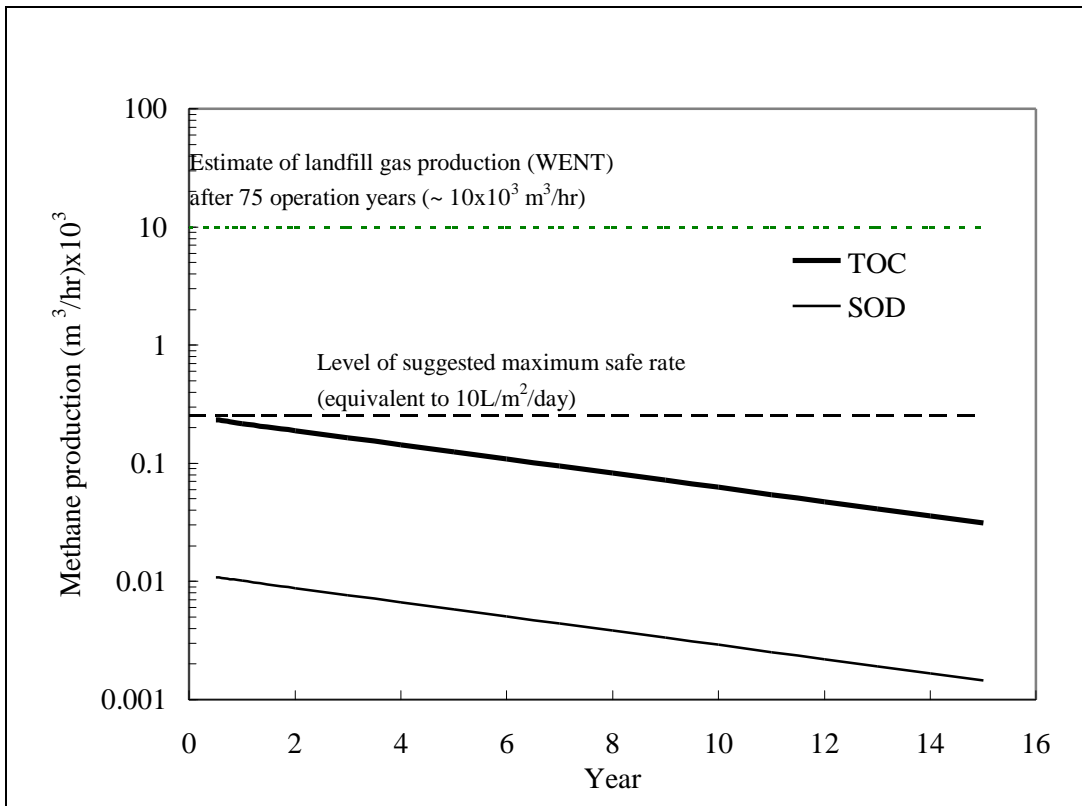


Figure 5H Methane generation potential for a Half-life Cycle of 5 years – Hoi Sham

5.5.3 **Reclamation Options and Associated Environment Impacts**

5.5.3.1 Reclamation may involve dredging and filling. Environmental impacts would arise during the carrying out of the reclamation activities and during the operational phase of the future developments.

5.5.3.2 Three options have been considered for implementation of the South East Kowloon reclamation. The proposed reclamation options include:

- a no dredged reclamation;
- a dredge for *ex-situ* treatment reclamation; and
- a minimum dredged reclamation.

5.5.3.3 The Government policy on waste minimization encourages to limit dredging and disposal of marine mud for reclamation projects. The no dredged reclamation is therefore considered as one of the reclamation options for the SEKD. The issues on potential biogas emission, settlement on the reclaimed land and foundation improvement should be dealt with for this option.

5.5.3.4 To eliminate the biogas risks to the future developments, dredging of all the contaminated sediments for *ex-situ* treatment would be a possible option. The reclamation option with dredging of sediments for *ex-situ* treatment is targeted to totally eliminate the biogas risks. Dredging of the uncontaminated sediments underneath the contaminated layer may also be required to provide a suitable condition for foundation construction of the major structures. *Ex-situ* treatment and beneficial uses of the dredged sediments would be considered to achieve high removal efficiency of the contaminants in the sediments and the target of no sediment disposal.

5.5.3.5 The ground condition for sea wall, breakwater and tunnel construction is an important factor to ensure the stability of the structures. Dredging of marine deposits in the locations under these structures is commonly adopted to minimize settlement. The proposed minimum dredged reclamation is to remove both the contaminated sediments and the uncontaminated marine deposits in the locations where sea wall, breakwater and tunnel construction would be carried out. The sediment volume in these locations would be much less than that of the whole development area. With suitable treatment and disposal arrangement of the dredged sediments, adoption of the minimum dredged reclamation would be a possible reclamation option. The inclusion of the no dredged, dredge for *ex-situ* treatment and minimum dredged reclamation options provides a full coverage of all the possible reclamation options.

5.5.3.6 Recommendations on the suitable reclamation options for the KTAC, KTTS and Hoi Sham developments are given following the brief description of each of the reclamation options presented below:

Option 1: No Dredged Reclamation

5.5.3.7 The no dredged reclamation is to leave all the sediments in place. There is no need to carry out dredging and disposal of the sediments for this reclamation option. Depending on the contaminant levels of the sediments and the potential methane risks to the future developments, two approaches can be included in the no dredged reclamation option:

- No dredging with application of *in-situ* treatment; and
- No dredging with monitoring and provision of protection measures.

5.5.3.8 The implementation of either one of the sub-options or both the two sub-options for the no dredged reclamation may depend on the effectiveness of *in-situ* treatment and methane gas monitoring results.

Sub-option 1: In-situ Treatment

- 5.5.3.9 The primary advantage of *in-situ* treatment is that no sediment dredging would be required. The potential contamination from sediment resuspension and release of contaminants, which are bound to the sediment particles, can be minimized. Spills and losses of the contaminated sediments can also be avoided because no sediment handling would be required. Odour emission is not likely to be an important issue in this case. One of the disadvantages of *in-situ* treatment is that the process control may be affected by the environmental conditions for treatment. The treatment efficiency of *in-situ* treatment needs to be determined through site trials. Settlement on the reclamation due to the presence of sediments is one of the engineering aspects that needs to be dealt with for adopting the no dredged reclamation. Suitable ground improvement technique should be considered to minimize the settlement.
- 5.5.3.10 *In-situ* treatment applies chemicals and/or microorganisms to degrade contaminants in soils or sediments. The natural degradation of contaminants in marine sediments is generally slow. Injection of suitable chemicals and/or microbe solution into the sediments can accelerate the degradation process. Examples of the reagents for *in-situ* treatment and estimated treatment costs are given in the following paragraphs.
- 5.5.3.11 Fenton's Reagent- Hydrogen peroxide is a strong oxidant and is typically used together with Fe^{2+} to form Fenton's Reagent. Pressure injection of Fenton's Reagent into the sediments creates free radicals to oxidize contaminants. Formation of free radicals is based on the reaction $Fe^{2+} + H_2O_2 \rightarrow Fe^{3+} + OH\cdot + OH\cdot$. This reagent can treat the organic contaminants including trichloroethene (TCE), tetrachloroethene (PCE), benzene, toluene, ethylbenzene, and xylene (BTEX), PAHs, PCBs and volatile organic chemicals that are very difficult to degrade. The application of Fenton's Reagent would also oxidize the sulfides contained in the acid volatile sulphide contents of the sediment, hence minimizing odour emissions. The resultant ferric ion reacts with hydroxide ion to form ferric hydroxide precipitate, which sorbs other heavy metals, making them unavailable for leaching. The potential secondary impacts of applying Fenton's Reagent would be minimal. Examples of the removal efficiencies of *in-situ* chemical oxidation using hydrogen peroxide are given in **Table 5.30**. The contaminants were reduced over 99% in the field application indicating a high performance of the reagent. It is expected that Fenton's Reagent would be more effective in treating the organic contaminants in the KTAC sediments.
- 5.5.3.12 The estimated costs for *in-situ* application of Fenton's Reagent would range from US\$40 to 100 per cubic meter of sediment with no dredging required. The treatment would take approximately several months to 1 year. Field trials would be required to collect necessary information before the full-scale application of this technique. The actual costs and treatment period could be more accurately calculated based on the information obtained from field trials.

Table 5.30 Contaminant Removal Efficiency for Hydrogen Peroxide

Contaminants	Removal Percentage	Media	Project Site
TCE, PCE	99% over 3 months	Soil and groundwater	Westinghouse Savannah River Site, Aiken, SC, 1997
TCE	99% over 4 months	Soil	Anniston Army Depot, Anniston, AL, 1997
BTEX	99% over 7 months	Sandy gravel	Former Sign Manufacturing Facility, Denver, CO, 1996

- 5.5.3.13 Oxygen Release Compound- The commercially available oxidant **ORC – (Oxygen Release Compound)** can prolong and stabilize the dissolved oxygen level within sediments. With the addition of magnesium peroxide, oxygen would be released slowly for treatment of organic contaminants. Slow release of oxygen can enhance microbial activity in sediments. Release of oxygen is based on the reaction $2MgO_2 + 2H_2O_2 \rightarrow 2Mg(OH)_2 + O_2$. The hydrated product, which will convert to a solid form, is harmless. Examples of the application of ORC to degrade organic contaminants in some overseas projects are presented in **Table 5.31**. The

high removal efficiencies of organic contaminants in the projects demonstrated the successful application of ORC. The estimated costs for applying this technique would be in a range from US\$30 to 50 per cubic meter of sediment with no dredging required. The time required for the treatment ranges from several months to 2 years. This biochemical treatment technique would also reduce the acid volatile sulphide contents in the sediments, hence minimize odour emission.

Table 5.31 Contaminant Removal Efficiency for ORC

Contaminants	Removal Percentage	Media	Project Site
BTEX	94% over 3 months	Clay and groundwater	A fuel service station site
BTEX	81% over 125 days	Clay/Silt/Sand	A retail service station site
BTEX, TPH	95% and 96% over 70 days	Silt and Clay	A service station site in Puerto Rico

(Information from Regenesis)

- 5.5.3.14 The data in **Tables 5.30** and **5.31** have indicated that hydrogen peroxide/Fenton's Reagent and ORC are strong oxidants with high performance on the removal of volatile organics. Use of these reagents can generate a higher oxidation potential, which is essential for oxidizing organic substances (volatile or heavier organics). The actual treatment efficiency of applying these reagents to treat the KTAC, KTTS and Hoi Sham sediments with heavier organic still has to be determined through the pilot tests.
- 5.5.3.15 Seditreat- The **Seditreat™** method was applied in the Shing Mun River bioremediation pilot test under the study *In-situ Bioremediation Trial in the Shing Mun River*. This method was to inject a slow-release oxidizing agent and microbe/nutrient solution to treat sediments in place and reduce odour. The pilot test results showed a good improvement in sediment quality in terms of organic contamination reduction and inhibition of hydrogen sulphide generation. The removal rates of TOC and COD concentrations in the sediments were up to 58% and 45-74% respectively. The estimated costs for applying the Seditreat™ method would be in a range between US\$40 and 70 per cubic meter of sediment with no dredging required. It would take approximately ½ year to 1 year to meet treatment standards.
- 5.5.3.16 Use of **calcium nitrate** for *in-situ* treatment was proposed in the previous SEKD study and in the study *"In-situ Treatment of Kai Tak Nullah Approach Channel Sediments"*. This reagent can oxidise the organic matter and eliminate odour emission. However, the application of this method would increase the concentrations of heavy metals and nitrate in the sediments causing secondary impacts. Calcium nitrate is relatively non-reactive oxidant when compared to Fenton's Reagent. It is expected that a very large amount of reagent is needed for *in-situ* treatment. Fenton's Reagent, which consists of mainly hydrogen peroxide, is more easily available than the calcium nitrate. Given the above reasons, it is recommended not to include calcium nitrate in the pilot tests.
- 5.5.3.17 In comparing the above-mentioned oxidants, Fenton's Reagent is a more vigorous oxidant using readily available reagents H₂O₂ and FeSO₄. There would be minimal odour impacts as reaction products of using Fenton's Reagent are H₂O and Fe(OH)₃.
- 5.5.3.18 An **injection system** would be required to delivery the reagent into the sediment layer during the application of *in-situ* treatment. The injection is conducted under sufficiently high pressures to form sub-horizontal fractures which allows the radial migration of the injected oxidant. This in turn allows the deep penetration of reagent into the sediment layer to enhance the treatment efficiency. Depending on the soil/sediment structure, the depth of injection could be down to 20m or lower from the soil/sediment surface.
- 5.5.3.19 The application of *in-situ* treatment in the SEKD could use the fluid injection system to delivery the reagent into the sediments from a barge-based operation, or the injection could be

accomplished after backfilling the reclamation areas, using a surface vehicle. Injection after backfilling not only would be less difficult to conduct, but the presence of the overburden pressures associated with the backfill would aid in greater lateral migration of the oxidant and the control of the injected solution. A number of injection points would be used to minimize the chance of areal expansion of the contaminant plume and reduce the problem of treating the areas with low permeability.

- 5.5.3.20 Excess pore water will be released upon consolidation of the proposed reclamation areas. To minimize the release of heavy metals into the pore water, the heavy metals contained in the sediments could be immobilized by adopting *in-situ* **geochemical fixation technique**. The ferric hydroxide formed by the Fenton's Reagent reaction serves to achieve such geochemical fixation of heavy metals. This is a well-developed technique to irreversibly fix metal into sediments. The technique can also be applied *ex-situ*. A bench scale demonstration of the chemical fixation technique was performed by Ensotech under the Great Lakes Demonstration Project to treat the Welland River sediment, which was contaminated with heavy metals. A reduction of 90% of heavy metal contents in the leachate was achieved after applying the technique. The geochemical fixation would be achieved at no additional cost or time requirement over the *in-situ* oxidation by means of Fenton's Reagent injection.

Sub-option 2: Monitoring and Protection Measures

- 5.5.3.21 When there is a limited route for methane gas to release into the atmosphere, methane gas may get into rooms below ground, underground car parks, lift pits, pumping stations and maintenance chambers. Methane gas would accumulate in the poorly ventilated areas. Under low atmospheric pressure conditions, there is a higher potential of methane gas to escape from the future reclaimed land.
- 5.5.3.22 The future reclaimed land comprises of residential housing blocks, schools and other amenities. Methane gas generated from the reclaimed land has the potential to cause fire, explosion or asphyxiation and would pose a constraint to the future developments. In order to minimize the methane hazards during the construction and operational phases of the SEKD, monitoring and protection measures may need to be incorporated into the development programme.
- 5.5.3.23 **Methane gas monitoring work** should be included as part of the environmental monitoring and audit programme. Monitoring of methane emission rate after reclamation can determine whether the actual rate would be higher or below the maximum safe rate of gas emission. Monitoring boreholes are usually installed to measure the actual methane emission rate. The depth of monitoring boreholes should be down to the groundwater level. A removable cap and a gas monitoring valve is normally installed in the monitoring well. Parameters to be monitored would include methane, carbon dioxide, oxygen and gas flow rates from the monitoring wells. The monitoring may last at least one year to cover the different meteorological conditions after reclamation. Details of methane gas monitoring are presented in the EM&A manual. In addition, monitoring of methane emission rate at the hotspot where *in-situ* treatment is applied serves the purpose of determining whether the treatment has achieved the target levels. This also ensures that the treated area would not pose any risks to the future developments.
- 5.5.3.24 The need for implementation of protection measures would be based on the monitoring results and the recommended criteria are given as follows:
- (1) Measured Methane Emission Rates higher than the Maximum Safe Rate of Gas Emission
- 5.5.3.25 In case where the methane gas emission rate measured from any boreholes in a particular area is higher than the maximum safe rate of gas emission (10 L/m²/d), protection measures should be provided to protect the buildings to be constructed in that area.

5.5.3.26 To convert the safe rate of gas emission (in unit of L/m²/d) to the safe flow rate of methane (in unit of L/d), the area of influence of the boreholes needs to be defined. In the previous *South East Kowloon Development Study* and the *Green Island Development Study*, the adopted value of area of influence was 20m³. It is recommended to use the same value in this study. The safe flow rate of methane emitted from a borehole is therefore calculated as 200 L/d. If the measured flow rate of methane is consistently higher than 200 L/d, protection measures are required.

(2) Measured Methane Emission Rates below the Maximum Safe Rate of Gas Emission

5.5.3.27 When the measured flow rate of methane in a particular area is consistently lower than the safe flow rate of 200 L/d, protection measures may not be required. However, the monitoring data should cover the flow rate of methane measured during the low atmospheric conditions to confirm whether there is any exceedance of the safe flow rate under unusual conditions. In addition, the trend of the monitoring results should be analyzed. Continuous monitoring would be required if an increasing trend of the flow rate in a particular area were found. To be conservative, provision of protection measures could be considered for this situation.

(3) Measured Methane Emission Rates occasionally exceed the Maximum Safe Rate of Gas Emission

5.5.3.28 If monitoring results show significant variations in the methane flow rate emitted from the boreholes and exceedances of the safe flow rate (> 200 L/d), continuous monitoring should be undertaken to confirm whether there would be an increasing trend or a decreasing trend of the methane flow rate. When there is a clear indication of the measured methane flow rate consistently below the safe flow rate, protection measures may not be required. Otherwise, suitable protection measures should be provided to prevent methane hazards to the individual developments or buildings in the area of concern.

5.5.3.29 It is anticipated that protection measures would only be required when the methane emission rate in a particular area remains high after applying *in-situ* treatment. A number of protection measures can be introduced to safeguard the individual developments or buildings, which are to be built in the area with high residual methane potential. Selection of suitable protection measures may depend on the monitoring results and the building designs. Some of the most commonly used protection measures to prevent methane hazards are given in the following paragraphs.

5.5.3.30 Provision of **control systems** in the ground and beneath/inside the building floor could collect and vent the methane gas generated underneath the reclaimed land. **Use of a porous fill material** allows the generated methane gas to migrate from underground to the surface of the fill material. Methane gas is easy to be dispersed in the atmosphere. **Installation of a gas collection layer** consisting of gravels would serve as a primary control of methane gas emission. The gas collection layer should be installed above groundwater level. The thickness of the gas collection layer may vary from 0.5 to 1.5m or above depending on the overall arrangement of the protection measures in the detailed design stage. At perimeter of the reclamation area, vent trenches filled with gravels or “no fines” crushed aggregate of uniform size should be connected to the gas collection layer to provide a route to vent off the collected methane gas.

5.5.3.31 Ingress and accumulation of methane gas would occur in below ground services. It is necessary to prevent penetration of methane gas into buildings through conduits, pipes, sewer drains and storm drains of the underground services. **Low gas permeability sealant** should be used to avoid the potential hazards. **Low permeability physical barriers** such as soil bentonite, cement bentonite or geosynthetics would prevent the migration of methane gas from entering the buildings on the reclaimed land.

- 5.5.3.32 **Installation of a membrane with low gas permeability** in the floor slab of buildings including underground car parks and rooms would prevent ingress of methane gas. Suitable measures should be undertaken to **seal any openings in the floor**. **Sufficient ventilation** should be provided within buildings to avoid accumulation of methane gas in the buildings to a dangerous level.
- 5.5.3.33 **Passive barriers and passive ventilation systems** can be used to protect individual buildings. Use of passive barriers is to prevent gases from entering the buildings by installation of the low-permeability geomembranes such as high density polyethylene sheet in the building floor slabs. Passive ventilation systems provide a route for the sub-slab gases to escape to the atmosphere through the voids below the building slabs. A gravel bedding and vent pipes can be placed beneath the buildings. The vent pipes would be connected to risers to release the sub-slab gases at a level above the building roofs. **Drawing No. 22936/EN/144** shows the sketches of the passive barriers and passive ventilation systems.
- 5.5.3.34 The authorities of the SEKD should take initiative to ensure that the recommended protection measures would be incorporated in the design, tender and construction stages of the development. It is recommended that protection measures should be included in the land lease document and specification for individual developments in the SEKD, if required. The installation of protection systems should be part of the construction requirements and be specified in the tender documents. During tender bidding, all the involved parties could fully consider the implications of the requirements to the construction projects. The awarded companies are liable for provision of mitigation measures as part of their contract agreements. The design of the protection measures should be based on the final development plan to avoid any constraints that would pose to the future developments.
- 5.5.3.35 In the event that the pilot tests confirm both *in-situ* treatment and *ex-situ* treatment not suitable for treating the sediments in the KTAC, KTTS and Hoi Sham, the proposed protection measures should be integrated into the development programme. The installation of gas collection pipes and protective materials to protect individual developments or buildings should be taken into account in the early stage of the design for site formation and building construction.
- 5.5.3.36 If the pilot tests confirm *in-situ* treatment to be feasible, the proposed protection measures for protection of individual developments or buildings would only be required in areas where methane emission rate remains high after applying *in-situ* treatment. However, it is worth noting that the pilot tests for *in-situ* treatment would be carried out in a selected area with the highest contaminant levels (most likely at KTAC). After the *in-situ* verification of the treatment method, it is considered that the selected *in-situ* treatment method should be able to deal with the sediments in the proposed reclamation areas at KTAC, KTTS and Hoi Sham to reduce the methane potential to acceptable levels. Even if some hotspots with high methane emission rate still exist after *in-situ* treatment, it is considered that the area covered by the hotspots would be small. Provision of protection measures in the small area would not pose constraints to the whole development on the reclaimed land.
- 5.5.3.37 The mechanisms for ensuring the implementation of protection measures on all future developments would be fully incorporated in the detailed design stage in accordance with the advice provided by Lands Department and Planning Department, if such protection measures are to be required.
- 5.5.3.38 Precaution measures during construction should also be considered. The sediments with high methane potential would pose a risk to the personnel at work during the construction phase of the development. Special precautions and safety measures should be undertaken for works to be carried out in confined space. Monitoring of the methane, carbon dioxide and oxygen levels in excavated areas and areas below ground would ensure a safe working environment to the workers. Sufficient ventilation should be provided in temporary structures including site

huts and unventilated enclosures to avoid accumulation of methane gas. Smoking and open fire should be prohibited in the region where drilling activities are carried out. In case where high concentrations of methane gas are detected, vent pipes should be used to collect and vent off the accumulated methane gas to the atmosphere.

Ground Improvement

- 5.5.3.39 The presence of soft soils may give rise to settlement and stability problems of marine structures such as sea walls and breakwaters. Sea wall is required as a retaining structure for the reclamation fill. They also serve to protect the reclamation against the influence of the sea. A seawall can take the form of a vertical wall or have a sloping face, the choice depending on many factors such as the functional use, etc.
- 5.5.3.40 The vertical sea wall is usually constructed with large concrete blocks, filled with sand and founded on dredged seabed. The soft materials at the base may have to be removed to ensure the stability of the sea wall. The sloping sea wall, in its simplest form, is usually constructed with quarry-run rockfill core with blocks at the seaward side for erosion protection. The marine deposits are dredged to provide a suitable foundation. In both cases, despite the removal of the soft marine deposits, stability may remain a problem for the following reasons:
- Trapped marine deposit beneath the reclamation, giving weak planes for slip surfaces; and
 - Inadequate shear strength in the alluvial clay.
- 5.5.3.41 The potential stability problems are increased with the recent Government policy to minimise the amount of dredging and consequent sea disposal of contaminated marine deposits. Ground treatment would be required if the marine deposits were to be left in place. In addition, treatment to the softer alluvium deposits may also be required.
- 5.5.3.42 Breakwater structures, unlike sea walls, do not require to retain reclamation fill. However, they are heavy structures subject to significant wave loading. Ground treatment may still be required if the structure were to be founded on the soft marine deposits or alluvium deposits.
- 5.5.3.43 Stability analysis of seawall and breakwater based on the typical geology at Hoi Sham and KTAC has been conducted to determine if the marine deposits will pose any stability problems. The results indicate that dredging is essential to provide the required stability against slip failure during reclamation and surcharging from an engineering point of view.
- 5.5.3.44 The long-term settlement in reclaimed land and short-term stability of marine structures are of concern. Ground improvement is often necessary to mitigate these problems. Ground improvement is particularly essential to areas where piles foundation is not to be adopted and the structures/ utilities are to be constructed soon after reclamation. Whilst the areas requiring ground improvement are scattered around whole development area, the ground improvement measures would be applied to all to allow more feasibility in planning. Ground improvement methods suitable for use in reclamation areas include:
- Pre-loading and installation of vertical drains;
 - Soil Mixing;
 - Vibroreplacement / vibrodisplacement; and
 - Lime columns.
- 5.5.3.45 A wide range of other techniques are also available for improving the properties of soils, such as dynamic compaction, soil displacement method, electro-osmosis, ground freezing and jet grouting, but are considered inappropriate or too expensive. The selection of ground treatment technique depends on the purpose of the improvement, the ground conditions and soil properties, available equipment, local experience and cost. The details and possible application of the recommended techniques suitable for this project are described in the following sections.

Vertical Drains with Preloading

5.5.3.46 During reclamation, the dissipation of excess pore water pressure in the compressible soils during primary consolidation would take place with drainage paths in the vertical direction only. The consolidation period can be reduced significantly by reducing the drainage path. This can be achieved by the installation of vertical drains through the highly compressible layers such as marine mud/alluvial clay layer, at typically 1m to 3m centres. The vertical drains can be sand drains but due to lower cost and higher installation rates, prefabricated vertical band drains are widely used nowadays. The consolidation process can be further accelerated by the use of surcharge (or pre-loading). If high surcharge is to be used for a prolonged period, the slope surface can be landscaped and vegetated, if necessary, to provide a more pleasing appearance to the public. The potential environmental impact associated with the application of vertical drains would mainly be the release of excess pore water, which may contain relatively high levels of suspended solids and contaminants. The outlets of vertical drains should be installed above the surface of the reclaimed land and be higher than the seawater level. Pore water releasing from vertical drains would spread on the interim ground surface. There would be no direct discharge of pore water into the nearby water body. The fill material would absorb the contaminants and the potential impact would be minimised.

5.5.3.47 In the formulation of ground improvement method, the following factors, which affect the accelerated consolidation in the ground improvement, have been considered.

Duration of the Surcharge

5.5.3.48 The longer the surcharge, the better effect to the accelerated consolidation but in a diminishing return. Duration of 6 months has been proposed in consideration of the requirement programme.

Spacing of the Vertical Drain

5.5.3.49 With closer spacing and hence greater cost, the ground improvement will be more effective. Alternatives of 1.2m and 1.5m spacing have been considered. The cost per square metre of 1.2m spaced vertical drains is approximately 50% more than that of 1.5m spaced drains.

Height of the Surcharge

5.5.3.50 The higher the temporary surcharge, the more effective of the ground improvement but obviously at an increased cost. At the same time, the availability of the temporary surcharge materials, the time for loading and unloading the temporary surcharge, and the potential environmental impact will be considered.

Soil Mixing

5.5.3.51 In this method, the soft soil is mixed *in-situ* with an appropriate additive using an auger or other mixing device. The additive used is typically cement or lime. No spoil removal is required. A similar technique, Deep Cement Method (DCM), has been developed in Japan, using cement slurry. The soil is strengthened through the introduction of solidified materials and mixing with the *in-situ* soil. The DCM is an *in-situ* sea bottom soft ground improvement technology and is widely used in Japan. The application of this method could minimize the dredging volume of marine sediment. A cement slurry is injected into the soft ground in where the strength of soil material or sediment is low. The reaction between the cement slurry and the soil material increases the strength of the final material. This results in material consolidation and reduction in water content of the material. The consolidated ground is capable of supporting structures. No excavation, shoring or dewatering processes would be required for DCM. Use of DCM has positive effect in term of environmental protection. The volume of sediments to be dredged and disposed of can be minimised. This in turn minimises

the effect on the capacity of the dumping sites. The potential impacts due to DCM would mainly be the release of leachate from the use of cement stabilizer. Noise and air impacts are expected to be minimal.

5.5.3.52 The construction procedures of DCM involves:

- Positioning of mixer;
- Insertion of mixer;
- Tip mixing;
- Withdrawal of mixer; and
- Relocation of mixer.

5.5.3.53 DCM may be used to improve the strength of the existing sediments so as to support the structures, box culverts, breakwaters and sea walls in the future developments. Site trials would be required to confirm the suitability of the DCM method to be applied in the development areas.

5.5.3.54 During the application of DCM, a sand blanket should be placed on top of the sediments to minimize the disturbance to the sediments when carrying out the work. Leachate generated from the use of cement stabilizer in the DCM process would have elevated pH value. Release of leachate should be controlled to avoid the potential impacts to the surrounding environment.

5.5.3.55 The cement slurry used for stabilization will be injected into the sediments. The injection rate should be controlled to avoid leaching out of cement slurry. The slurry waste generated during the DCM process should be properly disposed of. In addition, the treatment work should be properly planned and competent persons should be deployed for carrying out the work.

5.5.3.56 As the applicability of DCM still needs to be proven in Hong Kong, site trials would be required in order to determine the appropriate acceptance criteria for using this method. After reviewing the site trial results, the areas for application of DCM could be evaluated. During the trials, monitoring could be carried out to assess the residual environmental impacts arising from the use of DCM.

Vibroreplacement / Vibrodisplacement

5.5.3.57 Another method of reducing settlement of clay and silt is by use of vibroreplacement or vibrodisplacement. These techniques involve the installation of sand or gravel compaction piles commonly referred to as “stone columns”. The diameter of a typical sand compaction pile is 300mm. The piles can be constructed using a number of different methods such as vibrofloat with water jet (vibroreplacement), compressed air (vibrodisplacement), metal casing filled with sand or the Japanese “Compozer” process.

5.5.3.58 The settlement of soft clay with sand compaction piles installed is usually estimated by assuming that the columns and the surrounding soil act as a composite material. Past experience has shown that settlement is only significantly reduced if the piles are closely spaced (i.e. $s < 5d$, where d is the diameter of the column). The sand column will also act as vertical drains, hence reducing the drainage path of the compressible soils.

5.5.3.59 The sand compaction piles would provide significant increase in shear strength when dealing with stability problems associated with the seawall and breakwater structures. However, this method has primarily been used in Hong Kong to stabilise soft materials below structures by reducing settlement, rather than to provide an increase in shear strength in slope stability analyses. Use of water jet and compressed air may generate water, air and noise problems. It is expected that these potential impacts would be minimised through the suitable control of operational methods.

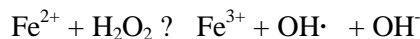
Lime Column

- 5.5.3.60 The use of lime piles is common in China and other Southeast Asia countries such as Singapore but less common in Hong Kong. Bores of around 300mm diameter are formed using close-ended pipes driven to the base of the compressible layer, usually by vibration. Unslaked lime is then introduced from the bottom trapdoor to fill the complete bore. The expansion from the quick lime causes consolidation of the soft clay between the lime piles, giving rise to an increase in shear strength and faster consolidation.
- 5.5.3.61 Past experience with lime piles showed that settlements were still significant after initial ground treatment using the method. Therefore, performance of lime piles, if adopted, will need to be monitored and verified on site during construction. In case of unsatisfactory results, further work will be needed to achieve the required standard. The potential environmental impacts may include the release of unslaked lime and noise emission from vibration. These can be mitigated and controlled to acceptable levels through the implementation of suitably designed work method statements.

Option 2: Dredge for *Ex-situ* Treatment Reclamation

- 5.5.3.62 The proposed sediment dredging would be implemented together with suitable *ex-situ* bioremediation techniques to eliminate biogas risks. The required dredging is to remove the contaminated sediments for *ex-situ* treatment. The treated material with low contaminant levels should be reused as fill material for reclamation as far as possible. The small volume of sediments that cannot be dredged would be treated using *in-situ* treatment techniques. Reuse of the treated material as fill material could eliminate the need for off-site disposal, hence the requirements for Tier II and Tier III screening.
- 5.5.3.63 *Ex-situ* bioremediation can be classified into slurry-phase treatment and solid-phase treatment. An aqueous slurry of contaminated sediments is maintained for slurry-phase treatment. Soil-pile treatment, land treatment and composting are typical examples of solid-phase treatment. The application of *ex-situ* sediment treatment requires sediment dredging, which is one of the major costs of this treatment option. The effectiveness of this treatment method is, however, not affected by hydrogeological conditions of the sites.
- 5.5.3.64 Biodegradation is a common biological treatment process, which is to remove organic matter by micro-organisms. Organic micro-pollutants such as PAHs and PCBs can also be reduced. The treatment process can be carried out in aerobic/anaerobic, suspended/attached, and continuous/batch reactors. Provision of land for setting up the treatment facilities would be required for *ex-situ* bioremediation. Wastewater generated from the treatment processes needs to be treated to acceptable levels prior to the final discharge.
- 5.5.3.65 The proposed *ex-situ* treatment method includes dredging of contaminated sediments from the reclamation areas. The unit operations of the treatment consist of in-pipe reaction of the dredged sediments and Fenton's Reagent to achieve destruction of organic contaminants, coarse screening, sediment washing, solids separation, agglomeration and heap leaching for treatment and removal of contaminants using both inorganic and biological reactions.
- 5.5.3.66 Suction dredging would be used for sediment dredging. When carrying out the suction dredge operation in water, release of odour would be minimized. The width of the KTAC is approximately 200m and water depth in the channel is about 4 to 5m. It is recognised that accessibility to the upper stream portion of KTAC is constrained by the Taxiway Bridge. The suction dredger, however, could be berthed downstream of the taxiway bridge, with the suction pipeline extended upstream. The maximum pipeline length involved is approximate 900m, which is within the capacity of even the small type suction dredger.

5.5.3.67 The treatment process would begin by feeding Fenton's Reagent, mixture of hydrogen peroxide (H_2O_2) and ferrous iron (Fe^{2+}) into the dredge pipeline to oxidize the organic contaminants. This reagent generates high reactive hydroxyl radicals, which can decompose the carbon-hydrogen bonds of organic molecules. The chemical reaction of the mixture forming the hydroxyl radical is:



5.5.3.68 Much of the AVS would react with the Fenton's Reagent before the sediment slurry reached a barge or the land. As high concentrations of AVS tend to generate odorous hydrogen sulphide gas, the reduction in AVS would minimize the odour problem during the operation. The oxidized acidic sediment slurry with ferric hydroxide material forms a coating on the larger sediment grains, binding the heavy metals into a low-solubility material.

5.5.3.69 The sediment slurry is pumped from the barge to liquid-solid separations units such as a vibrating screen and then to a land-based sediment washing unit. The vibrating screen removes the oversized debris. The sediment washing technique can be used on gravel, sand, silt, and clay, and can clean soil particles as small as 1 micron. It can lower both metal and organic pollutant levels, and can reduce sediment volume. Reagents for bioremediation containing no hazardous ingredients are added into the washing process. Multiple washes may be required for sediments with high contaminant levels. The slurry flow is diverted to a scrubber to further weaken the bonds between contaminants and particles. Physical separation processes using hydrocyclones and centrifuges can be applied to separate the sediment slurry to produce the sediments in solid form. The relatively clean fraction of sediments after dewatering may be used as fill material. Depending on the removal efficiency of the heavy metals and organic matter, the fraction of sediments with high concentrations of organic contaminants could go to a soil pile for further biotreatment.

5.5.3.70 It is estimated that the volume of wastewater would be large as a result of the use of suction dredge. An initial estimate of the wastewater volume would range between 2×10^4 and 10×10^4 m^3/d . The wastewater generated from the sediment washing unit contains metal oxides, which are mostly absorbed onto the suspended particles in the wastewater. The organic contaminants should have been degraded during the mixing process with Fenton's Reagent and sediment washing. The contaminant levels of the wastewater are therefore expected to be low. The need to install a wastewater treatment system and the wastewater disposal would be determined in the pilot tests.

5.5.3.71 Biotreatment of the soil pile to degrade organic contaminants can be carried out by inducing microorganisms in the highly contaminated fraction of sediments, if required. The growing conditions for microorganisms would be optimized through the improvement of porosity to the sediments and the addition of suitable reagents to provide source of carbon and nutrient.

5.5.3.72 Upon completion of biotreatment, the fully treated material should be reused as fill material for reclamation as far as possible. The beneficial uses of treated material as fill material have been well documented by the US Army Corps of Engineers.

5.5.3.73 To demonstrate the feasibility of sediment washing process in remediating heavily contaminated sediments, the BioGenesis™ Sediment Washing has been selected as an example to show the successful application of the process in similar projects.

5.5.3.74 A bench-scale test using the BioGenesis™ Sediment Washing was performed to treat the contaminated sediment in New York / New Jersey Harbour in 1997. The project was jointly directed by USEPA and Army Corps of Engineers and was funded by the Water Resources Development Act. The contaminants in the harbour sediment included PCBs (2320 ppb), PAHs (19502 ppm), Metals (852 ppm), TOC (3.58%) and others. The removal efficiencies on

these contaminants using the BioGenesis™ Sediment Washing are presented in **Table 5.32**. The estimated costs of sediment washing technique would range from US\$60 to \$300 per cubic meter and the treatment period would be approximately from several months to more than a year depending on the sediment volume and contaminant levels.

Table 5.32 Treatment Efficiency of the BioGenesis™ Sediment Washing Process

Contaminant	Removal Percentage
PCBs	95.3%
PAHs	84.7%
TOC	96.9%
Metals	96.3%

Note: Data was from BioGenesis Enterprises, Inc.

- 5.5.3.75 Daramend™ Bioremediation is an example of solid-phase biological treatment. A pilot-scale demonstration at Hamilton Harbour (1992-1993) was performed under the Contaminated Sediment Treatment Technology Program funded by the Great Lakes 2000 Cleanup Fund. Sediment in the Randle Reef Area near Hamilton Harbour was used to demonstrate the biological degradation of PAHs. Daramend™ Bioremediation process achieved a reduction in PAHs of approximately 74% over 100 days of treatment and a reduction of about 90% at the end of the test after 359 days. The PAHs in the sediment decreased from an initial concentration of 1140 mg/kg to the final concentration of 100 mg/kg over 359 days of treatment.
- 5.5.3.76 This technique has also successfully been applied to soils and sediments contaminated by petroleum hydrocarbons, pesticides and explosive compounds. Daramend™ demonstrated that the bioremediation process could achieve a 99% removal of phthalates (pilot test), 95% removal of toxaphene (bench scale test), and 99% removal of TNT (bench scale test). The estimated costs for the solid-phase biological treatment would be up to US\$150 per cubic meter.
- 5.5.3.77 It is anticipated that a certain amount of pollutants would be degraded through the in-pipe injection of Fenton's Reagent. During the sediment washing process (the first stage of *ex-situ* treatment), most of the organic pollutants would be removed and heavy metals would be released to the washing water. Chemical precipitation would be one of the treatment methods to remove the heavy metals from the wash water. The soil pile would be relatively less polluted and should be relatively free of metals, and if needed, could be treated by the Daramend™ Bioremediation to remove any remaining organics (second stage of *ex-situ* treatment). The proposed Daramend™ Bioremediation serves as a backup system and would be applied in case where the contaminant levels of soil pile are high. It will be determined through the pilot tests whether the soil pile generated from sediment washing process requires further treatment. If not, the subsequent bioremediation process may not be necessary. The suitability of reusing the treated material as fill material would also be determined in the pilot tests.
- 5.5.3.78 *Ex-situ* bioremediation can achieve high removal rates of organic contaminants and this approach eliminates the biogas risks to the future developments at KTAC. Protection measures would not be required for adoption of this reclamation option with full dredging of sediments.

Impacts due to Dredging and Mitigation Measures

- 5.5.3.79 The dredging of contaminated sediments in the reclamation areas would last several months to more than a year. The environmental impacts that may arise from the dredging activities would include spreading of sediment plume, releasing of contaminants into the water column and odour emission.

Spreading of Sediment Plume

- 5.5.3.80 The sediments in the proposed reclamation areas have found to be heavily polluted, the disturbance to the sediments during dredging would generate sediment plumes and cause the release of heavy metals and micro-pollutants into the water body. The areas that would be affected by the spreading of sediments and contaminants may include the existing Kwun Tong Typhoon Shelter, Hoi Sham and the Victoria Harbour waters. The water quality sensitive receivers located in these areas would potentially be affected.
- 5.5.3.81 The proposed *ex-situ* treatment adopts suction dredge, which uses a suction pipe to remove sediments from the seabed. The sediments together with a certain amount of seawater would be pulled into suction pipeline at the point of dredging. The sediment loss rate of a trailer suction dredger is approximately 6 times lower than that of a close grab dredger. However, a small amount of sediment particles may still disperse out of the dredging point. The contaminants absorbed in the sediment particles would be released into the seawater. The contaminants in dissolved phase would be shore-lived and dilution of the desorbed contaminants by the ambient water would reduce the contaminant concentrations. It is expected that the potential impacts due to spreading of sediment plumes and release of contaminants from the sediments would not be significant.
- 5.5.3.82 Suitable protection measures still be required to reduce the release of sediments from the dredging areas to the nearby water body and the measures should be incorporated into the dredging programme. In case where dredging would be carried out in the KTAC, KTTS and Hoi Sham, mitigation measures should be implemented.
- 5.5.3.83 After the diversion of Kai Tak Nullah and Jordan Valley box culvert, no inflow would enter the KTAC from the upstream locations. There would be no prevailing direction of water movement in the area. The slow water movement within the KTAC would limit the dispersion of sediment plumes. The only route for sediment plumes to escape from the KTAC is through KTTS. Silt curtains should be provided at the exit of the KTAC to avoid the sediment plumes from dispersing out of the KTAC dredging area. It is expected that the control of sediment plume dispersion by providing silt curtains at the KTAC exit would be effective as the KTAC is semi-enclosed by the disused Kai Tak Airport runway and the land boundary. There would be no significant impacts to the water quality in the vicinity of the dredging area.
- 5.5.3.84 KTTS is semi-enclosed by the disused Kai Tak Airport runway and the existing breakwaters. Control of sediment dispersion by placing silt curtains can be applied at the exit of the typhoon shelter. The areas near Cha Kwo Ling and Hoi Sham are more open and are directly affected by the tidal current. Silt curtains should be installed near the dredging locations to minimize the sediment dispersion.
- 5.5.3.85 Loading of the dredged sediments to the barge should be controlled to avoid splashing and overflowing of the sediment slurry to the surrounding water. Mitigation and protection measures should be implemented during the sediment dredging to minimize hazards that would be created by the contaminated sediments. It is recommended to minimize exposure to the contaminated sediments. The workers should wear protective gloves when carrying out the dredging work. Adequate washing and cleaning facilities should be provided on site.
- 5.5.3.86 The sediments should be transferred from the barge to the sediment washing unit immediately after dredging. Storage of the dredged sediments at the site is not recommended. The dredged sediments should be segregated from other wastes to ensure that the treatment operation would not be affected.

Odour

- 5.5.3.87 The proposed *ex-situ* treatment would adopt suction dredge, which uses a suction pipe to remove sediments from the seabed. The dredging operation is under a submerged condition and would prevent the exposure of dredged sediments in the atmosphere. Odour emission would be minimized by the addition of Fenton's reagent into the dredged sediments in the dredge pipeline, which would oxidize much of the AVS almost instantaneously and hence reduce the generation potential of odorous hydrogen sulphide gas. It is therefore unlikely that odour emission would be a critical issue when applying the proposed dredging and treatment methods.
- 5.5.3.88 After the completion of dredging and reclamation, the odour problem in the reclamation areas would be eliminated. Part of the existing KTTS will be reclaimed in the later stage of the development project. The water quality in the remaining part of KTTS would be improved as the major sources of pollution from the Kai Tak nullah and other box culverts would be diverted to Kowloon Bay and would not enter the KTAC and KTTS. Deterioration of water quality in the typhoon shelter is unlikely if there is no illegal discharge of effluent into the water by the boat users. When a normal flushing rate is maintained in the typhoon shelter, the potential odour problem from the typhoon shelter that may affect the future sensitive receivers in the KTAC would be unlikely.

Option 3: Minimum Dredged Reclamation

- 5.5.3.89 The minimum dredged reclamation is to remove both the contaminated and uncontaminated sediments in the locations where major marine structures are to be constructed. These include:
- sea wall;
 - breakwater;
 - tunnel; and
 - earth bund.
- 5.5.3.90 In areas where diaphragm wall or bored pile wall is to be used as the foundation works for the future developments, the design engineer shall take special attention during the detailed design stage. Any material extracted from the captioned operation shall be carefully examined, and appropriate treatment shall be applied, if necessary, prior to disposal at designated sites.
- 5.5.3.91 **Table 5.33** summarizes the estimated volumes of sediments to be dredged for the reclamation. The locations of dredging areas are shown in **Drawing No. 22936/EN/192**. The volume of sediments to be dredged for the minimum dredged option would be much smaller when compared to the reclamation option with full dredging of sediments for treatment.

Table 5.33 Estimated Sediment Volumes for the Minimum Dredged Reclamation

Dredging Zone	Dredging for Reclamation	Total Volume to be Dredged (M ³)	Volume of Contaminated Sediment to be Dredged (M ³)
Zone 1	Hoi Sham (Earth Bund)	108,000	68,350
Zone 2	Western Arm of New Typhoon Shelter	337,750	337,750
Zone 3	Eastern Arm of New Typhoon Shelter	632,500	420,150
Zones 4 and 5	Phase 1 of Hoi Sham (including D4 Tunnel)	261,720	112,750
Zone 6	Kwun Tong Typhoon Shelter (Strip Along Existing Seawall)	203,000	84,000
Zones 7 and 8	Stage 2 of Hoi Sham	309,200	154,400
Zone 9	Cha Kwo Ling	81,200	33,600
Zone 10	Marina Phase 2 Hoi Sham	114,450	68,250

- 5.5.3.92 The uncontaminated sediments from the dredged areas can be backfilled into the other reclamation areas where no dredging would be required. The contaminated sediments can be treated using *ex-situ* treatment method to reduce the contaminant levels. The treated material should be reused as fill material for reclamation as far as possible.
- 5.5.3.93 A relatively large portion of sediments would remain in the areas where no dredging is required, application of *in-situ* treatment and/or provision of protection measures should be implemented to protect the future developments. *Ex-situ* and *in-situ* treatment methods and protection measures have been presented in the preceding sections. The proposed treatment methods and protection measures are directly applicable to the minimum dredged reclamation option.
- 5.5.3.94 Although dredging would be limited to a number of dredging zones, spreading of sediment plume, releasing of contaminants and odour emission from the dredging activities should be fully considered when carrying out the minimum dredged reclamation option. The potential impacts and mitigation measures presented in the section on the dredge for *ex-situ* treatment reclamation option are applicable to this case.

5.6 Pilot Tests

- 5.6.1.1 The feasibility of *in-situ* treatment and *ex-situ* treatment should be demonstrated through pilot tests, which would include bench scale laboratory tests and field trials. The recommended *in-situ* treatment methods or reagents for sediment remediation in the SEKD include:
- Fenton's Reagent;
 - Oxygen Release Compound (ORC); and
 - Seditreat™.
- 5.6.1.2 The recommended *ex-situ* treatment methods are:
- BioGenesis Sediment Washing; and
 - Daramend™ Bioremediation.
- 5.6.1.3 Bench scale laboratory tests will examine the treatability of sediments by the *in-situ* and *ex-situ* treatment methods. The results obtained from the bench scale tests will be used for evaluation of the suitable methods/oxidants and formulation of the subsequent site trials. The proposed field trials for *in-situ* treatment and *ex-situ* treatment are as follows:

Field Trials for *In-situ* Treatment

- 5.6.1.4 Application of *in-situ* treatment is mostly conducted from a land-based operation. When applying the treatment in a submerged environment, the operation may be more difficult to control. This would affect the treatment performance. To deal with the situation in the SEKD, it is recommended to conduct the *in-situ* treatment in two selected areas. One of the areas can be backfilled prior to the application of *in-situ* treatment and no filling will be applied to the other one to represent the existing conditions.

A. In-situ Treatment after Backfilling

- 5.6.1.5 Construction of a 40-meter square test cell within the KTAC by enclosure within sheet piling and backfilling with selected material. Injection of the selected oxidants will then be applied through a series of injection points. The changes in contaminant levels will be monitored through short-screen monitoring wells.