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FEASIBILITY ASSESSMENT OF A NUCLEAR INSTALLATION SITE IN PATAGONIA - ARGENTINA

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ABSTRACT

Argentinian authorities requested James J. Johnson and Associates (JJJA), a USA firm, to perform an assessment (called "Study" in this paper) of a well-defined area of the Patagonia region, in Argentina, to identify any safety, non-safety, and security issues that could preclude this area from further consideration for housing a nuclear installation for a total electric power capacity of 10,000 MWe including other supporting facilities.

This Study corresponds with the site survey stage of the site selection and evaluation processes for a nuclear installation. It is aimed to identify potential areas for locating the site which should comply with a well-defined set of established acceptability criteria and safety standards requirements. This paper describes the methodology applied and the conclusions of the feasibility assessment regarding the finding of four candidate zones which were identified as "suitable" for a nuclear installation of the required size.

INTRODUCTION

The investigated area of the Patagonia region was defined by the Argentinian authorities to be on the northern coast of the San Matias Gulf (on the Atlantic Ocean Coast), in the Adolfo Alsina County of the Province of Rio Negro, in Argentina.

The coastal length of this area is about 180 km from the mouth of the Rio Negro River, in its eastern extreme, to the Punta Villarino of the San Antonio Este Port, in its western extreme, and it extends a few kilometres inland. Figure 1 shows the location of the indicated area, while the photo of Figure 2 provides a view of the shoreline with the high cliff.

The specific objectives of the feasibility assessment were as follows:

- Assess the suitability of the investigated area for selecting the candidate site(s) for a nuclear installation, including identification of suitable sub-areas.
- Identify sub-areas within the investigated area that are evaluated as unsuitable for selecting the candidate site(s).
- Develop a plan of future actions to complete the site selection and detailed evaluation and characterization stages.

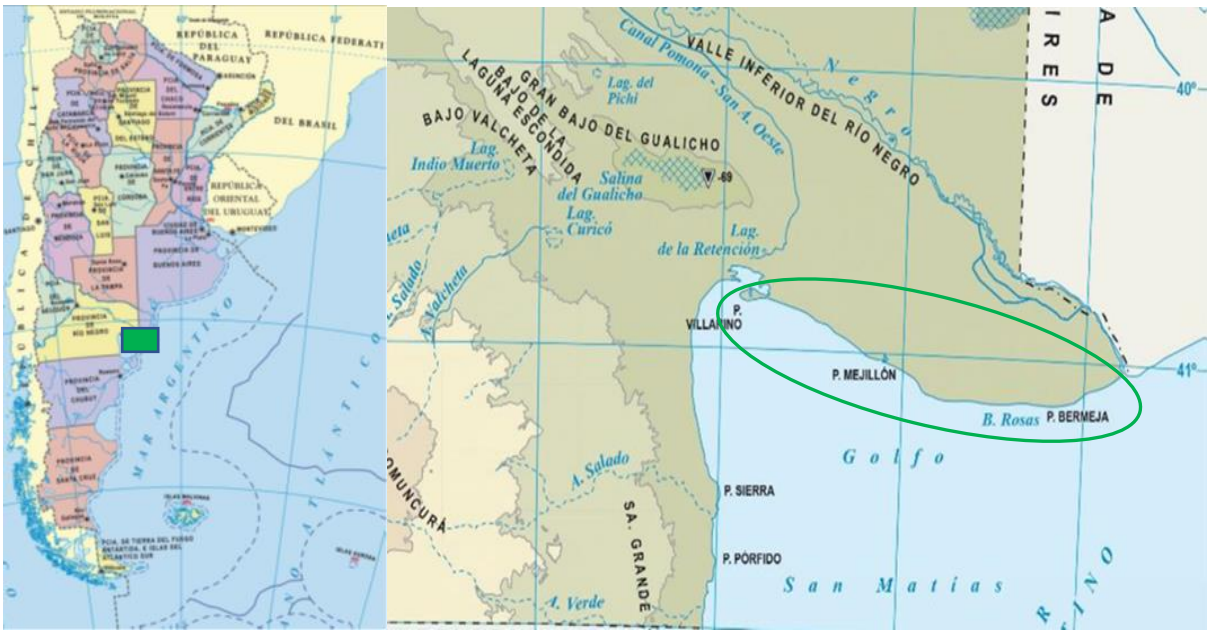

Figure 1: Location of the investigated region in the northern coast of San Matias Gulf, Atlantic Ocean, Patagonia Region, Argentina.

Figure 2: (Left) Shoreline of San Matias Gulf, with a (35-50 m) high cliff. (Right) Morphology and vegetation with the sand coastal dunes at the top of the cliff, extending several kms inland

An important consideration was the request from Argentinian authorities that the feasibility assessment should be conducted in the short period of three months. The schedule was driven by the intention of using the finally selected and procured site for a planned nuclear power plant unit of Chinese origin. The methodological approach and the collection of data was defined based on such requirement.

In addition, it was proposed and discussed with the Argentinian authorities that the selected site should have a size and capacity for locating nuclear power reactor units with a total capacity of 10,000 MWe including all supporting, auxiliaries and other nuclear facilities.

METHODOLOGY

Process and stages for selecting a nuclear installation site

The overall process for site selection and evaluation of a nuclear installation is conducted through a number of sequential stages during its life cycle as recommended by the International Atomic Energy Agency (IAEA) in numerous related safety standards and shown in Figure 1:

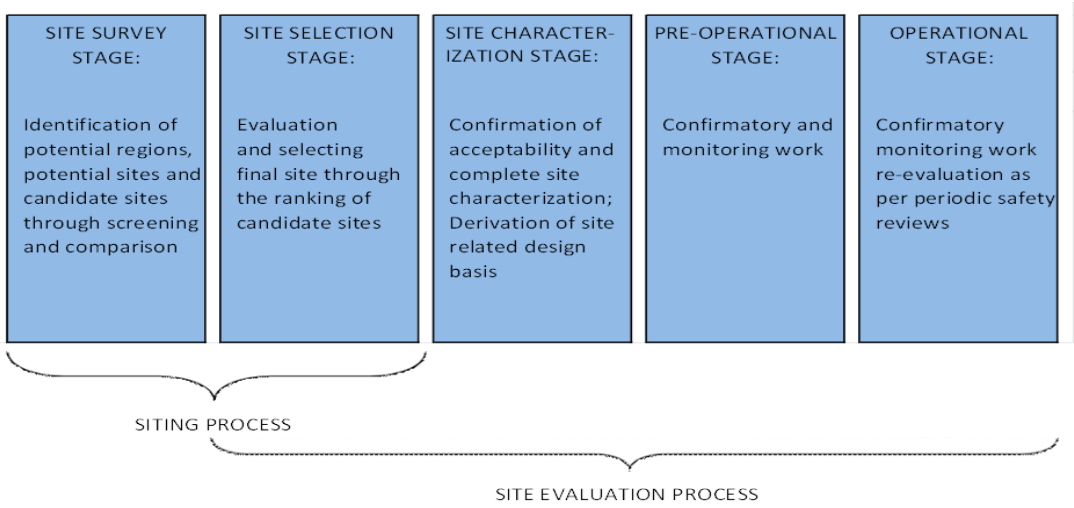

Figure 3: Stages in the site selection and site evaluation processes in the operating lifetime of a nuclear installation [IAEA SSG-35].

The selection for a suitable site for a nuclear installation, also noted as “siting process”, is a systematic and multi-faceted process, which is comprised of a step-by-step evaluation of safety, non-safety, and security considerations using mainly available public data and information. It is usually constituted by two stages, the site survey stage and the site selection stage, as indicated in Figure 3. This Study was focussed on the site survey stage aimed to identify potential candidate areas for locating the site within the investigated area.

Screening criteria

Having identified the region under investigation and the objectives of the Study, the next step was to define the acceptability criteria. In that regard, two types of screening were applied: (i) exclusionary and (ii) discretionary screening.

Exclusion criteria are used to eliminate sites that are unacceptable (or unsuitable) based on the existence of issues, events, phenomena, or hazards for which design features, site protection measures, or administrative procedures cannot compensate.

Discretionary criteria are used to eliminate a site judged to be less favourable than other sites even though issues, events, phenomena, or hazards can be compensated by design features, site protection measures, or administrative procedures. Discretionary criteria, when implemented, are a valuable tool in narrowing the selection to a smaller number of possible sites.

The tools for screening may be based on distance (Screening Distance Value – SDV) and on an annual probability of occurrence (Screening Probability Level - SPL). The SDVs are utilized to screen out hazards (or groups of hazards) based on the calculated impact of the hazard on the nuclear installation given its size and proximity to the site. The SPLs should be specified as being non-consequential to the nuclear installation based on its likelihood of occurrence. Usually, the SPL values adopted in current practice are in the range of 10^{-7} per annum.

The JJJA Team presented to the Argentinian authorities a specific proposal of non-acceptable exclusionary eight factors (see Table 1), which could preclude the investigated region from further consideration for a nuclear installation site based on the IAEA safety and other non-safety requirements.

Table 1: Exclusionary criteria for events, phenomena, and hazards

No.	Event, phenomenon or hazard for which engineering, site protection or administrative measures are not considered feasible	Screening values or parameters
1	Surface fault displacement phenomena, distance from capable faults[1]	Site vicinity area[2]
2	Volcanic phenomenon considered as exclusion conditions (SSG-18, IAEA)	Site vicinity area
3	Geotechnical Hazards at the site area: - Massive Slope Instability - Collapse or existence of open cavities - Massive Liquefaction	Site area[3]
4	Distance from airports with attributes of Type 2 events[4]:	> 7.5 km
5	Distance from military installations in which military activities are conducted and are potential hazards to the nuclear installation, e.g., any live ammunition or explosives activity, storage of explosives, etc. Distance from military air space activities, such as take-off, landing, and training activities that are potential hazards to the nuclear installation.	>30.0 km
6	Distance from industrial facilities that store, use, or handle flammable, toxic, corrosive or explosive material in quantities large enough to pose a potential hazard to the nuclear installation; this includes transportation routes	Site vicinity area
7	Population centres containing more than 25 000 residents.	Located within a radius of 10 km from the site boundary
8	Reserves (nature and other), bio-sensitive regions, endangered species, recreational areas	Site vicinity area

Aspects that were assessed

The next step was to identify the safety, non-safety and security aspects to be considered and evaluated. Thus, a comprehensive list of twenty-four (24) safety, non-safety and security aspects was presented by JJJA and approved by the Argentinian authorities which were evaluated in this Study:

Safety Related Aspects:

1. Geological and Seismological Data-Seismic Hazards.
2. Volcanological Data-Volcanic Hazards.
3. Hydrogeological and Geotechnical Data.
4. Oceanography and Coastal Data – Flooding Hazards.

[1] Capable fault is a tectonic fault that may cause surface displacement in the site vicinity
[2] Site vicinity area typically defined by 5 km radial distance from the fence or the centre of the site
[3] Site area is defined by the site boundary enclosing the nuclear installation
[4] Type 2 events: Accidental aircraft crash at the site as a result of take-off or landing operation at a nearby airport.

5. Surface Water - River Data.
6. Meteorological Data and Hazards.
7. Human Induced Hazards – Data and Preliminary Assessment.
8. Demography and Population Data.
9. Land and Water Use Data.
10. Atmosphere and Hydrosphere Dispersion of Effluents.
11. Feasibility for Implementation of Emergency Planning and Measures.

Non-safety Related Aspects:

12. Applicable Laws and Regulations.
13. Argentina Nuclear Regulatory Authority Regulations.
14. Geography and Topography.
15. Maximum Electric Power Capacity-Site Size-Other Facilities.
16. Availability of Water.
17. Accessibility and Transport Infrastructure.
18. Access to Major Load Centers-National or Regional Electricity Grid.
19. Non-radiological Environmental Impacts.
20. Socio-economic Impacts.
21. Site Development Aspects.

Security Related Aspects:

22. General Considerations
23. Design Basis Threat
24. Beyond Design Basis Threat

Data collection and site reconnaissance visits

After defining the methodology, acceptability criteria and the 24 aspects to be assessed as indicated above, the most critical task was the collection of available public data and information in the very short period. Meetings with authorities of governmental agencies and institutions were conducted speeding up the process of collecting maps and updated data. In this regard, examples of valuable contributions are the information obtained from the National Meteorological Service (SMN), the Navy Hydrography Service, the Geology and Mines Service (SEGEMAR), the Census and Statistics Institute, and the Government of Rio Negro Province.

Another important source of information was the field reconnaissance visits and the meetings with officers and scientists of the government of Rio Negro Province, including the visit to the Port of San Antonio Oeste which was confirmed as adequate for sea transportation of heavy and large plant components. The complete list of collected information is made available in the References to this paper.

FINDINGS

The detailed findings of the assessments are contained in a 213 pages full report covering the 24 analysed aspects. As a brief description of the safety related findings on natural external hazards, the following is presented in this paper.

Geological and seismological data-Seismic hazards

Table 2 summarizes the results of the evaluation of geological and seismic hazard phenomena and their impact on the investigated area. In conclusion, there are no feasibility issues due to geological and seismic hazards (as discussed below) that would constrain the selection of a site in the investigated area.

Six phenomena related to the seismic and associated geological hazards have been analysed in relation to their potential of occurrence that may affect the feasibility for a nuclear installation. The analysis was conducted on basis of the currently available public geological, geotechnical, seismological

information and data, as well as the data collected and observations during the field reconnaissance. No geophysical data was made available.

Based on the data and observations mentioned above, the result of the analysis is that none of the potential hazards related to the occurrence of permanent ground deformation which may affect the feasibility of the installation was detected or identified. Consequently, it may be concluded that there are no seismic and associated geological hazards which can exclude a site from further consideration within, in principle, the full extent of the investigated area. Particularly, regarding permanent ground deformation due to earthquakes, no potential hazards were identified or encountered during this Study.

Table 2: Summary of feasibility analysis of geological and seismic hazards at the investigated area

N.	Seismic and associated geological hazards	First estimate of hazard likelihood and severity
1	**Faulting**	Fractures and faults of potential syn-sedimentary origin are seldom visible in the sea cliff. However, the faulting is affecting only the Rio Negro Formation with no marks in the Pleistocene surficial layer. Thus, the gathered data indicate that surface fault rupture would not be a safety issue for the feasibility of the installation.
2	**Ground motion**	The investigated area is in a very reduced seismic hazard zone as indicated by Argentina national regulations. It is expected that PGA values will range from 0.10 to 0.30g for design and evaluation levels as result of the detailed seismic hazard assessment to be performed during the site characterization stage and the extreme annual frequencies of occurrence for such purposes (~ 10^{-4} annual frequency).
3	**Natural and or man-made origin regional subsidence**	No possibility, based on the stratigraphy and position of the groundwater table.
4	**Seacliff retreat**[5]	The available data shows an average retreat speed of 0.81 m/year, approximately, with extreme values that vary from 1.44 m/year to 0.2 m/year at Creek Bay. This phenomenon should be duly considered during the NPP design, but it will not represent a feasibility problem.
5	**Beach destruction and migration of sand dunes**	No problems related to these hazards because of the geomorphology of the investigated area. Adequate protective measures will be taken during design installation stage. Sand dunes migrate but it will not represent a feasibility problem.
6	**Cavities of natural and man-made origin**	Non presence of cavities in the investigated. Thus, this phenomenon will not represent a feasibility problem.

It should be indicated that all sub-areas within the investigated area (including the inland part) with active sand dunes and low level of the sea cliff are less suitable in comparison with the rest of the investigated area. In this regard, the sub-area extending from El Condor Beach, in the East, to Creek Bay, in the West, is the most suitable portion of the investigated area, with some exceptions, such as Rosas Bay sector.

[5] Sea cliff retreat and beach destruction and migration of sand dunes are not strictly geological phenomena associated to earthquake occurrence. They are related to tidal and sea waves and wind actions, respectively

In relation to earthquake vibratory ground motion as one of the elements of the seismic hazards, the conclusion is that the investigated area is in a very reduced zone of seismicity. Therefore, the earthquake design basis - to be determined in the next detailed characterization stage for the finally selected site, including the extended design condition as required by current international standards and regulations - will be within the range of values of current standard designs for this type of nuclear installations.

Volcanological data-Volcanic hazards

Thirteen volcanic hazards were assessed. Nine of the thirteen hazards are considered as exclusionary hazards and the result of the evaluation performed allows to conclude that none of these hazards affect the investigated area. Of the remaining four items, two (tephra fallout and gases and aerosols) will require consideration in the site characterization stage; and, if deemed necessary, appropriate design bases will be developed for the installation. In conclusion, there are no feasibility issues related to volcanic hazards that would constrain the selection of a site in the investigated area.

Hydrogeological and geotechnical data

The results of the evaluation of the geotechnical and hydrogeological hazards phenomena and their impact on a nuclear installation show that there are no feasibility issues that would constrain the selection of a site in the investigated area.

Flooding hazards

There are no flooding hazards from the Rio Negro River or from the Atlantic Ocean that would adversely affect the feasibility of the selection of a site in the investigated area. Three potential sources of external flooding were evaluated and assessed in this Study, as follows:

Coastal flooding:	storm surges and wind generated waves, from the sea (Atlantic Ocean)
Coastal flooding:	earthquake and volcano generated tsunamis, from the local near and distant regions (Scotia Arc tectonic plate and Mid-Atlantic Range);
Surface flooding:	from temporary rivers created by flash floods.

No historical records or evidence were available regarding the occurrence of such flooding phenomena. However, detailed collection of data and assessment of hazards in accordance with the IAEA international standards and worldwide practice shall be conducted in the next site characterization stage, including proper derivation of related design bases and considerations of protective measures for coastal erosion and water intake structures of the nuclear installation.

Meteorological data and hazards

Regarding the meteorological aspects, two important objectives need to be considered: (i) design of the nuclear installation for the loading conditions imposed by the potential occurrence of meteorological extreme hazards; and (ii) evaluation of the meteorological conditions for the dispersion of releases of radioactive materials from the nuclear installation into the atmosphere in normal operation and accident conditions. Extreme and rare meteorological events are to be addressed as meteorological hazards.

Meteorological data from the National Meteorological Service (SMN) showed that the SMN has six meteorological stations in a radius of about 300 km around the investigated area. Through a combination of: (i) non-applicability of specific events to the investigated area or to Argentina in general, and (ii) assessment of the preliminary data obtained during this Study, it was concluded that no rare meteorological events negatively affect the feasibility of the investigated area for a nuclear installation.

During the site characterization stage, updated data shall be collected, an on-site meteorological station will be installed and put in operation and specific assessments will be made in developing the design bases for the meteorological hazards and for determining the bases for atmospheric dispersion characteristics during normal operation and accident conditions.

Oceanography data

Significant information was provided by the Navy Hydrography Service on available data related to sea bathymetry, sea currents, tidal data, sea water temperature and sediments of the seabed. As a summary, the structure of the circulation induced by the dominant winds (from the West) generates a cyclonic gyre in the East that, in the San Matias Gulf, connects with the continental shelf. That means that in the San Matias Gulf the circulation of currents is produced in cyclonic gyre and in the coast of the eastern portion of the investigated area the sea current direction will be from West to East, towards the Atlantic Ocean offering excellent dispersion conditions.

A recent study performed on the stability of the coast of the San Matias Gulf with consideration of climate change impact was also available. According to that study the eastern portion of the investigated area is the most favourable one regarding this aspect.

Detailed and specific oceanographic data will be collected during the site characterization stage to derive the appropriate design basis for the nuclear installation, including the installation of on-site monitoring stations.

RESULTS AND CONCLUSIONS OF THE ASSESSMENT

Four zones, indicated as Z.1/Z.2/Z.3/Z4 in Figure 4 below were identified as suitable considering that they did not present feasibility issues associated with safety-related, non-safety related, and security aspects in compliance with the established exclusionary criteria (Table 1). The four identified suitable zones are:

Zone 1: between eastern extreme of Creek Bay and the western extreme of Promontorio Belén;
Zone 2: between eastern extreme of Promontorio Belén and Bajada Echandi;
Zone 3: between Bajada Echandi and western extreme of Rosas Bay; and
Zone 4: between eastern extreme of Rosas Bay and western extreme of Punta Bermeja Protected Natural Area.

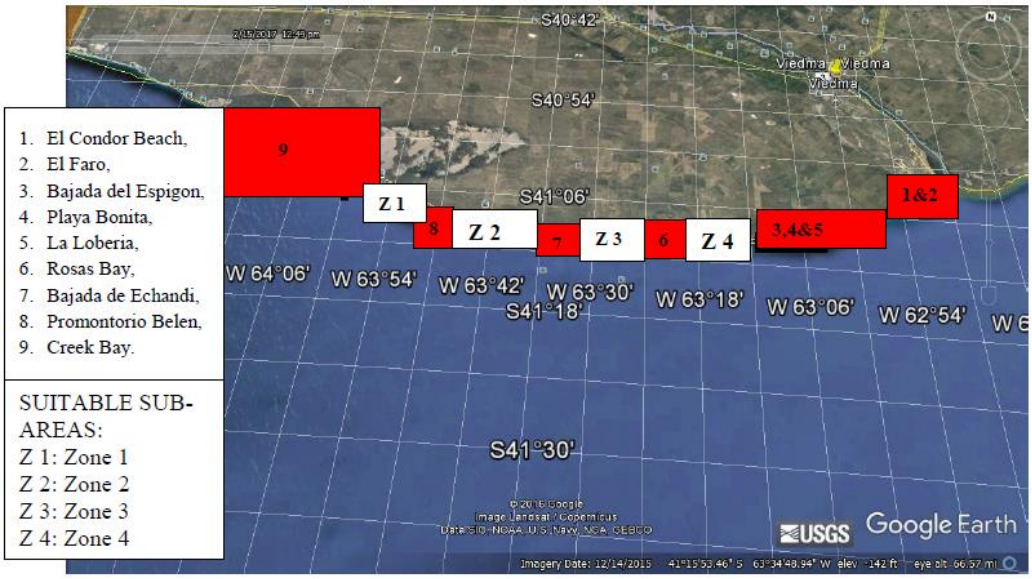

Figure 4: Sea Coast between Rio Negro River Mouth (Condor Beach) and Creek Bay – Recreational and Tourist Spots, Las Aguadas and Punta Bermeja Reserves (red rectangles, not in scale) and Suitable Sub-areas Z.1 to Z.4 (white rectangles).

All touristic and recreational spots and protected natural areas existing in the investigated region were considered as unsuitable for a nuclear installation site and they were excluded from further consideration.

As a conclusion of this feasibility assessment, the Survey Stage was completed in the requested short period of three months with the result being the identification of four candidate zones within the

investigated region at the northern of the San Matias Gulf, on the Atlantic Ocean Coast, in the Patagonia region (Argentina). The four identified zones are considered as "suitable" for construction and operation of a nuclear installation of the required size, and they fully comply with all established exclusionary criteria including nuclear safety, non-safety, security and environmental protection requirements.

The positive aspects were identified as: (i) a very stable geological environment with a low intensity of extreme external (natural and human induced) hazards, (ii) unlimited availability of cooling water to implement the most preferred "once-through" cooling system for a power plant with several power units, (iii) very favourable dispersion characteristics in the atmosphere and hydrosphere, and (iv) low population region with significant implications in relation to the possibility of implementing effective non-onerous emergency measures and evacuation plans, if required.

Negative aspects were also identified which were considered as non-exclusionary issues but to be more deeply evaluated in the next phase of the site evaluation process. They were as follows: (i) no existing connection to the national electricity grid; and (ii) the need to plan, schedule and carry out a detailed site development infrastructure programme.

Finally, a complete programme for conducting the site selection and procurement stage was prepared and presented to the Argentinian authorities, including the initial draft of the programme for performing the detailed site evaluation and characterization stage of the finally procured site.

As general conclusion, based on the worldwide extensive experience of the authors, the investigated area and the identified candidate sites present one of the most favourable locations they have ever seen or evaluated from the point of view of nuclear safety requirements. Unfortunately, later, the investigated region was cancelled by the province authorities because of strong public and political opposition. Thus, an opportunity to make available an adequate nuclear installation site in full compliance with all applicable safety, non-safety and security requirements was lost.

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