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Preparation of safety analysis reports (SARs) for near surface radioactive waste disposal facilities

Format and content of SARs

INTERNATIONAL ATOMIC ENERGY AGENCY IAEA

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PREPARATION OF SAFETY ANALYSIS REPORTS (SARs) FOR NEAR SURFACE RADIOACTIVE WASTE DISPOSAL FACILITIES

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FOREWORD

All facilities at which radioactive wastes are processed, stored and disposed of have the potential for causing hazards to humans and to the environment. Precautions must be taken in the siting, design and operation of the facilities to ensure that an adequate level of safety is achieved. The process by which this is evaluated is called safety assessment. An important part of safety assessment is the documentation of the process. A well prepared safety analysis report (SAR) is essential if approval of the facility is to be obtained from the regulatory authorities. One conclusion of missions of the IAEA Waste Management Advisory Programme (WAMAP) to Member States is that adequate safety assessments of waste management facilities have often not been performed and seldom documented. In response to these observations, the present publication has been prepared.

This TECDOC describes the format and content of a safety analysis report for a near surface radioactive waste disposal facility and will serve essentially as a checklist in this respect. To aid the preparation of an SAR, previously published IAEA Safety Series reports on performance assessment of radioactive waste repositories can be referred to. These publications are being updated in a new series, the Radioactive Waste Safety Standards (RADWASS).

The first draft of this TECDOC was prepared by the IAEA Secretariat with the assistance of a group of consultants in 1991. This report is a revised version taking account of IAEA staff comments and the experience of its use in IAEA training courses and a mission of the IAEA Waste Management Assessment and Technical Review Programme (WATRP).

The IAEA wishes to express its thanks to all those who took part in the preparation of this report. The officer responsible at the IAEA for this work was S. Hossain from the Waste Management Section, Division of Nuclear Fuel Cycle and Waste Management.

EDITORIAL NOTE

In preparing this document for press, staff of the IAEA have made up the pages from the original manuscript(s). The views expressed do not necessarily reflect those of the governments of the nominating Member States or of the nominating organizations.

Throughout the text names of Member States are retained as they were when the text was compiled.

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CONTENTS

1. INTRODUCTION

1.1. BACKGROUND

A Member State decision to use or generate radioactive materials for any of several beneficial purposes requires the establishment of a national programme to safely manage the material in use, and to manage and dispose of the material as waste when it is no longer useful. It should be appreciated that before a practice that generates radioactive waste is implemented, a waste management infrastructure including a legal framework, with independent regulatory features should be established and the identification and responsibilities of the parties involved in the different phases of waste management should be addressed. A national radioactive waste management system will involve all of the steps from generation of the waste to disposal, including packaging, collection, treatment, transportation, interim storage, emplacement in a disposal facility, closure of the facility, and post-closure care.

Facilities and procedures used in the national radioactive waste management system will require safety assessments to establish and document safety levels and features. The Waste Management Advisory Programme (WAMAP) of the IAEA tries to impress upon visited Member States that all important components of a waste management system are required to be approved by competent regulatory authorities based on safety analysis reports (SARs). Most of these countries need guidance on how to prepare such safety analysis reports for radioactive waste management facilities, and on their format and content.

This publication describes the format and content of such an SAR to be prepared by an applicant and will serve essentially as a check list in this respect. To aid the preparation of an SAR, previously published IAEA Safety Series reports on performance assessment of radioactive waste repositories can be referred to (see Bibliography). These are being updated in a new series, the Radioactive Waste Safety Standards (RADWASS).

A typical SAR should contain principally narrative information and summary data in the body of the report with contents oriented explicitly for various readers. Supporting detailed mathematical and numerical data should be supplied in appropriate separate appendices or accompanying volumes.

1.2. OBJECTIVE AND SCOPE

The objective of this publication is to describe the format and content of the safety analysis report for disposal facilities. It is envisaged that the SAR will be prepared by, or on behalf of, the party proposing to establish the disposal facility for submission to the licensing authority.

The present TECDOC was prepared with near surface disposal facilities in mind because this is the main type of repositories currently being operated, but the main features of the SAR would remain the same for all types of disposal facility.

A near surface disposal facility may include the following features:

- cavities, trenches, engineered structures, or other spaces for waste emplacement;
- backfill material between and around the packages;
- temporary covers or barriers for shielding or weather protection;

- final permanent barrier to close the facility;
- physical markers or other means to inform future generations; and
- monitoring systems.

These facilities are normally used for low level wastes, mostly from institutional sources (hospitals and research centres), industrial uses, and nuclear power stations.

1.3. REPORT FORMAT

After the introductory material in Section 1, the main content of this document, i.e. the recommended format of the SAR, is contained in Section 2. The topics included in this section are to be considered as examples and need not necessarily be considered in every case. The volume and content of an actual SAR has to be adjusted to the potential risks associated with the facility.

2. FORMAT AND CONTENT OF A SAFETY ANALYSIS REPORT (SAR)

2.1. GENERAL INFORMATION

This section should provide a brief summary of information about the facility, its purpose, principles of operation, and previous licensing activities.

2.1.1. Facility description

The applicant should describe the general location, the purposes and goals of the project, the primary activities to take place at the facility, the capacity of the facility, the envisioned life of the facility, personnel involved, and potential benefits of the project. The land-use survey based on local land-use plans, topographic maps, or other sources may also be provided.

2.1.2. Time schedules

The applicant should provide the proposed schedules for:

- construction,
- start of operation,
- operations,
- closure, and
- regulatory reviews, licensing, and public hearings.

2.1.3. Conformance to regulatory guides

The applicant should refer to relevant regulatory documents and comment on the degree to which this facility is in conformance and/or nonconformance with them. The reasons for nonconformance should be given.

2.1.4. Material incorporated by reference

Duplication of information should be avoided. If similar or identical information is requested in various sections it should be presented only in the principal part of the SAR and appropriately referenced in the other sections. Reports or other documents that are referenced in the text should be listed at the end of relevant section.

2.2. SITE INFORMATION

The applicant should provide information on the natural and demographic characteristics of the site and vicinity and should show the adequacy of the site characteristics with respect to the long-term performance of the disposal system.

2.2.1. Geography and demography

The location of the site should be described sufficiently so that there is no ambiguity about its relation to other features described in this section. The description of the site and its boundaries and areas beyond the boundaries that might be exposed to hazards by the operation should include:

- the region in which the site is located;
- location of the site relative to prominent natural and manmade features, such as rivers and lakes, and nearby population centers;
- map of the site on a scale adequate to clearly define the boundary of the site and the distances of significant facility features from the site boundary;
- traffic and transportation routes and on-site transmission lines; and
- a definition of the meaning of "site boundary" for the operation with respect to exclusion areas, access control areas, property lines, and distance to the boundary from the effluent release points.

Population information based on the most recent census data is to be included in order to show the population distribution as a function of distance and direction from the operation. Additional information may include:

- significant transient or seasonal populations;
- location and population of nearby schools, prisons, hospitals, and other similar institutions;
- description of work force on-site; and
- the projected population by decade, if the population is expected to change significantly.

2.2.2. Meteorology and climatology

The applicant should provide a meteorological description of the site and its surrounding area. Meteorological conditions that influence the design and operation of the facility must be identified. The sources of information and data should be stated. In many cases, the details of the following topics can be found in existing documents that are published and accessible.

(a) Regional climatology

Types of information that may be relevant for discussions of the regional climatology are:

- climate of the region, including characteristics attributable to the terrain;
- seasonal weather conditions, including temperature, precipitation, relative humidity, and prevalent wind direction; and
- data on occurrence (frequency and intensity) of severe weather conditions such as cold spells, thaws, heavy snow or rain, ice storms, thunderstorms and lightning strikes, and strong winds and tornadoes.

(b) Local meteorology

Types of information that may be relevant for discussions of the local meteorology are:

- summary of data for nearby or on-site weather;
- normal and extreme values of meteorological parameters, if appropriate, in the form of monthly summaries, including parameters such as wind speed and direction, temperature, humidity, precipitation, and atmospheric stability; and
- topographic information that affects the meteorological parameters.

(c) Meteorological measurement programme

Types of information that may be relevant for discussions of the meteorological measurement programme are:

- the on-site meteorological measurement programme to develop local data;
- the programme to estimate off-site concentrations of stack effluents; and
- the diffusion equations and appropriate parameters used for diffusion estimate calculations for both routine effluent (long-term) and accidental (short-term) releases.

(d) Contribution to design considerations

The methodology and data used to determine the bases for meteorological phenomena, such as extreme heat, wind, snow, and ice loads, used to determine the design criteria should be described.

2.2.3. Geology and seismology

This section should include the basic geologic information upon which the more detailed seismic information and analysis are based. It is desired to indicate what data have been analyzed and selected for use in determining design criteria. Types of information to be considered for inclusion are:

- basic geologic characteristics of the region and the site;
- the regional and site physiography;
- the relationship between the regional and site physiography;
- geologic history;
- lithologic, stratigraphic, and structural geologic conditions of the region and the site;
- the tectonic structures in the vicinity of the site of significance to the analysis; and
- the geologic features and conditions that could affect facility structures.

The applicant should describe in detail the data and analysis methods used to determine the design basis earthquakes that are used to define the related design criteria. Types of information to be included are:

- description of the methodology for determining the design basis earthquakes;
- how the data were selected for determination of the design basis for vibratory ground motion;
- behavior of the site during prior earthquakes;
- static and dynamic engineering properties of the materials underlying the site;
- earthquake history;
- identification of active faults within a relevant distance of the site;
- identification of capable faults within a relevant distance of the site that may be of significance in establishing earthquake criteria;
- historic earthquakes of greatest magnitude or intensity that have been correlated with tectonic structures or that are identified with tectonic provinces on which the site is located;
- the response spectrum for the maximum vibratory acceleration at the site;
- geologic evidence of fault offset at or near the ground surface, at or near the site;
- capable faults in the vicinity of the site;
- correlation of earthquakes with capable faults; and
- information on likelihood of earthquakes.

2.2.4. Hydrology

The applicant should describe the hydrological features of the region, area, and site and identify the sources of hydrological information, the types of data collected, and the method and frequency of collection. Types of information to be considered for inclusion are:

- population groups that use, as a potable supply, surficial water subject to normal or accidental effluents of the operation, including size, location, and use rate of the population groups;
- the drainage basin and watercourse flow for streams, rivers, lakes, and reservoirs, including maximum and minimum historical observations for watercourse flow;
- changes to natural drainage features brought about because of the operation;
- upstream, and downstream river control structures; and
- probable minimum flow rate and water level resulting from the most severe drought considered possible in the area, if the water supply is safety related.

If appropriate, sufficient information must be included to support the choice of the design basis flood level and the accompanying flood-induced forces that were used to determine flood design criteria. Types of information to be considered for inclusion are:

- frequency, intensity, and cause of past flooding;
- the probable maximum water level from a stream flood, surge, combination of stream flood and surge in estuarial areas, wave action or tsunami (whichever is applicable and/or greatest), or dam failure, whichever may cause the highest water level;
- the probable maximum precipitation and its effects on the drainage area and site drainage systems;
- the hydrologic response of the watershed to precipitation;
- nearby large bodies of water that could result in surge- or seiche-type flooding; and
- regional ice and ice-jam floods or other possible ice-produced forces.

Information in this section should also describe the features that are important in determining the effects that operations or accidents may have on groundwater. Types of information to be considered for inclusion are:

- the groundwater aquifers, formations, sources, and sinks relative to the site location;
- ground-water levels, flow, permeability, porosity, and gradients at the site;
- sources and usage anticipated at the facility;
- location of monitoring wells to check for leakage from the facility;
- the potential for contamination from the operation leaking into ground water and the time to reach the nearest potential user; and
- boundaries of hydrological structure.

2.2.5. Geotechnical characteristics

The applicant should provide information on the geotechnical characteristics of the facility site. Information should be presented that thoroughly defines the conditions and engineering properties of both soil and/or rock at the facility. Information on the geotechnical characteristics of the site should include:

- the scope and results of geotechnical and geophysical investigations conducted at the site;

- the scope and results of field and laboratory tests conducted to determine the engineering properties of various materials at the site;
- the groundwater conditions at the site; and
- interpretation of the site stratigraphy and selection of the design parameters on the bases of data in the SAR.

2.2.6. Geochemical characteristics

The applicant should provide information on the background and anticipated changes in water chemistry for groundwater and surface water systems that may be affected by facility construction. Data on the descriptions of the following parameters should be included:

- chemical analysis;
- pH, oxidation/reduction conditions, alkalinity, ionic strength, dissolved solids, and density;
- temperature;
- nature of colloidal-sized materials; and
- observation of degassing.

The information on the classification, identification of the mineralogy, and chemical characterization of the soils and rock units are required as well as description of sampling, preservation, storage, analytical, and experimental procedures used.

2.2.7. Natural resources

The applicant should provide an analysis demonstrating that there will be no adverse effect on the site if natural resources such as minerals, hydrocarbons and water were exploited during construction, operation, and after closure. In addition, the applicant should describe the known natural resources at or near the site, the exploitation of which could result in inadvertent intrusion into the wastes after removal of institutional control.

2.2.8. Ecological features

Special ecological features, such as the presence of any rare or endangered plant or animal species, may affect the design, construction, or operation of the facility. The applicant should describe any such features to the extent that they have an impact on the facility.

2.2.9. Pre-operational monitoring programme

The applicant's development of the pre-operational environmental monitoring programme will draw on information about the ecology, meteorology, climatology, hydrology, geology, geochemistry, and seismology of the disposal site, which will be provided under other sections of the SAR. In this section, the applicant should describe the organizational structure of the environmental monitoring programme. This environmental monitoring and surveillance plan should consider both on-site and off-site measurements in air, water, soil, vegetation, local fauna, and local sources of food. The applicant should provide the rationale for:

- the location of the monitoring points;
- the media to be sampled at each location;
- the frequency of sample collection at each location;

- the selection of the radiological and non-radiological constituents of the samples taken from each media that are to be sampled and analyzed;
- the instrumentation and methods selected for field sampling, surveys, and laboratory analysis;
- the processing of the samples, including the types and frequencies of analyses (e.g., gamma spectroscopy and chemical oxygen demand) and the minimum detectable amounts and lower limits of detection for each constituent that is to be analyzed; and
- the statistical basis to be used for comparing the baseline measurements to the corresponding measurements in the operational and post-closure periods of site operation.

2.3. FACILITY DESIGN AND CONSTRUCTION

The purpose of this section is to identify the applicable design and performance criteria important to safety and to make a clear statement of the extent to which the facility complies with the design criteria.

2.3.1. Principal design features

The applicant should describe the principal design features of the facility that are designed to provide long-term isolation of disposed waste, minimize the need for continued active maintenance after site closure, and improve the site's natural characteristics in order to protect public health and safety. Principal design features should be identified and described for each of the following functional requirements:

- minimizing the infiltration of water into disposal units;
- ensuring the integrity of disposal unit covers;
- providing the structural stability of backfill, waste, and covers;
- minimizing contact of waste with standing water;
- providing adequate site drainage;
- minimizing the long term maintenance;
- providing a barrier against inadvertent intrusion;
- maintaining occupational exposure as low as reasonably achievable (ALARA), social and economic factors being taken into consideration;
- providing adequate site monitoring; and
- providing an adequate buffer zone for monitoring and potential mitigative action.

2.3.2. Design considerations for normal/abnormal conditions

The applicant should present the principal design criteria for the proposed facility. The design criteria should ensure that the principal design features under normal, abnormal, and accident conditions are designed to:

- provide sufficient isolation of radioactive materials;
- minimize the need for continued active maintenance after facility decommissioning; and
- improve the site's natural characteristics in order to protect public health and safety.

The applicant should list the natural phenomena and design basis accidents that define the major design specifications for the facility. For the natural phenomena, identifying characteristics are listed such as return period, intensity, speed, acceleration, pressures, or loading, as appropriate to the nature of the phenomenon. For the design basis accidents, the

defining physical characteristics are listed such as intensity, pressures, or temperatures, as appropriate to the nature of the accident.

2.3.3. Construction considerations

The applicant should provide information on the construction methods and features of the disposal site and its facilities. This should include information on the following items:

- site preparation;
- control and diversion of water;
- construction of the facility and its cover;
- concrete and steel constructions;
- backfilling;
- site plans, engineering drawings, and construction specifications; and
- construction equipment.

2.3.4. Auxiliary systems and facilities

The applicant should describe the utility systems such as electricity, water, etc. of the proposed facility, how each system provides the support required for the operational needs of the proposed facility, and any adverse effects that the utility system design or potential failure could have on overall facility performance.

The auxiliary facilities such as buildings and traffic systems of the proposed facility should be described, mentioning how the auxiliary facilities support the operational needs or construction requirements of the facility, and any adverse effects that the auxiliary facility design or failure could have on overall facility performance. The applicant should describe the fire protection system and the system's capability to safely protect the facility and workers from radiation and fire hazards if an accidental fire should occur. The fire protection system includes the equipment, procedures, training, management, and emergency planning required for fire protection at the facility.

The applicant should provide hydrologic analyses and design details of the flood control system. Those features that will provide protection against erosion and flooding during the operational period should be fully described.

2.4. FACILITY OPERATIONS

This section provides a comprehensive description of the operations performed in the facility. Descriptions should be sufficiently detailed so that a technically knowledgeable reviewer would be able to understand the hazards involved in the operation, evaluate the adequacy of the hazard identification and accident analysis, and assess the suitability of the choice of controls and mitigators.

2.4.1. Receipt and inspection of waste

The applicant should describe the procedures or contracts in place that will ensure that arriving shipments comply with applicable regulatory and waste acceptance criteria that might be incorporated into the disposal facility license as conditions. These regulations and acceptance criteria should govern the acceptability of waste packages for routine handling operations and for long-term disposal.

2.4.2. Waste handling and interim storage

If waste handling and interim storage are performed at the site, the applicant should provide information on the operations that will be carried out following acceptance and receipt of the waste packages. The applicant should describe the operation in sufficient detail to demonstrate that the waste will be handled safely and stored in a manner that will prevent contact of water with the stored waste. Information on waste handling should include procedures to protect facility workers during handling.

2.4.3. Waste disposal operations

The applicant should present information on all the waste disposal operations and procedures beyond waste handling and interim storage (if these are required) from the actual emplacement of the waste into the individual disposal units up to closure of the unit. Major operations for waste disposal to be described by the applicant in this section include:

- waste emplacement in the individual units;
- filling the void spaces;
- waste covering;
- locating disposal units and boundary markers;
- closure and stabilization; and
- buffer zone around and beneath the disposal facility.

2.4.4. Operational monitoring

The applicant should describe how the possible impacts of facility operation as well as post-operational activities are monitored and surveyed to demonstrate that the facility cannot cause any uncontrollable threat to personnel, public or environment.

2.5. FACILITY CLOSURE AND POST-OPERATIONAL CONTROLS

The applicant should provide all necessary information on planned activities that are aimed at preparation of the site for unrestricted use.

2.5.1. Site stabilization

The applicant should demonstrate that disposal unit covers are designed to minimize infiltration of water into the disposal unit, to direct percolating or surface water away from disposed waste, and to resist degradation by surface geologic processes and biotic activity.

The applicant should provide the description of site flood control, drainage, and wind/water erosion systems, namely those of:

- engineering details;
- placement and equipment specifications;
- components' lifetime data;
- quality assurance procedures and supervision; and
- monitoring systems.

2.5.2. Decontamination and decommissioning

The information provided in this section should be sufficiently detailed to allow a thorough assessment of the applicant's decommissioning plan. The plan should focus on the

actions necessary to return the disposal facility to a condition that will not require active maintenance.

2.5.3. Post-operational monitoring

The applicant should describe how the environmental and surveillance programme will be used to demonstrate that the disposal site is stable and ready for post-operational control. To explain how the monitoring system will provide an early warning of releases of radionuclides from the disposal site before they reach the site boundary, the applicant should postulate a number of hypothetical accident scenarios, describe action levels (concentrations of radiological and non-radiological pollutants in the media) that will trigger mitigative activities, and discuss the reasons for the selection of these levels.

2.6. SAFETY ASSESSMENT

2.6.1. Radionuclide inventory

The applicant should supply detailed projections of the quantities and physical, chemical, and radiological characteristics of the wastes to be disposed of at the facility. This projection should allow for defendable modelling of potential radiological impacts associated with disposal.

2.6.2. Infiltration

The applicant should provide hydrologic infiltration values for input into the description of how disposal site covers will be designed to minimize, to the extent practicable, water infiltration and to direct percolating or surface water away from the waste. Furthermore, the applicant should provide infiltration values for input into the analyses of the long-term stability of the disposal site and the need for ongoing active maintenance after closure.

2.6.3. Radionuclide release - normal conditions

The applicant should provide a reasonable, yet conservative, assessment of radioactivity release into each of the most significant radioactive transport mechanisms for each of the periods of concern in the life of a disposal facility. The most significant transport mechanisms include groundwater, air, surface water, direct radiation and biotic pathways. The periods of concern include the operational, institutional control, and post-institutional control periods. The applicant should provide an analysis that identifies and quantifies the most significant scenarios based on the specific details of the site environment, the waste acceptance criteria and the facility design and operation practices.

2.6.4. Radionuclide release - accidents or unusual operational conditions

The applicant should provide information regarding the types, significance, and magnitudes of radioactivity release associated with principal accidental or unusual operational scenarios. These should also include scenarios related to intruder disturbances.

2.6.5. Radionuclide transport to human access locations

In this section, the applicant should provide a reasonable, yet conservative, assessment of each of the most significant radioactivity transport mechanisms, groundwater, air, surface

water, direct radiation, and biotic pathways, for each of the three periods of concern (see Section 2.6.3). The information provided herein provides an analysis of the mechanisms by which releases reach human access locations. Both offsite individuals under normal facility conditions, and onsite individuals (custodial personnel) conducting normal activities during the institutional control period need to be considered.

Groundwater transport. The applicant should calculate potential radionuclide concentrations transferred by groundwater to human access locations, such as streams, wells, springs etc. The applicant should provide all information to calculate radionuclide concentrations and groundwater travel time at appropriate distances from the site. This information should include a description of conceptual model, input parameters, mathematical models used and calculated results, including associated uncertainties in the methods and data.

Air transport. The applicant should describe the models and computer codes used to estimate the downwind atmospheric and surface concentrations of gaseous and particulate contaminants released from the disposal site for both routine and accident conditions.

Surface water. The applicant should calculate potential radionuclide concentrations at human access locations located in water bodies that could receive contamination from the site. The applicant should provide all the information for these calculations, including a description of surface water flow system, input parameters used, mathematical models used and calculated results (including uncertainty analysis).

Other transfer mechanisms. The applicant should describe transfer mechanisms in addition to those describe above, such as biotic transfer, that contribute to scenarios having radiological impacts on human. For all transfer mechanisms covered in this section, the applicant should fully describe and justify the mathematical models or analytical methods and data used.

2.6.6. Assessment of impacts and regulatory compliance

This section provides a culmination of the analysis and information presented in Sections 2.6.1 through 2.6.5. The applicant should provide information that demonstrate compliance with regulatory limits for potential radiological impacts associated with the disposal facility, including discussion on associated uncertainties.

2.6.7. Long-term stability

The applicant should present discussion, data, and stability analyses that provide reasonable assurance that there will be no need for ongoing active maintenance of the disposal site after closure. This demonstration should be based on quantitative analyses of active natural processes such as erosion, slope failure, settlement of wastes and backfill, infiltration through covers over the disposal areas and adjacent soils, and surface drainage of the disposal site. In the stability analyses, the applicant should identify:

- the method, the input data, and assumptions used for each process analyzed; and
- the assumed contributions of siting, design, use, operation, and closure if they affect long-term stability.

The applicant should discuss the uncertainties of the results and any anomalous model behaviour and analysis output.

2.7. OCCUPATIONAL RADIATION PROTECTION

The purpose of this section is to document the conditions, limitations, administrative controls, and bases thereof required to ensure safe operation of the facility. The applicant should provide information on the methods to be used for radiation protection and estimated occupational radiation exposures to operating and construction personnel during normal operation and anticipated operational occurrences.

2.8. QUALITY ASSURANCE

For the safe management of radioactive waste there will be a regulatory requirement that quality assurance be applied to all activities related to waste management system. The licensing authority will set out the detailed provisions that should be covered by a licensee's quality assurance arrangements and on the methods of assessment and monitoring available to them. In this section, the applicant should describe the quality assurance programme that will be established and executed during the design, construction and operation of the facility.

2.9. FINANCIAL ASSURANCE

The applicant should provide sufficient information to demonstrate that the financial qualifications are adequate to carry out the activities for which the license is sought.

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