

9. HAZARD TO LIFE

9.1 Introduction

9.1.1.1 There are some existing hazardous installations within the South East Kowloon Development (SEKD) study boundary that may be of risk concern to the future residents of SEKD. According to the Environmental Impact Assessment (EIA) Study Brief, there are 2 main areas of concern that need to be addressed in the present *Comprehensive Feasibility Study for the Revised Scheme of South East Kowloon Development* (the present study):

- Potential hazard associated with the Ma Tau Kok Gas Works North Plant and its facilities; and
- Potential hazard associated with non-fuel gas facilities within the study boundary.

9.1.1.2 The locations of these facilities are shown in **Drawing No. 22936/EN/110**. These facilities have the potential to impact on the SEKD because they handle a certain amount of hazardous material and they are situated within or very close to the SEKD New Development Area.

9.1.1.3 The potential hazards from these installations in relation to the South East Kowloon Development is discussed in this Section. The same risk issues were discussed in the previous SEKDFS¹ and reference will be made to this previous study whenever applicable.

9.2 Legislation, Policies, Plans, Standards and Criteria

9.2.1.1 In Hong Kong, the risk associated with a potential hazardous installation (PHI) is expressed in both Individual Risk and Societal Risk. The assessment criteria are clearly defined in Annex 4 of the *EIAO-TM*, which is copied in **Drawing No. 22936/EN/037**.

9.2.1.2 The requirement and procedure of conducting a risk assessment is also set out in the Professional Persons Environmental Consultative Committee (ProPECC) Practice Note PN 2/94 "*Potentially Hazardous Installations*" and Chapter 11 of the Hong Kong Planning Standards and Guidelines (HKPSG).

9.2.1.3 The definitions and threshold quantities of PHIs are given in the HKPSG, as well as the role of different Government dealing with different types of PHIs.

9.3 Ma Tau Kok Gas Works and its Associated Facilities

9.3.1 Introduction

9.3.1.1 This section is the Risk Assessment for Ma Tau Kok Gas Works (MTK Gas Works) of the Feasibility Study for Revised Scheme of South East Kowloon Development. The Risk Assessment has been carried out by DNV.

Background

9.3.1.2 The Government is planning to develop the South East Kowloon areas in which Ma Tau Kok Gas Works is located in the north east of the Kowloon peninsula. The areas are proposed to be developed for various uses such as residential, schools and community facilities etc.

¹ Feasibility Study for South East Kowloon Development, Environmental Impact Assessment Report, Technical Report No. RW7, Maunsell Consultants Asia Limited

9.3.1.3 Previous Quantitative Risk Assessment (QRA) studies relating to the area and the MTK Gas Works have been carried out by DNV (DNV Technica, 1991, DNV Technica 1992, DNV Technica 1996 and DNV 1998). The methodology of these studies has been used in this Risk Assessment. Reference should be made to these analyses if further details are required.

The Consultation Zone for MTK Gas Works

9.3.1.4 The MTK Gas Works is classified as a Potentially Hazardous Installation (PHI) and a Consultation Zone (CZ) has been defined around the site, extending 300 m from its boundary (see **Drawing No. 22936/EN/034**). Proposals for developing the surrounding areas will result in an increase in the number of persons living or working within the CZ. Such plans have to be submitted to the Co-ordinating Committee on Land-use Planning and Control relating to Potentially Hazardous Installations (CCPHI) for consideration.

9.3.1.5 The risks to the public are to be confined within the acceptable limits (according to the Government Risk Guidelines). Where guidelines cannot be met for existing PHIs, CCPHI will consider the necessary risk mitigation measures to bring the risk level down.

Objectives

9.3.1.6 The overall objective of this risk assessment is therefore to identify the potential hazards and assess the risk impact of the Potentially Hazardous Installations on the future South East Kowloon Development and to recommend practical mitigation measures if necessary.

9.3.1.7 This assessment considered the level of risk for the MTK Works including the relocated naphtha jetty, pipeline and pigging station. Under the current development program, the existing naphtha jetty will be relocated to its permanent location at the marina after completion of the southern portion of reclamation in Hoi Sham area and no temporary relocation of the naphtha jetty is anticipated. Before relocation of the existing naphtha jetty, the northern portion of reclamation in Hoi Sham area would not be in place and population intake to the new reclamation area within the consultation zone of the existing jetty is not anticipated.

The Scope of the Risk Assessment

9.3.1.8 This Risk Assessment considered the level of risk for the following cases:

1. Base Case - current operation of MTK Gas Works with the planned South East Kowloon Development population.
2. Mitigated Case - current operation of MTK Gas Works (buried gas outlets) with the planned South East Kowloon Development population.

9.3.1.9 It is therefore necessary to carry out the following activities:

- Identify the PHIs in the Area;
- QRA of the activities of the MTK Gas Works;
- Evaluate the individual and societal risk to the population in the surrounding areas;
- Assess the risk in terms of the Hong Kong Risk Guidelines and, if appropriate, to propose risk mitigation measures to demonstrate that:
 - The levels of societal risk to the various population cases are acceptable or ALARP; and
 - The individual risk is acceptable.

9.3.2 Study Area Data

Introduction

9.3.2.1 This section summarises the study area data used in the risk model. To reflect variations in population and weather conditions, the model has used two time periods namely day and night.

The Ma Tau Kok Gas Works

9.3.2.2 The MTK site is located in the north east of the Kowloon peninsula. The site is presently surrounded by high rise flats located in the north east, a cattle holding site at the north west boundary, various factory buildings on the south and south east side, and old low rise residential flats on the east. Based on the Outline Master Development Plan of South East Kowloon Development, residential developments are proposed to be located at the north east and south east sides of the site.

9.3.2.3 The layout of the MTK Gas Works consists of naphtha storage tanks, naphtha-reforming plants, gasholders, administration office and other ancillary compressor, boiler and pump houses. In addition to the gas works, there is a naphtha receiving jetty, an off-take station and a pigging station. The layout of the site is shown in **Drawing No. 22936/EN/035**.

9.3.2.4 Naphtha is imported to the MTK site by oil barges, unloaded at the jetty and pumped into the feedstock storage tanks (TK9 and TK10). Naphtha is the feedstock for gas production and the Naphtha Jetty allows for the loading/unloading of Naphtha, which is transported by sea from the Tai Po Gas Plant. The proposed relocated jetty shown on the Outline Master Development Plan is located at the end of embankment extended from site 3G. There is also a proposed relocated pigging and off-take station located adjacent to Hoi Sham Park. The pipeline leading to the naphtha storage is laid underground along San Ma Tau Street and Road D1. The two storage tanks at MTK Gas Works are identical. Each has an internal floating roof with tank capacity of 1779 m³. Both tanks are in a bund of 800 m² area and 3 m height.

9.3.2.5 The MTK Gas Works employs a cyclic reforming cycle process to produce Towngas from a naphtha feedstock. The process is based on the reaction between steam and naphtha feedstock in the presence of a catalyst at elevated temperature. The process cycle is approximately 5 minutes and is divided into two characteristic phases. The reaction is endothermic and the heat absorbed from the catalyst during the make phase is restored during the subsequent heating phase. There are 6 identical gas production plants in MTK Gas Works producing town gas. Each of these plants consists of a combustion chamber and reactor with burner, a naphtha vapouriser, a waste heat boiler, a water scrubber and exhaust and vent stacks.

9.3.2.6 The produced towngas is stored in gas holders located at the southern end of the site. These are water sealed, full column guided holders with above ground water tank. Gas holder no. 4 has a capacity of 19 tonnes while the smaller gas holder no. 2 with nominal capacity of 9 tonnes is being kept at an inventory of about 1.6 tonnes, and will only be put into service when gasholder no. 4 is decommissioned for maintenance or under emergency.

Ignition Sources

9.3.2.7 The ignition sources inputs in SAFETI are consistent with previous studies (Technica, 1991). The detailed modelling of ignition sources is described in **Appendix 9A**.

Population

Off-site Population around the MTK Gas Works

9.3.2.8 The off-site population surrounding the MTK Gas Works, naphtha jetty and associated pipelines has been modelled in the analysis. The population data is for the 2 time periods day (D) and night (N) but includes only offsite populations. Maps showing all the population locations defined in this study are shown in **Drawing No. 22936/EN/356**.

9.3.2.9 The off-site population considered in this Risk Assessment for the Ma Tau Kok gas production plant is listed in **Table 9.1**. The existing population data has been taken from the previous study (DNV, 2000) and the data for the planned SEKD derived from the Feasibility Study.

Table 9.1 Existing Offsite Population of Ma Tau Kok Gas Production Plant

Location's Description	Predominant Land Use	Total Population		Population Density	
		Day	Night	Day	Night
3a	Residential	1890	10440	0.07	0.36
3b	Residential	170	990	0.05	0.29
5	Residential	1620	11350	0.08	0.54
10a	Residential	780	1590	0.16	0.33
10b	Residential	790	1550	0.18	0.35
10c	Residential	630	820	0.15	0.20
11	Substation	5	1	0.002	0.0004
13	Industrial	3030	0	0.55	0
14	Recreation Ground	100	0	0.01	0
15	Cattle Depot	50	0	0.003	0
16	Industrial	4100	0	0.19	0
18	Industrial	4780	160	0.16	0.01
3T	Commercial	7318	732	0.67	0.067
3R+3S	Residential	2857	5979	0.14	0.29
3U	Residential	916	3663	0.07	0.29
3V	Residential	2443	5056	0.12	0.25
3X-R	School	1019	10	0.13	0.001
3Q-R	Residential	2027	3656	0.10	0.18
3Q-PS	School	1423	10	0.23	0.002
3Q-SS	School	1019	10	0.15	0.001
3X-PS	School	1423	10	0.23	0.002
20	Schools	2038	20	0.5	0.005
21	Park	200	20	0.007	0.0007
3N-R	Residential	1860	3368	0.11	0.20
3N-C	Community Facilities	481	48	0.07	0.007
22	Pump Station	5	1	0.002	0.0003
3M-SS	School	1019	10	0.14	0.001
3M-R	Residential	1204	2195	0.10	0.19
3F	Residential	783	1497	0.08	0.15
3G	Residential	588	1125	0.06	0.12
23	Substation	5	1	0.004	0.0009
Road "D1"	Traffic	282	28	0.006	0.0006
Road "L5"	Traffic	282	28	0.006	0.0006
To Kwa Wan Road	Traffic	338	33	0.02	0.002
Ma Tau Kok Road	Traffic	97	10	0.02	0.002
San Shan Road	Traffic	191	19	0.02	0.002
Kowloon City Road	Traffic	294	29	0.02	0.002
24	Marina	50	5	0.002	0.0002

On-site Population

- 9.3.2.10 This is not considered in this Risk Assessment as the staff operating the Gas Works are considered to be voluntary takers of risk.

Weather

- 9.3.2.11 The weather for the study area is described in **Appendix 9A**. The prevailing wind is from the east south east over half of the time and west south west roughly 15% of the time. Ambient and ground temperatures have been modelled as 25°C and 20°C respectively and the relative humidity modelled as 75%.

Topography

- 9.3.2.12 The site is bounded by high rise developments on all sides except the west side which is a low rise Cattle Depot. Taking that into account, a surface roughness of 0.33 has been used in the analysis to reflect the combination of high rise/low rise and other land surfaces in urban areas.
- 9.3.2.13 The geographical data are described in more detail in **Appendix 9A**.

9.3.3 Safety Management System and Human Interfaces of Ma Tau Kok Gas Plant

Introduction

- 9.3.3.1 DNV have reviewed the Safety Control Procedures, which is part of the ISO 9002 Documentation for the Ma Tau Kok Works site. This section summarises this document. The main sections of the document are:

- Definitions;
- Responsibilities;
- Qualifications or Training;
- Procedures; and
- Records.

- 9.3.3.2 There are also sections specifying the document's purpose, application, reference documents and attachments, which are examples of forms and report formats to be used.

Definitions

- 9.3.3.3 Definitions are given for:

- Authorised Persons;
- Certificate of Entry into Confined Space;
- Confined Space;
- Permit (of Permit-to-Work System);
- Safety Audit;
- Safety Survey; and
- Plant Manager.

Responsibilities

- 9.3.3.4 Responsibilities are specified for the following positions:

- Production Manager;
- Plant Manager;
- Risk Manager;
- Safety and Health and Environmental Manager; and
- Safety Health and Environmental Officer.

Qualifications or Training

9.3.3.5 This section states that:

The responsible HKCG personnel are trained with this Company Operating Procedure and the associated documents.

The Safety Health and Environmental Officer shall be a registered Safety Officer under the Factories and Industrial Undertakings (Safety Officers and Safety Supervisors) Regulations.

Procedures

9.3.3.6 Procedures are specified for the following:

- Safety Management System, its development and implementation;
- Safety committees;
- Permit-to-Work system (extensive details of several procedures);
- Entry into confined spaces;
- Safety audit/survey;
- Accident reporting, investigation and statistics; and
- Safety control of contractors.

Records

9.3.3.7 The procedure specifies how long and who is to keep, the following safety related documents:

- TP and MTK Plants' Safety Committee Meeting minutes;
- Permits-to-Work and Certificate of Entry into Confined Space;
- Expired Permit-to-Work and Certificate of Entry into Confined Space;
- Safety Audit/Survey Reports, replies from the plant regarding non-conformities, Accident reports, investigation reports and Monthly Accident Statistics Reports; and
- WIs of the Safety Management System.

MANAGER Audit by DNV in 1991

9.3.3.8 As part of the QRA of the Ma Tau Kok Works, finalised by DNV in November 1991, DNV carried out an audit of the site's safety management system, using their MANAGER audit protocol.

9.3.3.9 This has 114 questions which fall into 12 categories:

- Written procedures;
- Incident reporting;
- Safety Policy;
- Formal safety studies;
- Operations;
- Maintenance;
- Emergency procedures and facilities;
- Training;
- Management of change;
- Control room, instrumentation and alarms;
- Fire protection; and
- Miscellaneous (housekeeping, etc.).

9.3.3.10 The performance of the site is evaluated compared to the average for large scale North American or European chemical processing industry. Responses to questions are graded as average, better than or worse than this average. The purpose of the audit is to calculate a management factor, which is used to factor the generic failure rate data to be used in the QRA.

- 9.3.3.11 In the 1991 audit, the management factor calculated was 1.00, i.e. no adjustment was needed to generic failure frequencies. It was observed that a score of 1.00 on a small site, without the same scale of resources as a large chemical facility or power station, indicates many better than average factors to cancel out the few poorer ones that are inevitable on smaller sites due to economies.

Human Interfaces

- 9.3.3.12 For the base case, the main types of accident on the MTK site which can affect the surrounding population are releases of gas from the export pipework, which would result in jet fires or flammable clouds, releases of naphtha at the jetty or at the naphtha tanks, and releases of gas at the pigging station. These releases have their fatal effect within a relatively short period and so this will not be significantly influenced by actions such as isolation, FSD action.
- 9.3.3.13 The main effect on risk will be factors influencing the frequency of the initiating event. The management factor summarised above is aimed at adjusting the generic frequencies to account for site-specific factors. This section aims to highlight some of the relevant human interfaces at the MTK Works.
- 9.3.3.14 As a general observation, HKCG have obtained the ISO 9002 accreditation.

Written Procedures

- 9.3.3.15 HKCG has developed extensive written procedures for normal operations, start up and shut down, power failure, maintenance and inspections. These are considered to be better than average.

Accident and Incident Reporting and Investigation

- 9.3.3.16 HKCG has formal procedures for investigating all accidents and they are considered better than average in this area. The purpose of this activity is to determine causes and try to avoid recurrence of similar accidents or incidents.

Safety Policy

- 9.3.3.17 HKCG has a safety committee and a Senior Executive Committee Meeting which always has safety on the agenda. There is good safety promotion on the site.

Training

- 9.3.3.18 HKCG operate a conventional training program and staff turnover is low. The gas works is a relatively simple process and operator's tasks are not complex. Half day's annual refresher courses are run on process control and plant operations.

Operations

- 9.3.3.19 The management structure is clear and job descriptions exist for all significant positions. These are distributed to staff.
- 9.3.3.20 There is no production bonus system that might lead to safety short cuts, but performance is measured and rewarded.

Operator Workload and Stress

- 9.3.3.21 HKCG run a system of 4 shifts with 7 to 8 staff per shift. There is normally no gas making operations at night in the gas works and 4 shifts is considered adequate.

Maintenance Systems

- 9.3.3.22 HKCG runs a permit-to-work system for hot work, cold work and confined space entry. Contractors are required to adhere to the system. There is a regular annual maintenance program for all equipment.

Control Facilities

- 9.3.3.23 Compared to most process facilities, the dynamics of the gas production system are far faster. Potentially in a hazard condition, operators might find diagnosis more difficult, however shutdown is rapid and easy.

Miscellaneous

- 9.3.3.24 Housekeeping on the site is good. Record keeping and internal communications appeared to be about average.

Conclusion

- 9.3.3.25 Overall, it is considered that the human interfaces at the MTK Works are about average or above.

9.3.4 Risk Assessment Methodology

Hazard Identification and Development of Incidents

- 9.3.4.1 In QRA it is important to identify all the potential hazards and based on these develop a complete set of incidents or failure cases. A systematic review of the facility and activities is carried out to identify representative failure cases that may result in the release of hazardous material.

- 9.3.4.2 The main hazards associated with the gas works arise from the unloading, transportation, storage and handling of naphtha and towngas. These are highly flammable materials. The following hazardous materials are present at the MTK Gas Works and have been modelled in the analysis. The properties of naphtha and towngas set in SAFETI are consistent with previous studies (Technica, 1991).

- 9.3.4.3 Naphtha is a colourless hydrocarbon liquid at normal conditions. It is a mixture of various hydrocarbons and its physical and chemical characteristics have been modelled as a composition of 50 mol% n-pentane and 50 mol% h-hexane.

- 9.3.4.4 Towngas is a colourless and odourless gas, unless odourisers are added. It is buoyant and releases will rise. The composition of the Towngas produced at the MTK Gas Works is shown in **Table 9.2**.

Table 9.2 Towngas Composition

CONSTITUENTS	COMPOSITION BY VOLUME IN %
Carbon Dioxide	11.5
Hydrogen	57.8
Carbon Monoxide	12.1
Methane	2.7
Nitrogen	10.3
Oxygen	0.2
Hydrocarbon (C _n H _m)	5.4
	100.0

- 9.3.4.5 The flammable hazards associated with towngas are fire and explosion due mainly to hydrogen and methane components, and to a lesser extent the carbon monoxide and alkanes.

Failure Case Identification

- 9.3.4.6 Failures are considered only for equipment items that contain substantial inventory and the release sizes that contribute to the off-site risk. The failure cases used in the analysis for the Ma Tau Kok Gas Works and naphtha jetty remain consistent with those used in previous analyses (DNV Technica, 1996). No new failure cases have been developed for this Risk Assessment.

Frequency Estimation

- 9.3.4.7 An estimate of the likelihood of failure for each failure case is made. The frequency is calculated based on generic data for the appropriate equipment items that contribute to that failure case. The failure rates have also been modified to account for specific local circumstances. The failure rate database for generic failure frequencies used in this Risk Assessment is consistent with those presented in Appendix IV (Technica, 1991) and Main Report (DNV Technica, 1996). The same failure cases as the previous studies were used with minor revisions to account for the risk mitigation measures adopted at the works following the 1996 study.

- 9.3.4.8 The selected failure cases that are considered to have potential off-site impact and modelled in this Risk Assessment are summarised in **Table 9.3**.

Table 9.3 Summary of Failure Cases Modelled

Event Code	Description	Failure Frequency (per year)
1/1 ^(a) – cluster event	Major spill of naphtha in the bund	1.35 x 10 ⁻³
1/6 ^(a) – cluster event	Minor spill of naphtha in the bund	7.59 x 10 ⁻³
1/9 ^(a) – cluster event	6kg/s naphtha spill in the process area	4.90 x 10 ⁻³
1/15 ^(a) – cluster event	2kg/s naphtha spill in the process area	3.74 x 10 ⁻³
3/5	Full bore rupture of gas lines before compressors	6.00 x 10 ⁻⁶
4/7	Full bore rupture of gas outlets	2.12 x 10 ⁻⁶
5/3 ^(b)	Full bore rupture of gas pipes at offtake/pigging station	8.60 x 10 ⁻⁷
3/2	200mm leak of gasholder no. 2/4	4.00 x 10 ⁻⁵
S8	Blown seal in gas holder (1m equivalent hole)	4.00 x 10 ⁻⁵
5/7 ^(c)	Full bore rupture of naphtha loading arm	3.77 x 10 ⁻⁴
5/8 ^(c)	20mm leak of naphtha loading arm	4.55 x 10 ⁻⁴
15/1 ^(d)	Full bore rupture of naphtha cargo line	5.60 x 10 ⁻⁷
15/2 ^(d)	10% leak of naphtha cargo line	4.00 x 10 ⁻⁶

Notes:

- (a) Clustering of failure cases were detailed in the previous study (Technica 1991).
- (b) Emergency Shutdown Valves (ESDVs) are assumed to be installed in the gas export pipelines.
- (c) Automatic excess flow valves are assumed to be installed at the naphtha barge to reduce / eliminate the naphtha transfer spill quantity in case of loading arm failure.
- (d) Complete burial of the pipelines is assumed to be done along the shoreline, the only above ground features being the offtake unit and the pig launchers.

Consequence and Impact Analysis

- 9.3.4.9 The consequences and risks of all release cases have been estimated with the latest SAFETI program (SAFETI Expert V5.2) for all modelling aspects. This is considered to be a standard software tool for use in Hong Kong. Details of the modelling theory are provided in the SAFETI Theory Manual (DNV,1996). For flammable materials, the possible outcomes include:

- Fireball/BLEVE;
- Flash fire;
- Vapour cloud explosion;
- Jet fire; and
- Pool fire.

9.3.4.10 The assessment has generally used the standard SAFETI parameters for risk assessment of this type in Hong Kong. Details of the parameters used are presented in **Appendix 9B**.

9.3.5 The Regulatory Situation

Definition of Ma Tau Kok Gas Works as Potentially Hazardous Installation

9.3.5.1 MTK Gas Works is permitted to store a maximum of 29.5 tonnes of towngas and thus falls within the definition of a Potentially Hazardous Installation (PHI) as adopted by CCPHI.

Dangerous Goods Classification

9.3.5.2 Naphtha and Towngas are flammable and classified as Dangerous Goods (Category 5 and 2 respectively) under the Dangerous Goods Ordinance (DGO, Cap 295).

Hazard Assessment

9.3.5.3 Hazard assessment considers the level of societal and individual risk from the PHI to members of the public against Government Risk Guidelines (RGs) to determine what, if any, actions need to be taken to reduce risks to acceptable levels. The societal risk is assessed both for the existing population and the future proposed South East Kowloon Development.

The Hong Kong Risk Guidelines

9.3.5.4 The Government Risk Guidelines (RGs) define acceptable risks as follows:

- Individual Risk (the risk to a single individual in a specific location): The maximum involuntary individual risk of death associated with accidents arising at PHIs should not exceed 1 chance in 100,000 per year (10^{-5} per year);
- Societal Risk (the risk to the population as a whole, independent of geographical location): The societal risk associated with a PHI should comply with the FN diagram shown as **Drawing No. 22936/EN/037**. The drawing is a graphical representation of the cumulative frequency, F, of a number, N, or more fatalities resulting from potential accidents at a PHI plotted against N on a log-log scale. Three areas of risk are shown:
 - Acceptable where risks are so low that no action is necessary;
 - Unacceptable where risks are so high that they should usually be reduced regardless of the cost or the hazardous activity should not proceed; and
 - ALARP (As Low As Reasonably Practical) where the risks associated with the PHI should be reduced to a level "as low as reasonably practical", under this principle the priority of measures is established on the basis of practicality and cost to implement versus risk reduction achieved.

9.3.5.5 Risk mitigation measures may take the form of:

- Radical measures (e.g. alternative materials and process at the PHI);
- Engineered or procedural measures at the PHI; and
- Development (i.e. population) controls in the vicinity of the PHI.

Interpretation of the HKRGS

9.3.5.6 Risk reduction is effected within the concept of the ALARP principle, which, in respect of the MTK Gas Works is interpreted as follows:

- MTK Gas Works is an existing PHI. Risks for existing PHI sites should lie below the upper "Unacceptable" limit of the RG, i.e. should be "ALARP". This applies to the level of risk in the current situation and for the future situation (i.e. population levels and intensity of operation of MTK Gas Works); and

- For developments within the CZ which do not yet have planning permission from government, the proponent of such development is usually required to conduct a Hazard Assessment and only if EMSD / CCPHI consider the risk acceptable are such developments allowed to proceed.

9.3.6 Risk Assessment Results

Base Case

(i) Individual Risk

- 9.3.6.1 The individual risk contours for the current case at the MTK Gas Works are shown in **Drawing No. 22936/EN/357**. Contours are plotted for the following levels of individual risk: 10^{-5} , 10^{-6} , 10^{-7} and 10^{-8} per year.
- 9.3.6.2 The 10^{-5} per year contour covers the bund and process areas at the MTK Gas Works where leaks from the storage and process equipment occur at higher frequencies. Part of the contour, a relatively minor segment, breaches the boundary to the cattle holding area. The assessment of the individual risk can essentially be considered negligible for off-site risk and it is below the HK PHI RG for individual risk, which states that off-site risk should not exceed 10^{-5} per year. Therefore, the level of individual risk for the base case is considered to be acceptable.
- 9.3.6.3 The areas where the higher frequency contours extend off-site are essentially the areas where persons are more likely to be killed. These areas are primarily pigging station, the naphtha tanks and the export pipework from the gas holder. There is an approximation in the modelling from the previous studies which has been followed in this Risk Assessment, where the pipework leaks have all been modelled at the gas holder. If anything this is considered to be slightly pessimistic, particularly with respect to the proposed development.
- 9.3.6.4 With reference to the area identification shown in **Drawing No. 22936/EN/356** and the contours shown in **Drawing No. 22936/EN/357**, the 10^{-7} and 10^{-8} contours around the works extend to cover areas including 3V and 5 (both residential). 10^{-8} contour around the pigging station extends to cover areas including park (21) and the community facilities (3N-C). Area 20 (school) is on the fringe of the contour and is barely affected. The park acts as a buffer zone around the pigging facilities to minimise the risk.
- 9.3.6.5 Based on the Outline Master Development Plan of SEKD, the new naphtha jetty is located at the end of extended embankment (into the sea) so virtually no population is at risk from the jetty activities.

(ii) Societal Risk

- 9.3.6.6 The FN curve for the current background population is shown in **Drawing No. 22936/EN/358** and is found to lie in the ALARP region of the HK RGs.
- 9.3.6.7 The PLL from the MTK Gas Works including the new jetty and pigging operation for the base case is 1.55×10^{-3} per year. The main risk contributors to affect the existing population surrounding the site and the South East Kowloon Development are naphtha spills in the bund and in the process area, rupture of gas outlets at the Ma Tau Kok North Works and rupture of gas pipes at the off-take/pigging station.

Mitigated Case

- 9.3.6.8 A risk mitigation measure to bury the gas export pipework could be implemented at the works. It is currently being considered by HKCG and is modelled as a mitigated case.
- 9.3.6.9 The town gas export pipelines associated with the MTK Gas Works are connected into the gas supply mains distributing to various locations in Kowloon. The main gas outlets are located

next to To Kwa Wan Road and San Shan Road and some pipe sections are at about 6m aboveground. The failure of these pipelines could result in jet fire engulfing the nearby residential developments facing opposite to the MTK north work. The burial of gas outlets would significantly reduce the failure frequencies and hence the risk due to failure of the associated pipework.

9.3.6.10 The buried gas export pipelines are assumed to be:

- Inspected free from defects and cathodically protected;
- Covered by a reinforced concrete slab with reasonable thickness;
- Not subject to digging and ploughing impacts; and
- Not placed in a common trench with other pipelines operated by other companies.

(i) Individual Risk

9.3.6.11 The individual risk contours for the mitigated base case are shown in **Drawing No. 22936/EN/359**. The level of individual risk does not exceed the “Acceptable” limit of Hong Kong Risk Guidelines and therefore is considered to be acceptable.

9.3.6.12 The mitigation measure results in a smaller area covered by the contours and consequently a smaller area covering the new development. The influence of the gas export pipework near to the gas holder has reduced considerably and persons in the development are now barely affected by the risk from the works site. The contours around the pigging station remain unchanged. Since the areas around the pigging station are relatively low population, this layout is considered favourable from a risk point of view.

(ii) Societal Risk

9.3.6.13 The FN curves for the base case and the mitigated base case are shown in **Drawing No. 22936/EN/360**. The FN curve for the mitigated base case lies in the mid ALARP region of the HK RGs.

9.3.6.14 The PLLs calculated for the base and mitigated cases are summarised in **Table 9.4**. A risk reduction of approximately 17% is achieved by the proposed mitigation measure.

Table 9.4 PLLs for the Mitigated Base Case (buried gas outlets)

	Base Case (Current Operation of MTK Gas Works with SEKD)	Mitigated Base Case (Current Operation of MTK Gas Works with SEKD)	Risk Reduction (Percentage)
PLL	1.55×10^{-3} per year	1.28×10^{-3} per year	2.66×10^{-4} per year (17%)

9.3.7 Conclusions

9.3.7.1 In order to establish the acceptability of the proposed South East Kowloon Development, a quantified risk assessment of the risk from the Ma Tau Kok Gas Works to the surrounding population has been carried out.

9.3.7.2 This Risk Assessment has considered two cases, as follows:

- Base Case - current operation of MTK Gas Works with South East Kowloon Development population.
- Mitigated Case - current operation of MTK Gas Works (buried gas outlets) with South East Kowloon Development population.

- 9.3.7.3 The levels of individual risk for the current and mitigated current cases do not exceed the “Acceptable” limit (10^{-5} per year) of the Hong Kong Risk Guidelines and therefore no parts of the development lie within any unacceptable areas of individual risk.
- 9.3.7.4 The 10^{-7} and 10^{-8} individual risk contours around the works extend to cover areas including Site 3V and Wyler Garden (both residential). 10^{-8} contour around the pigging station extends to cover areas including the district open space in Site 3Y2 and the community facilities in Site 3N5. Site 3Y3 (school) is on the fringe of the contour and is barely affected. The district open space acts as a buffer zone around the pigging facilities to minimise the risk.
- 9.3.7.5 The mitigation measure results in a smaller area covered by the individual risk contours and consequently a smaller area covering the new development. The influence of the gas export pipework near to the gas holder is reduced considerably and persons in the development are now barely affected by the risk from the works site. The contours around the pigging station remain unchanged. Since the areas around the pigging station are relatively low population, this layout is considered favourable from a risk point of view.
- 9.3.7.6 With the risk mitigation measure at the gas works, there is virtually no risk to the SEKD. However, it is unusual for a planning study to result in mitigation at a hazardous site, rather the development should accommodate the areas of risk in its layout. Hence the Project must liaise with HKCG to ensure that the mitigation measure is implemented particularly before occupation of the residential blocks adjacent to the gas works.
- 9.3.7.7 There is uncertainty regarding the timing of relocation of the MTK Gas Works. If before the South East Kowloon Development is complete when the works is closed or relocated no mitigation measures will be necessary.

9.3.8 Recommendations

- 9.3.8.1 The proposed South East Kowloon Development for the mitigated case should be permitted to proceed, subject to the recommendations below:
- The Project must liaise with HKCG to ensure that the mitigation measure is implemented particularly before occupation of the residential blocks adjacent to the gas works. However, there is uncertainty regarding the timing of relocation of the MTK Gas Works. If before the South East Kowloon Development is complete when the works is closed or relocated no mitigation measures will be necessary.
 - Since the proposed naphtha jetty would be located very close to the marina (offshore population), a minimum safety distance of 100 m between the naphtha jetty and the marina population is recommended.
 - No further development resulting in population increases nearby the site should be permitted unless supported by a hazard assessment, to be submitted to relevant government departments for consultation.

9.3.9 References

- DNV, 1991. Hazard Assessment of the Management Tau Kok Gas Works for the HKCG.
- DNV, 1996. Risk Assessment Study: Re-development of the Ma Tau Kok South Works.
- DNV Technica (1997), ARF Technical Library, T14, Rev.1.