Appendix 19.1: Selected Details from the Quantitative Risk Assessment - Onshore Sections. Intecsea Report 10-00050-10-SR-REP-0040-0010

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As detailed in the Qualitative Risk Assessment (Ref. 19.1), there are different types of risk including risk to life and health, risk to the environment and economic risks, which may impair the survival of a company or impact a local or regional economy. The risk (R) is commonly described by its two dimensions, i.e. the probable consequence of an accidental event (C) and the probable frequency of these events (F).

This is expressed by the equation: R = C x F.

The frequency of an event usually is a composite magnitude e.g. for an ignited gas leak the primary leak frequency will be multiplied by the conditional probability of igniting the gas cloud resulting from the leak. Under certain conditions even more conditional probabilities may factor into this product to yield the total frequency of a certain event e.g. the probability of in-time detection of a flammable cloud or the conditional probability, that certain isolation measures (e.g. ESD system) work, when required.

It has become common practice to discriminate between individual risk (i.e. the risk, to which a single person is exposed), and societal or group risk (i.e. the risk to which a certain group of people are exposed). The level of exposure to risk which is generally found to be acceptable by individuals or society can be defined by criteria known as risk acceptance criteria.

The risk acceptance criteria adopted for the Project are based on the risk acceptance criteria used in the United Kingdom (UK). The risk acceptance criteria given in the UK regulations are selected because these risk acceptance criteria are internationally well known and applied and are compatible with the UK databases of leak frequencies used in the QRA calculations. Also the regulations in the UK regarding risk based land planning and land use practices are considered as one of the best developed, together with regulations in The Netherlands. The main reason to define project specific risk acceptance criteria is because the local Russian legislation, regulations or guidelines are either not transparent for use in the Project or not clearly defined.

Acceptance Criteria: Individual Risk

Risk to offsite population is expressed as the fatality risk per year. Generally, individual risk is calculated under the assumption that the exposed person is present and unprotected at the same location for 24 hours per day over 365 days per year. For pipelines there is no distinction between onsite and offsite and the group risk is valid for all people potentially exposed to the effect of pipeline accidents.

The acceptance criterion for individual risk (IR) is given as the annual frequency for loss of life of the most exposed individuals (excluding personnel working on the assessed development):

- IR = 1×10^{-5} per year (one fatality every 100,000 years), level of risk at which risk has to be reduced to the level As Low As Reasonably Practicable (ALARP); and
- IR = 1×10^{-6} per year (one fatality every million years), broadly acceptable level of risk, applicable for significant developments involving more than 75 people or involving vulnerable objects with more than 300 people such as schools, recreation areas, sport fields, etc.

These acceptance criteria are based on the UK regulations and are considered best practice for assessing individual risk of industrial installations toward the public. When translated for the purpose of land planning i.e. for creating zones near installations limiting certain activities (referred to as safety exclusion zones for this Project and consisting of a buffer zone that establishes a minimum distance between a pipeline and third party objects and persons or between the pipelines themselves), the following zones are defined in the UK regulations:

- Zone < 1 x 10^{-5} per year: within this zone isolated developments involving less than 25 people (housing) or less than 100 people (retail, community, etc.) are allowed, subject to a specific assessment;
- Zone 1 x 10^{-5} to 1 x 10^{-6} per year: significant developments involving more than 75 people or involving vulnerable objects with more than 300 people such as schools, recreation areas, sport fields are allowed, subject to a specific assessment. Highly vulnerable objects with less than 25 people are also allowed; and
- Zone 1 x 10^{-6} to 3 x 10^{-7} per year: no restrictions. Highly vulnerable objects with no limitations on the number of people are allowed subject to a specific assessment.

Normally the IR for an installation or pipeline is presented as a risk contour or a risk transect. The calculated risk should not exceed the above criteria in case the contour or transect covers areas in which people are expected to be present. These contours and transects are often used to define the applicable exclusion zone outside which to allow the construction of buildings or other projects in which people are expected to be present.

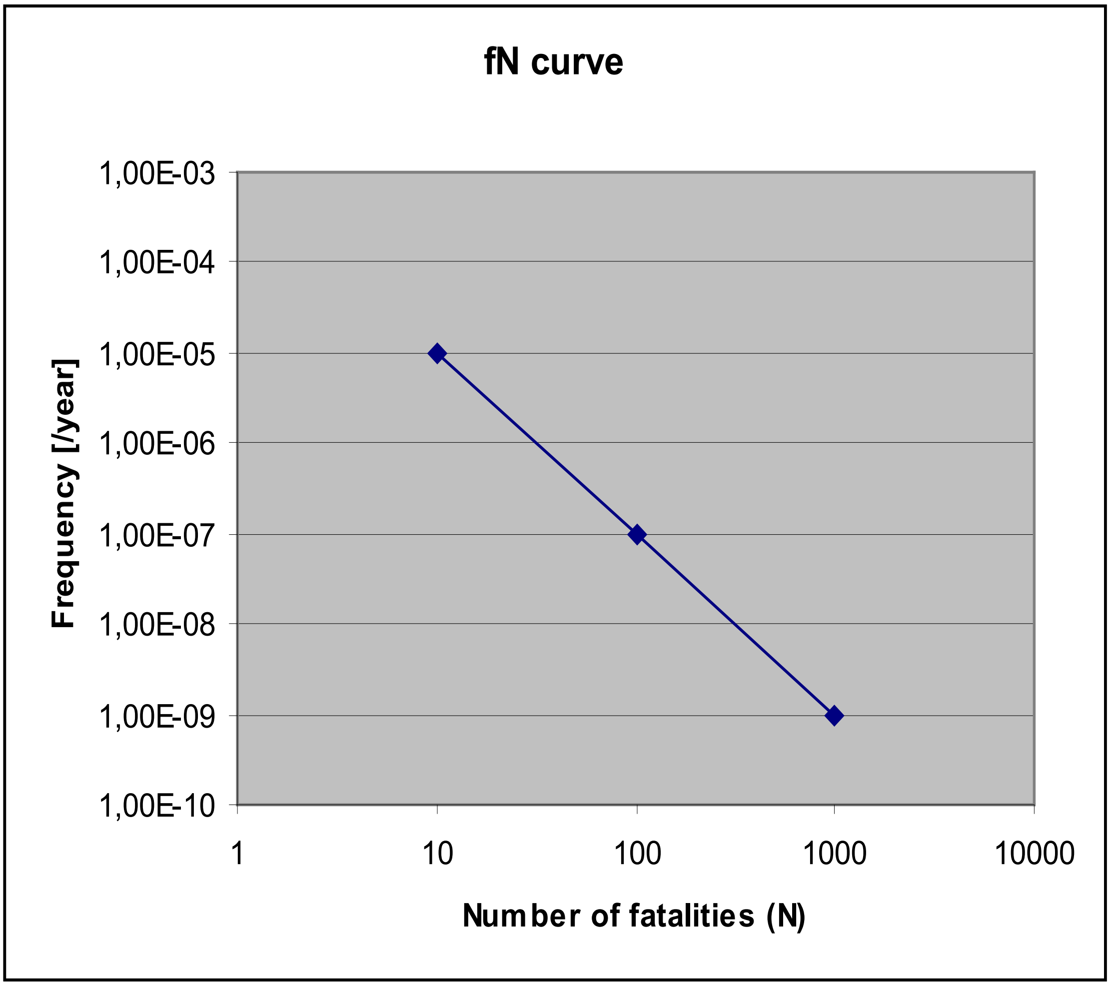
The risk to workers (e.g. during maintenance or inspection of the Pipeline) follows the same acceptance criteria.

Acceptance Criteria: Societal Risk

Societal risk (or group risk) represents the risk to a group of people outside the plant. For pipelines there is no distinction between onsite and offsite and the group risk is valid for all people potentially exposed to the effect of pipeline accidents.

Societal risk is usually quantified with the so-called fN-curve (see Figure A19.1.1), specifying the frequency (f) at which a number of people (N) are affected by fatal consequences. The fN-curve represents the upper limit for acceptable risk. The criterion applies to groups of people for a representative 12-month period. Unlike the calculations for individual risk, the group risk takes into account the actual exposure of the persons, i.e. consideration is given to the proportion of time spent by a person that is not involved with the particular installation (indoors and outdoors).

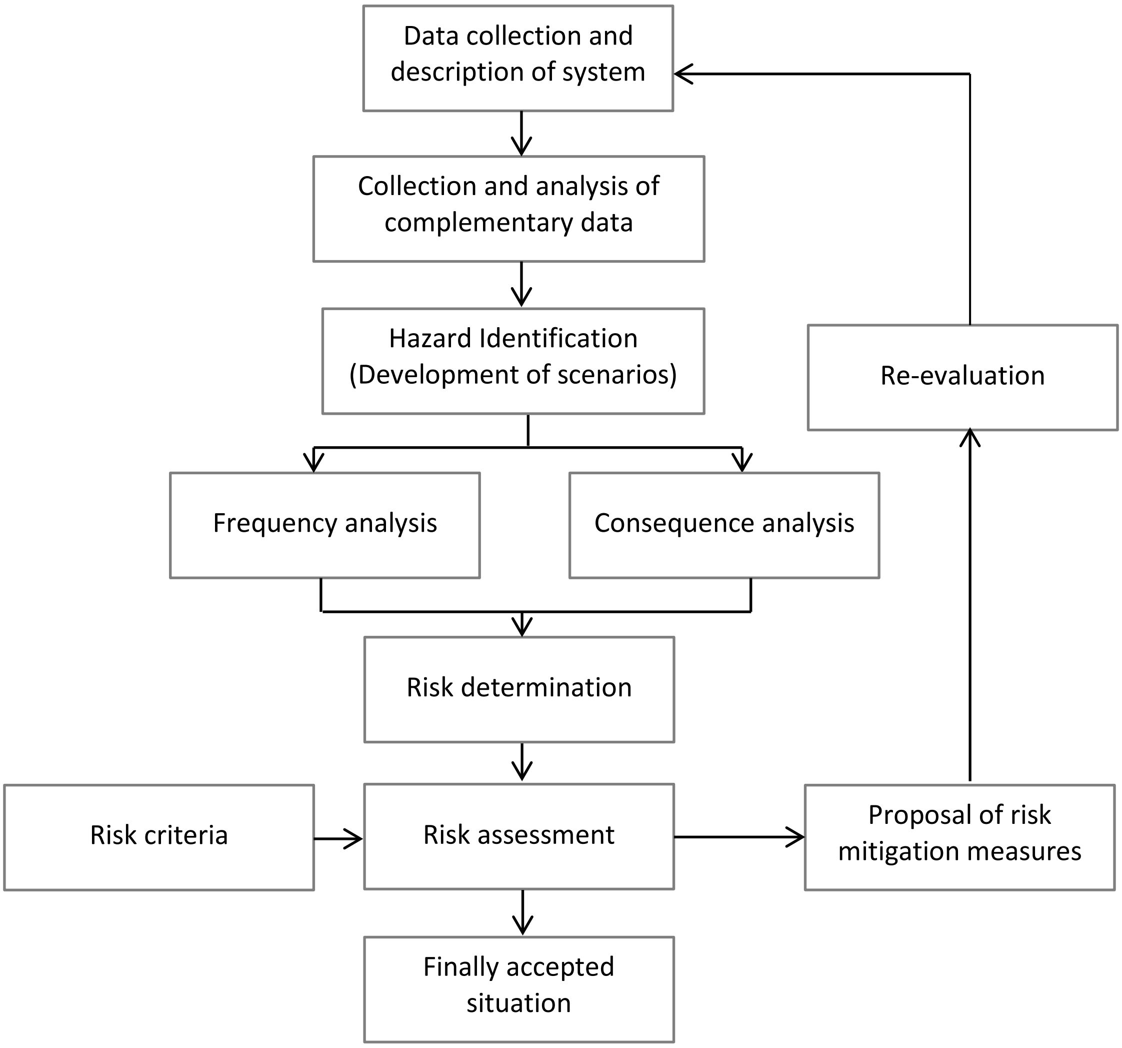
FigureA19.1.2 fN Curve - Acceptance Criteria for Societal Risk



Quantifies Risk Analysis Method

The risk analysis methodology adopted in the QRA is presented in Figure A19.1.2.

Figure A19.1.2 QRA Methodology



The IR is calculated by summing the frequencies of all different scenarios and the effect of those scenarios, all of which have different distances for a hazardous effect. This generates data for the so-called IR risk transect. The IR risk transect for a pipeline is derived by calculating the individual risk as a function of distance from the pipeline centreline. The IR is a maximum directly above the pipeline, and decreases to zero as the distance from the pipeline increases. The risk at any given location is a function of:

- The distance from the pipeline (measured at a right angle);
- The risk of a release from the pipeline (usually measured as the frequency of a release per year per kilometre of pipeline); and
- The distance from the release at which an observer at a given location would be affected by the release (sometimes called the "range of hazardous effect").

In the simplest case (where the effect of a pipeline release is experienced equally at all points around the release, e.g. ignoring directionality and predominant wind effects) an observer standing on the pipeline can be affected by a release from the pipeline if it occurs anywhere within the "range of hazardous effect" distance in either direction along the pipeline. Thus, the length of the pipeline that could affect the observer if a release occurs is twice the "range of hazardous effect" distance. This is called the "effective length", and will decrease as the observer moves away from the pipeline.

"Effective length" is used in the risk calculation to estimate the frequency of releases that could affect a given point, since pipeline release frequency is expressed as "releases per km per year" and so must be multiplied by the "effective length" to obtain a frequency as "releases per year".

The data required for the calculation of the Risk Transects are based on:

- A specific failure frequency analysis using pipeline specific databases and guidelines;
- A specific consequence analysis using the effect modelling tool PHAST for determination of the effects of dispersion and fire of the different release scenarios; and
- A specific event tree analysis.

For the landfall facilities and the above ground equipment of the pig launchers and receivers a similar approach is followed with different failure scenarios and different failure frequencies and effects resulting from the consequence analysis. Also for the landfall facilities a Risk Transect is determined.

Identified Scenarios

For transmission pipelines of natural gas, the main major hazard scenario is the loss of containment as a result of a leak or rupture.

Loss of containment of the high pressure gas containing pipeline has the potential to expose people to harmful effects of the released and dispersed natural gas. Specifically for the large diameter, high pressure pipelines and loss of containment scenario can extend over a considerable distance and thus affect third party objects near the pipeline. Also, the large inventory of the pipeline can cause significant damage to the environment and assets when exposed to the prolonged effects of a gas leak.

For the pipelines, two scenarios are distinguished:

- Leaks in the pipeline resulting in either vertical (unobstructed) releases or horizontal (obstructed) releases; these releases will result in jet fires after immediate ignition or in flash fires after delayed ignition; and
- Ruptures of the pipeline resulting in releases from both open ends of the ruptured pipeline. The release from a rupture will result in a jet fire obstructed within the crater after immediate ignition or in a flash fire after delayed ignition.

For the landfall facilities two types of leak scenario are distinguished:

- Leaks in the above ground pig receiver and launcher equipment. These leaks are subdivided in medium, large and very large size resulting in horizontal and vertical (unobstructed) jet fires of different size after immediate ignition or in flash fires after delayed ignition; and
- Leaks in the underground equipment located in various pits, i.e. Emergency Shutdown Valves (ESV) and bypass arrangements. These leaks are subdivided in medium, large and very large size resulting in horizontal and vertical (unobstructed) jet fires of different size after immediate ignition or in flash fires after delayed ignition.