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Recommendations for the guidance of contractors for the assessment of the possible environmental impacts arising from exploration for marine minerals in the Area

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I. Introduction

1. During prospecting and exploration for marine minerals, the International Seabed Authority is required to, among other things, establish and keep under periodic review environmental rules, regulations and procedures to ensure effective protection for the marine environment from harmful effects which may arise from activities in the Area and, together with sponsoring States, apply a precautionary approach to such activities on the basis of recommendations by the Legal and Technical Commission. In addition, contracts for mineral exploration in the Area require the contractor to gather oceanographic and environmental baseline data and to establish baselines against which to assess the likely effects of its programme of activities under the plan of work for exploration on the marine environment and a programme to monitor and report on such effects. The contractor shall cooperate with the Authority and the sponsoring State or States in the establishment and implementation of such monitoring programmes. The contractor shall report annually on the results of its environmental monitoring programmes. Furthermore, when applying for approval of a plan of work for exploration, each applicant is required to provide, inter alia, a description of a programme for oceanographic and environmental baseline studies in accordance with the relevant Regulations and any environmental rules, regulations and procedures established by the Authority that would enable an assessment of the potential environmental impact of the proposed exploration activities, taking into account any recommendations issued by the Legal and Technical Commission, as well as a preliminary assessment of the possible impact of the proposed exploration activities on the marine environment.

2. The Legal and Technical Commission may from time to time issue recommendations of a technical or administrative nature for the guidance of contractors to assist them in the implementation of the rules, regulations and

procedures of the Authority. Under article 165, paragraph 2 (e), of the 1982 United Nations Convention on the Law of the Sea, the Commission shall also make recommendations to the Council on the protection of the marine environment, taking into account the views of recognized experts in that field.

3. It is recalled that in June 1998 the Authority convened a workshop on the development of environmental guidelines for exploration for polymetallic nodule deposits. The outcome of the workshop was a set of draft guidelines for the assessment of possible environmental impacts from exploration for polymetallic nodule deposits in the Area. The workshop participants noted the need for clear and common methods of environmental characterization based on established scientific principles and taking into account oceanographic constraints. One year after the approval of the Regulations on Prospecting and Exploration for Polymetallic Nodules in the Area (ISBA/6/A/18), the Legal and Technical Commission issued guidelines in 2001 as document ISBA/7/LTC/1/Rev.1 and later revised them in 2010 in the light of increased understanding (see ISBA/16/LTC/7). In the light of the approval of the Regulations on Prospecting and Exploration for Polymetallic Sulphides in the Area (ISBA/16/A/12/Rev.1) in 2010 and of the Regulations on Prospecting and Exploration for Cobalt-rich Ferromanganese Crusts in the Area (ISBA/18/A/11) in 2012, it was decided that there was a need to create a combined set of environmental guidelines that included guidance with regard to exploration for polymetallic sulphides and cobalt-rich ferromanganese crusts.

4. A workshop entitled “Polymetallic sulphides and cobalt crusts: their environment and considerations for the establishment of environmental baselines and an associated monitoring programme for exploration” was held in Kingston from 6 to 10 September 2004 in response to the need for environmental guidance during exploration for those two resources. The recommendations of the workshop were based on the current scientific knowledge of the marine environment and the technology to be used.

5. Unless otherwise noted, the recommendations herein relating to exploration and test mining apply to all types of deposits. At some sites it may not be reasonably feasible to implement some of the specific recommendations. In that situation, the contractor should provide arguments to that effect to the Authority, which can then exempt the contractor from the specific requirement, if appropriate.

6. The Commission was of the opinion that, given the technical nature of the recommendations and the limited understanding of the impact of exploration activities on the marine environment, it was vital to provide, as annex I to the recommendations, an explanatory commentary. The explanatory commentary is supplemented by a glossary of technical terms.

7. The nature of the environmental considerations associated with test mining depends on the type of mining technology used to extract the minerals and on the scale of the operation (i.e. the number of tons extracted per annum per region). Mechanical removal without initial processing at the seabed was deemed the most likely technology to be used and is the method of mineral extraction assumed herein. It is likely that future mining operations will employ techniques not considered here. Given that the recommendations contained herein are based on the current scientific knowledge of the marine environment and the technology to be used at the time at which they were prepared, they may require revision at a later date, taking into account the progress of science and technology. In accordance with

each set of Regulations, the Commission may from time to time review the present recommendations, taking into account the current state of scientific knowledge and information. It is recommended that such a review be carried out periodically and at intervals of no more than five years. To facilitate the review, it is recommended that the Authority convene workshops, at appropriate intervals, in which the members of the Commission, contractors and recognized experts from the scientific community are invited to participate.

8. After approval of the plan of work for exploration in the form of a contract and prior to the commencement of exploration activities, the contractor is required to submit to the Authority:

(a) An impact assessment of the potential effects on the marine environment of all proposed activities, excluding those activities considered by the Legal and Technical Commission to have no potential for causing harmful effects on the marine environment;

(b) A proposal for a monitoring programme to determine the potential effect on the marine environment of proposed activities; and to verify that there is no serious harm to the marine environment arising from the prospecting and exploration for minerals;

(c) Data that could be used to establish an environmental baseline against which to assess the effect of future activities.

II. Scope

A. Purpose

9. These recommendations describe the procedures to be followed in the acquisition of baseline data, and the monitoring to be performed during and after any activities in the exploration area with potential to cause serious harm to the environment. Their specific purposes are:

(a) To define the biological, chemical, geological and physical components to be measured and the procedures to be followed by contractors to ensure effective protection for the marine environment from harmful effects which may arise from the contractors' activities in the Area;

(b) To facilitate reporting by contractors;

(c) To provide guidance to potential contractors in preparing a plan of work for exploration for marine minerals in conformity with the provisions of the Convention, the 1994 Agreement relating to the implementation of Part XI of the United Nations Convention on the Law of the Sea and the relevant Regulations of the Authority.

B. Definitions

10. Except as otherwise specified in this document, terms and phrases defined in each set of the Regulations shall have the same meaning in these recommendations. A glossary of technical terms is contained in annex II to the present document.

C. Environmental studies

11. Every plan of work for exploration for marine minerals shall take into consideration the following phases of environmental studies:

(a) Environmental baseline studies;

(b) Monitoring to ensure that no serious harm is caused to the marine environment from activities during prospecting and exploration;

(c) Monitoring during and after testing of collecting systems and equipment.

12. Contractors shall permit the Authority to send its inspectors on board vessels and installations used by the contractor to carry out exploration activities in the Area to, among other things, monitor the effects of such activities on the marine environment.

III. Environmental baseline studies

13. It is important to obtain sufficient information from the exploration area to document the natural conditions that exist prior to test mining, to gain insight into natural processes such as dispersion and settling of particles and benthic faunal succession, and to gather other data that may make it possible to acquire the capability necessary to make accurate environmental impact predictions. The impact of naturally occurring periodic processes on the marine environment may be significant but is not well quantified. It is therefore important to acquire as long a history as possible of the natural responses of sea-surface, mid-water and seabed communities to natural environmental variability.

Baseline data requirements

14. To set up the environmental baseline in the exploration area as required under the relevant Regulations, the contractor, utilizing the best available technology, including the Geographical Information System, and using robust statistical design in preparing the sampling strategy, shall collect data for the purpose of establishing baseline conditions of physical, chemical, biological and other parameters that characterize the systems likely to be impacted by exploration and possible test-mining activities. Baseline data documenting natural conditions prior to test mining are essential in order to monitor changes resulting from test-mining impacts and to predict impacts of commercial mining activities.

15. Data to be addressed should include:

(a) For physical oceanography:

(i) Collect information on the oceanographic conditions, including the current, temperature and turbidity regimes, along the entire water column and, in particular, near the sea floor;

(ii) Adapt the measurement programme to the geomorphology of the seabed;

(iii) Adapt the measurement programme to the regional hydrodynamic activity at the sea surface, in the upper water column and at the seabed;

(iv) Measure the physical parameters at the depths likely to be impacted by the discharge plumes during the testing of collecting systems and equipment;

(v) Measure particle concentrations and composition to record distribution along the water column;

(b) For geology:

(i) Produce Geographic Information System regional maps with high-resolution bathymetry showing major geological and geomorphological features to reflect the heterogeneity of the environment. These maps should be produced at a scale appropriate to the resource and habitat variability;

(ii) Collect information on heavy metals and trace elements that may be released during test mining and their concentrations;

(c) For chemical oceanography:

(i) Collect information on background water column chemistry, including water overlying the resource, in particular on metals and other elements that may be released during the mining process;

(ii) Collect information on heavy metals and trace elements that may be released during test mining and their concentrations;

(iii) Determine what additional chemicals may be released in the discharge plume following processing of the resource during test mining;

(d) For sediment properties:

(i) Determine the basic properties of the sediment, including measurement of soil mechanics and composition, to adequately characterize the surficial sediment deposits which are the potential source of deep-water plume;

(ii) Sample the sediment taking into account the variability of the seabed;

(e) For biological communities, using high-resolution bathymetric maps to plan the biological sampling strategy, taking into account variability in the environment:

(i) Gather data on biological communities, taking samples of fauna representative of variability of habitats, bottom topography, depth, seabed and sediment characteristics, abundance and mineral resource being targeted;

(ii) Collect data on the sea floor communities specifically relating to megafauna, macrofauna, meiofauna, microfauna, demersal scavengers and fauna associated directly with the resource, both in the exploration area and in areas that may be impacted by operations (e.g. the operational and discharge plumes);

(iii) Assess pelagic communities in the water column and in the benthic boundary layer that may be impacted by operations (e.g. the operational and discharge plumes);

(iv) Record in dominant species baseline levels of metals that may be released during mining;

(v) Record sightings of marine mammals, other near-surface large animals (such as turtles and fish schools) and bird aggregations, identifying the relevant species where possible. Details should be recorded in transit to and from areas of exploration and on passage between stations. Temporal variability should be assessed;

(vi) Establish at least one station within each habitat type or region, as appropriate, to evaluate temporal variations in water column and seabed communities;

(vii) Assess regional distribution of species and genetic connectivity of key species;

(viii) Collections should be photo-documented (and indexed to video imaging) in situ to provide an archive of context/setting information for each sample;

(f) For bioturbation: where appropriate, gather data on the mixing of sediments by organisms;

(g) For sedimentation: gather time series data on the flux and composition of materials from the upper water column into the deep sea.

16. In addition to analyses of the data, raw data should be provided in electronic format with annual reports as agreed with the secretariat. These data will be used for regional environmental management and assessment of cumulative impacts.

IV. Environmental impact assessment

17. The best available technology and methodology for sampling should be used in establishing baseline data for environmental impact assessments.

A. Activities not requiring environmental impact assessment

18. On the basis of available information, a variety of technologies currently used in exploration are considered to have no potential for provoking serious harm to the marine environment and thus do not require environmental impact assessment. These include:

(a) Gravity and magnetometric observations and measurements;

(b) Bottom and subbottom acoustic or electromagnetic profiling of resistivity, self-potential or induced polarization, or imaging without the use of explosives or frequencies known to significantly affect marine life;

(c) Water, biotic, sediment and rock sampling for environmental baseline study, including:

(i) Sampling of small quantities of water, sediment and biota (e.g. from remotely operated vehicles);

(ii) Mineral and rock sampling of a limited nature, such as that using small grab or bucket samplers;

(iii) Sediment sampling by box corer and small diameter corer;

(d) Meteorological observations and measurements, including the setting of instruments (e.g. moorings);

(e) Oceanographic, including hydrographic, observations and measurements, including the setting of instruments (e.g. moorings);

(f) Video/film and still photographic observations and measurements;

(g) Shipboard mineral assaying and analysis;

(h) Positioning systems, including bottom transponders and surface and subsurface buoys filed in notices to mariners;

(i) Towed plume-sensor measurements (chemical analysis, nephelometers, fluorometers, etc.);

(j) In situ faunal metabolic measurements (e.g. sediment oxygen consumption);

(k) DNA screening of biological samples;

(l) Dye release or tracer studies, unless required under national or international laws governing the activities of flagged vessels.

B. Activities requiring environmental impact assessment

19. The following activities require prior environmental impact assessment, as well as an environmental monitoring programme to be carried out during and after the specific activity, in accordance with the recommendations contained in paragraphs 29 and 30. It is important to note that these baseline, monitoring and impact assessment studies are likely to be the primary inputs to the environmental impact assessment for commercial mining:

(a) Sampling for on-land studies for mining and/or processing if the sampling area of any one sampling activity exceeds the limit stipulated in the specific guidance to contractors for specific mineral resources as stated in section IV.F below;

(b) Use of systems to create artificial disturbances on the sea floor;

(c) Testing of collection systems and equipment;

(d) Drilling activities using on-board drilling rigs;

(e) Rock sampling;

(f) Sampling with epibenthic sledge, dredge or trawl, unless permitted for areas less than that stipulated in the specific guidance to contractors for specific mineral resources as stated in section IV.F below.

20. The prior environmental impact assessment and the information set out in the recommendation contained in paragraph 27 and the relevant environmental monitoring programme is to be submitted by the contractor to the Secretary-General at least one year before the activity takes place and at least three months in advance of the annual session of the Authority.

21. Environmental monitoring data are required prior to, during and following test mining at the mining site and at comparable reference sites (to be selected according to their environmental characteristics and faunal composition). Impact assessment

must be based on a properly designed monitoring programme that should be able to detect impacts in time and space and to provide statistically defensible data.

22. The main environmental impacts are expected to be at the sea floor. Additional impacts may occur at the tailings-discharge depth and in the water column. The impact assessment should address impacts on benthic, benthic boundary layer and pelagic environments. The impact assessment should address not only areas directly affected by mining but also the wider region impacted by near-bottom plumes, the discharge plume and material released by transporting the minerals to the ocean surface, depending on the technology used.

23. Mining tests may be conducted by contractors individually or collaboratively. In a mining test, all components of the mining system will be assembled and the entire process of test mining, lifting minerals to the ocean surface and discharge of tailings will be executed. For environmental assessments, this test phase should be monitored intensively, as should tests of any test-mining component. When mining tests have already been carried out, even if by another contractor, the knowledge gained through those tests should be applied, where appropriate, to ensure that unanswered questions are resolved by new investigations.

24. Monitoring of test mining should allow the prediction of impacts to be expected from the development and use of commercial systems.

25. A discharge plume in surface water may interfere with primary productivity by increasing nutrient levels and decreasing light penetration into the ocean. The introduction of cold deep water from depth will also alter sea surface temperature locally and release carbon dioxide into the atmosphere. Before large volumes of deep water are brought to the surface in a test-mining activity, an environmental impact assessment is required, because environmental changes may alter food chains, disturb vertical and other migrations and lead to changes in the geochemistry of an oxygen-minimum zone, if present. Because oxygen-minimum zones vary in size regionally and to some extent seasonally, environmental studies should determine the depth range of the oxygen-minimum layer in each test-mining area.

C. Information to be provided by the contractor

26. The contractor will provide the Authority with a general description and a schedule of the proposed exploration programme, including the programme of work for the immediate five-year period, such as studies to be undertaken in respect of the environmental, technical, economic and other appropriate factors that must be taken into account during test mining. This general description should include:

(a) A programme for oceanographic and environmental baseline studies in accordance with the relevant set of Regulations and any environmental regulations and procedures issued by the Authority that would enable an assessment of the potential environmental impact of the proposed exploration activities, taking into account any guidelines issued by the Authority;

(b) Proposed measures for the prevention, reduction and control of pollution and other hazards to, as well as possible impacts on, the marine environment;

(c) Preliminary assessment of the possible impact of the proposed exploration activities on the marine environment;

(d) Delineation of impact reference areas and preservation reference areas. The impact reference area should be representative of the site to be mined in terms of environmental characteristics and the biota. The preservation reference area should be carefully located and large enough not to be affected by mining activities, including the effects from operational and discharge plumes. The reference site will be important in identifying natural variations in environmental conditions. Its species composition should be comparable to that of the test-mining area.

27. The contractor is to provide the Secretary-General with some or all of the following information, depending on the specific activity to be carried out:

(a) Size, shape, tonnage and grade of the deposit;

(b) Mineral collection technique (passive or active mechanical dredge, hydraulic suction, water jets, etc.);

(c) Depth of penetration into the seabed;

(d) Running gear (skis, wheels, caterpillars, Archimedes screws, bearing plates, water cushion, etc.) which contacts the seabed;

(e) Methods for separation on the sea floor of the mineral resource and the sediment, including washing of the minerals, concentration and composition of sediment mixed with water in the operational plume created at the seabed, height of discharge above the sea floor, modelling of particle size dispersion and settlement, and estimates of depth of sediment smothering with distance from the mining activity;

(f) Processing methods at the seabed;

(g) Mineral crushing methods;

(h) Methods for transporting the material to the surface;

(i) Separation of the mineral resource from the fines and the sediment on the surface vessel;

(j) Methods for dealing with the abraded fines and sediment;

(k) Volume and depth of discharge plume, concentration and composition of particles in the discharged water and chemical and physical characteristics of the discharge;

(l) Mineral resource processing on the surface vessel;

(m) Location of the mining test and boundaries of the test area;

(n) Probable duration of the test;

(o) Test plans (collecting pattern, area to be perturbed, etc.);

(p) Baseline maps (e.g. side-scan sonar, high-resolution bathymetry) of the deposits to be removed;

(q) Status of regional and local environmental baseline data.

28. Each contractor should include in its programme for specific activity a specification of the events that could cause suspension or modification of the activities owing to serious environmental harm, if the effects of the events cannot be adequately mitigated.

D. Observations and measurements to be made while performing a specific activity

29. The contractor is to provide the Secretary-General with some or all of the following information, depending on the specific activity to be carried out:

(a) Width, length and pattern of the collector tracks on the sea floor;

(b) Depth of penetration in the sediment or rock and the lateral disturbance caused by the collector;

(c) Volume and type of material taken by the collector;

(d) Ratio of sediment separated from the mineral source by the collector, volume and size spectra of material rejected by the collector, size and geometry of the operational plume at the seabed, trajectory and spatial extent of the operational plume relative to the particle sizes within it;

(e) Area and thickness of sedimentation from the operational plume and the distance where sedimentation is negligible;

(f) Volume of discharge plume from the surface vessel, concentration and composition of particles in the discharged water, chemical and physical characteristics of the discharge, behaviour of the discharged plume at the surface, in mid-water or at the seabed, as appropriate.

E. Observations and measurements to be made after the performance of a specific activity

30. The contractor is to provide the Secretary-General with some or all of the following information, depending on the specific activity to be carried out:

(a) Thickness of redeposited sediment and rock rubble over the area affected by the operational plume caused by the mining test activity and by the discharge plume;

(b) Abundance and diversity of benthic communities and changes in behaviour of key species subjected to smothering by sedimentation;

(c) Changes in the distribution, abundance and diversity of benthic communities in the mining area, including rates of recolonization;

(d) Possible changes in the benthic communities in adjacent areas not expected to be perturbed by the activity, including the operational and discharge plumes;

(e) Changes in the characteristics of the water at the level of the discharge plume during the mining test, and changes in the behaviour of the fauna at and below the discharge plume;

(f) For mineral deposits, post-test-mining maps of the mined area, highlighting changes in geomorphology;

(g) Levels of metals found in dominant benthic fauna subjected to resettled sediment from the operational and discharge plumes;

(h) Resampling of local environmental baseline data at reference and test zones and evaluation of environmental impacts;

(i) Changes in fluid flux and response of organisms to changes in hydrothermal settings, if relevant;

(j) Changes in water currents and the response of organisms to changes in circulation.

F. Additional requirements specific to individual resource types

Polymetallic nodules

31. In addition to the information provided above, the following information is specific to polymetallic nodules: environmental impact assessment is required if any one sampling activity by epibenthic sled, dredge or trawl, or a similar technique, exceeds 10,000 m^2.

Polymetallic sulphides

32. In addition to the information provided above, the following information is specific to polymetallic sulphides:

(a) Any modification of fluid discharge in hydrothermal settings and associated fauna (using photo documentation, temperature measurements and other metrics, as appropriate) should be recorded;

(b) For active sulphide deposits, temperature-fauna relationships should be analysed (e.g. 5-10 discrete, video-documented temperature measures within each subhabitat);

(c) The presence of key taxa, including specialist localized chemosynthetic communities, should be mapped and their position relative to potential mining locations assessed to a radius of 10 km from the proposed mine site;

(d) Meiofaunal and microbial community structure and biomass associated with the polymetallic sulphide deposits should be examined from rock dredge and rock drill samples, or obtained from remotely operated vehicle/submersible sampling, where possible. A statistically defensible number of samples should be taken from polymetallic sulphides, from which species that live on the rock or in crevices and pits in the deposit should be identified;

(e) Fauna should be collected using precision sampling remotely operated vehicle/submersible technology by subhabitat and placed into discrete sample boxes;

(f) Abundance and coverage of the dominant taxa in each subhabitat should be determined.

Cobalt-rich ferromanganese crusts

33. In addition to the information provided above, the following information is specific to cobalt-rich ferromanganese crusts:

(a) Communities associated with cobalt-rich ferromanganese crusts may have a highly localized distribution. Biological sampling must therefore be stratified by habitat type, which will be defined by topography (e.g. summit, slope and base for seamounts), hydrography, current regime, predominant megafauna (e.g. coral mounds), oxygen content of the water (if the oxygen minimum layer intersects the feature) and, potentially, depth. Replicate biological samples should be obtained using appropriate sampling tools in each subhabitat;

(b) Biological sampling should be carried out, insofar as possible, on a representative subset of all features of potential mining interest within each claim area in order to build a picture of the distribution of the community within that area;

(c) Photographic or video transects should be undertaken to determine habitat type, community structure and associations of megafauna with specific types of substrata. Abundance, percentage cover and diversity of megafauna should be based initially on at least four transects. These transects should extend from the flat sea floor 100 m or more from the base of the seamount, along the slope of the seamount and across its summit. More limited sampling may be required on larger seamount features. Further transects should be carried out in crust areas of potential test-mining interest;

(d) A statistically defensible number of replicate remotely operated vehicle/submersible samples per stratum is recommended for collection of specimens and to assess species richness;

(e) Prior to test mining, demersal fish and other nekton living over the sea floor should be assessed on the basis of towed photographic/video transects, with deployed cameras set up to record at different time periods, or with submersible/remotely operated vehicle observations and photographs. Seamounts can be important ecosystems with a variety of habitats for a number of fish species that form aggregations there for spawning or feeding. Test mining operations could affect fish behaviour;

(f) Meiofaunal and microbial community structure and biomass associated with the cobalt-rich ferromanganese crust should be examined using remotely operated vehicle/submersible sampling. A statistically defensible number of samples should be taken from cobalt-rich ferromanganese crusts, from which species that live on the rock or in crevices and pits in the crust should be identified.

V. Data collection, reporting and archival protocol

A. Data collection and analysis

34. The types of data to be collected, the frequency of collection and the analytical techniques in accordance with the present recommendations should follow the best available methodology and the use of an international quality system and certified operation and laboratories.

B. Data archival and retrieval scheme

35. A cruise report with station list, list of activities and other relevant metadata should be submitted to the secretariat of the Authority within one year of the completion of the cruise.

36. The contractor should provide the Authority with all relevant data, data standards and inventories, including raw environmental data in the format agreed with the Authority. Data and information that are necessary for the formulation by the Authority of rules, regulations and procedures concerning protection and preservation of the marine environment and safety, other than proprietary equipment design data (including hydrographical, chemical and biological data), should be made freely available for scientific analysis no later than four years after the completion of a cruise. An inventory of the data holdings from each contractor should be accessible on the World Wide Web. Metadata that detail the analytical techniques, error analyses, descriptions of failures, techniques and technologies to avoid, comments on sufficiency of data and other relevant descriptors should be included with the actual data.

C. Reporting

37. Assessed and interpreted results of the monitoring shall be periodically reported to the Authority together with the raw data in accordance with the prescribed format.

D. Transmission of data

38. All data relating to the protection and preservation of the marine environment, other than equipment design data, collected pursuant to the recommendations contained in paragraphs 29 and 30 should be transmitted to the Secretary-General to be freely available for scientific analysis and research within four years of the completion of a cruise, subject to confidentiality requirements as contained in the relevant Regulations.

39. The contractor should transmit to the Secretary-General any other non-confidential data in its possession which could be relevant for the purpose of the protection and preservation of the marine environment.

VI. Cooperative research and recommendations to close gaps in knowledge

40. Cooperative research may provide additional data for the protection of the marine environment and may be cost-effective for contractors.

41. Interaction between multiple oceanographic disciplines and multiple institutions can be useful in closing gaps in knowledge resulting from contractors working individually. The Authority can give support in the coordination and dissemination of the results of such research, in accordance with the Convention. The Authority should serve in an advisory capacity to mining contractors in terms of identification of cooperative research opportunities, but contractors should seek their own links to academic and other professional expertise.

42. Cooperative research programmes may prove especially synergistic, bringing together the expertise, research facilities, logistic capability and common interests of mining companies and cooperative institutions and agencies. In this way, contractors may make best use of large-scale research facilities such as vessels,

autonomous underwater vehicles and remotely operated vehicles and expertise in geology, ecology, chemistry and physical oceanography of academic institutions.

43. To answer certain questions on the environmental impacts of mining, specific experiments, observations and measurements must be conducted. All contractors need not execute the same studies. Repeating certain experiments or impact studies would not necessarily add to scientific knowledge or to impact assessments, while needlessly consuming financial, human and technological resources. Contractors are encouraged to explore opportunities to unite their efforts in international cooperative oceanographic studies.

Annex I

Explanatory commentary

1. The aim of these recommendations is to define the biological, chemical, geological and physical oceanographic information required to ensure the effective protection of the marine environment from harmful effects which may arise from activities in the Area. The recommendations also provide guidance to prospective contractors in preparing plans of work for exploration for marine minerals.

2. A plan of work for exploration should include activities that address the following environmental requirements:

(a) Establish an environmental baseline study against which to compare both natural change and impacts caused by mining activities;

(b) Provide methods to monitor and evaluate the impacts of deep seabed mining on the marine environment;

(c) Provide data for an environmental impact assessment required for an exploitation contract for marine minerals in the Area, including the designation of impact reference zones and preservation reference zones;

(d) Provide data for the regional management of resource exploration and exploitation, the conservation of biodiversity and the recolonization of areas affected by deep seabed mining;

(e) Establish procedures to demonstrate no serious harm to the environment from exploration for marine minerals.

3. On the basis of current proposed methodologies, the main impacts are expected to occur at the sea floor. Additional impacts may be caused by processing on board the mining vessel and from the discharge plume or as a result of different technologies being used.

4. At the seabed, the mining equipment will disturb and remove the sea floor (rock, nodules and sediment), creating a near-bottom operational plume of particulate material, in some cases potentially releasing harmful chemicals, which will impact marine life. It will be necessary to mitigate the loss of substrate, provide for the natural recolonization of the seabed and develop methods that minimize impacts in space and time from direct disturbance of the sea floor and from material carried in, and deposited from, the operational plume.

5. Processing of mineral slurry at the sea surface on board the mining vessel will bring large quantities of cold, nutrient-rich, carbon-dioxide-replete and particle-laden water to the sea surface, which must be carefully controlled so as not to alter sea surface ecosystems, allow the degassing of climate-active gases and the release of harmful metals and compounds from the mining process, in particular in relation to reduced mineral phases, such as sulphides. Any chemicals added to separate the mineral phases from the waste material and water need to be assessed for potential harmful effects.

6. The discharge plume needs to be controlled to limit harmful environmental effects. Discharge at the sea surface may introduce particle-laden water to oligotrophic particle-sparse waters, limiting light penetration, changing sea temperature and introducing high levels of nutrients to nutrient-poor regions with

significant impacts on the species composition of primary producers and the pelagic ecosystem. Discharge within the deeper waters of the oxygen-minimum zone or zones may trigger the release of harmful bioactive metals, while discharge at even greater depths may introduce particle-rich water to sparse, but generally diverse, pelagic communities. Discharge at the seabed would add to the operational plume with warmer water and finer particles.

7. Baseline data requirements include seven categories: physical oceanography, geology, chemistry/geochemistry, biological communities, sediment properties, bioturbation and sedimentation.

8. Physical oceanographic data are required to estimate the potential influence of the operational and discharge plumes and, together with information on the geomorphology of the sea floor, to predict the potential distribution of species. Information is required on currents, temperature and turbidity at the sea surface, in mid-water and in the benthic boundary layer overlying the sea floor.

9. At the proposed depth of the discharge plume, measurements of the currents and particulate matter are required to predict the behaviour of the discharge plume and to assess natural particle loads in the water.

10. The oceanographic structure of the water column is measured by conductivity-temperature-depth systems. Temporal variation in the physical structure of surface water is required. The conductivity-temperature-depth profiles and sections should be performed from the sea surface to the sea floor so as to characterize the stratification of the entire water column. Current and temperature field structures can be inferred from long-term mooring data and from supplementary acoustic Doppler current profilers. Remote systems such as autonomous underwater vehicles or gliders may be used to provide spatial and temporal information. The number and location of the moorings need to be appropriate for the size of the area to adequately characterize the current regime, in particular in areas of complex geomorphology. The recommended sampling resolution is based on World Ocean Circulation Experiment and Climate Variability and Predictability Research standards, with station spacing not exceeding 50 km. In regions of large lateral gradients (e.g. in boundary currents and near major geomorphologic structures), the horizontal sampling spacing should be decreased in order to allow resolution of the gradients. The number of current meters on a mooring is dependent upon the characteristic scales of topography of the area studied (difference in heights from the bottom). The suggested location of the lowest meter should be as close as possible to the sea floor, normally 1 m to 3 m. The location of the upper current meter should exceed the highest element of the topography by a factor of 1.2 to 2. Along with this, the basic levels of the current meters should be 10 m, 20 m, 50 m, 100 m and 200 m above the seabed.

11. A satellite-data analysis is recommended for understanding synoptic-scale surface activity in the area and for larger-scale events.

12. The water column structure should be defined either by continuous profiling or by water column samples. For samples, measurements of water properties in the vertical plane should be no more than 100 m apart. The resolution should be greater in high-gradient regions (e.g. to locate and quantify the boundaries of oxygen-minimum zones). For parameters without significant horizontal gradients, the determination of base-line ranges (e.g. means and standard deviations) is adequate.

For parameters with significant spatial structure (gradients, extremes), the sampling resolution must allow the physical oceanographic structure of the area to be characterized. Because of the strong influence of topography on the spatial scales of oceanic features, it is expected that this will require a survey plan with station spacing depending on local geomorphological scales (e.g. finer resolution is required in areas with steep slopes).

13. The second baseline data group (chemical oceanography) is a specific requirement targeted at collecting data prior to any discharge in the water column or at the seabed. The data gathered are important for assessing the possible influence of mining, including test mining, on the composition of the water, e.g. concentrations of metals, and on ecosystem processes (biological activity). Samples should be collected at the same locations as the physical oceanography measurements. The water overlying the mineral deposits and the pore water in the sediments should be characterized chemically, where possible, to evaluate processes of chemical exchange between the sediment and the water column. The chemical parameters to be measured and the suggested protocols are listed in chapter 23 of the Authority's report entitled *Standardization of Environmental Data and Information: development of guidelines*. In the same report, table 3 lists the minimum requirements of parameters that should be measured (phosphate, nitrate, nitrite, silicate, carbonate alkalinity, oxygen, zinc, cadmium, lead, copper, mercury and total organic carbon). Once details of the proposed test-mining techniques are known, the parameter lists should be extended to include any potentially hazardous substances that may be released into the water column during test mining. All measurements must be accurate in conformance with accepted scientific standards (e.g. Climate Variability and Predictability Research and GEOTRACES protocols).

14. To allow for later analysis of additional parameters, water samples suitable for analysis of dissolved and particulate matter should be collected and archived in a repository accessible for future study.

15. Vertical profiles and temporal variation also need to be addressed in the field measurement programme.

16. A general scheme for physical and chemical oceanographic baselines includes:

(a) Collection of water column hydrographic and light-transmission data of sufficient resolution to characterize the dominant patterns, taking into account the characteristics of geomorphology and topographic characteristics of the seabed at the exploration site, where appropriate;

(b) Collection of data appropriate for assessing the horizontal and vertical advective and eddy-diffusive dispersal potential of dissolved and particulate matter on environmentally relevant time and space scales;

(c) Set-up and validation of a numerical circulation model that covers the temporal and spatial scales important for dispersal, and the carrying out of experiments, e.g. to investigate the potential impact of accidental spills.

17. Regardless of the mining techniques to be employed, it is expected that some particulate and/or dissolved mining by-products will be released into the water column in the vicinity of the mined deposits, the transport conduits and processing at the sea surface. With the currently proposed exploration and test-mining techniques, the primary anticipated test-mining by-products are particles created by

the mechanical break-up of the mined minerals. While it is expected that mining operators will minimize the loss of economically valuable minerals, it does not seem realistic to assume zero loss. Since the particle size range is not known, it is assumed that the by-products of test mining will include very small particles, which can remain in suspension for months. The possibility of the introduction of toxic substances cannot be excluded. While bound metals are not biologically available, dissolution of metals and consequent metal toxicity may take place under particular environmental conditions (e.g. low pH, including within the guts of marine fauna, oxygen-minimum zones in the water column). Other possible examples include accidental or intended release of chemicals used during exploration and test mining. A primary goal of the physical baseline data collection consists of assessing the dispersal potential both for particles and for dissolved substances. Knowledge of the dispersal potential is also required for monitoring and mitigating the effects of accidental spills relating to the test-mining operations. The dispersal potential near possible mining sites should be assessed even if the design target of the mining technology includes avoidance of the release of any test-mining by-products into the environment.

18. For each test-mining by-product, the timescale over which it causes significant environmental impact must be modelled. If these timescales depend on dilution, determination of vertical and horizontal mixing rates near the target site must be included in the dispersal assessment. Dispersal potential must be assessed over timescales that range from the tidal frequencies to the largest of these environmental-impact timescales. An assessment of the dispersal potential in the deep ocean generally requires long-term monitoring. Even the determination of mean-flow directions and speeds at depth can require several years of current-meter data. Assessing eddy-diffusive dispersal is difficult and generally requires the application of Lagrangian techniques, such as neutrally buoyant floats or dye-release experiments. For these reasons, it is recommended that an assessment of the regional dispersal potential at several levels in the water column begin early during exploration. It may be possible to assess dispersal near the surface and near 1,000 m from available data — surface drifters and Array for Real-time Geostrophic Oceanography floats, respectively. Before test mining is to begin, the dispersal potential must be assessed at all levels where harmful by-products may be released into the water column by test mining and where accidental spills may occur. The required vertical resolution will depend on the regional dynamical regime (vertical shear of the horizontal currents), but it is anticipated that at least three levels will need to be sampled (near-surface, mid-depth and near-bottom). The flow near the seabed in particular must be temporally and spatially resolved, e.g. using bottom-mounted acoustic Doppler current profiler measurements with sufficient sampling to resolve the dominant tidal flows. In regions of geomorphological relief near the test-mining site, horizontal and vertical resolutions should be increased to allow dynamical structures associated with deep-sea geomorphology (e.g. boundary currents, trapped eddies, overflows) to be resolved.

19. Near active hydrothermal vent fields, it is often possible to gain useful first-order dispersal information at the level of neutrally buoyant plumes from hydrographical, chemical and optical observations. Interpreting plume-dispersal observations in terms of dispersal potential for mining by-products is complicated by a variety of factors, including poor knowledge of the temporal and spatial characteristics of hydrothermal sources; that hydrothermal plumes disperse at their

equilibrium level, which depends both on the source and environmental background characteristics; and that the particle composition (and, thus, the settling velocity) of hydrothermal plumes cannot be controlled. Nevertheless, when such plumes occur in the vicinity of a mineral resource, it is expected that hydrothermal-plume dispersal observations will be useful, in particular for designing controlled follow-up dispersal studies. To complete an assessment of the dispersal potential, a three-dimensional hydrodynamic numerical model that covers the temporal and spatial scales important for dispersal must be constructed.

20. The contractor should use a model that is accepted by the ocean modelling community as suitable for dispersal studies near the seabed; simple box models or z-coordinate models with coarse vertical resolution at depth are not expected to be adequate. The details of this model will be dependent on the topographic and oceanographic settings of the target site. Resolution should be in accordance with the scales described above (i.e. gradients should be resolved by several points) and the model needs to be validated by comparison with the observational data. After validation, the numerical model should be used to investigate potential scenarios, such as to estimate the potential impact of accidental spills or for certain extreme cases (e.g. atmospheric storms).

21. Modelling will be important in extrapolating from test mining to commercial-scale mining.

22. The third baseline data group (sediment properties, including pore water chemistry) is targeted at predicting the behaviour of the discharge plume and the effect of test-mining activity on sediment composition. In this context, the following parameters should be measured: specific gravity, bulk density, shear strength and grain size, as well as the sediment depth of change from oxic to suboxic, or suboxic to oxic, conditions. Measurements should include organic and inorganic carbon in the sediment, metals that may be harmful in some forms (iron, manganese, zinc, cadmium, lead, copper and mercury), nutrients (phosphate, nitrate, nitrite and silicate), carbonate (alkalinity) and the redox system in pore waters. The geochemistry of the pore water and sediments should be determined as far down as 20 cm. Recommended protocols are listed in tables 1 and 2 of chapter 23 of the Authority’s report entitled *Standardization of Environmental Data and Information: development of guidelines*. Representative pre-test-mining cores and sediment samples should be collected and archived.

23. The fourth baseline data group (biological communities) is targeted to collect data on “natural” communities, including “natural spatial and temporal variability”, to evaluate the potential effects of the activities on the benthic and pelagic fauna.

24. The characterization of pelagic and benthic communities should be carried out within all subhabitats that may be impacted by mining operations and to determine the regional distributions for the creation of preservation reference areas and for mitigation strategies to promote the natural recolonization of areas affected by mining activities.

25. Geographic Information System mapping tools are recommended for habitat mapping, recording sampling locations and planning stratified random sampling programmes.

26. Standard practices for the preservation of organisms should be followed, including discrete sampling of subhabitats into separate sample containers

(preferably insulated) with closed lids to prevent washing on recovery; recovery of samples within 12 hours of collection to obtain high-quality material; and immediate processing and preservation of samples on deck or maintenance in cold rooms for durations of no more than six hours before preservation (or less where molecular assays are planned).

27. Multiple preservation methods should be used, including preservation in formalin for taxonomic studies; freezing or preservation in 100 per cent ethanol for molecular studies; drying of whole animals and/or selected tissues for stable isotope analyses; and freezing of whole animals and/or selected tissue for trace metal and biochemical analyses.

28. Colour photographic documentation of organisms should be obtained whenever possible (organisms in situ and/or fresh material on deck to document natural colouration). The photographs should be archived.

29. All samples and sample derivatives (e.g. photographs, preserved material, gene sequences) should be linked to relevant collection information (the minimum requirement is date, time, method of sampling, latitude, longitude, depth).

30. Identification and enumeration of samples at sea and in the laboratory should be complemented by molecular and isotopic analyses, as appropriate. Species-abundance and species-biomass matrices should be standard products wherever practical.

31. Specimens must be archived for comparison with taxonomic identifications from other sites and to understand the details of changes in the composition of species over time. If species composition does change, it might be subtle, and reference back to the original animals (where there might only have been a putative identification) is essential. It is recommended that samples be archived as part of national or international collections.

32. Standardization of methodology and reporting of the results is extremely important. Standardization should include instruments and equipment; quality assurance in general; sample collection; treatment and preservation techniques; determination methods and quality control on board vessels; analytical methods and quality control in laboratories; and data processing and reporting. Method standardization will allow for comparison of results across provinces and lead to selection of critical parameters for monitoring efforts.

33. Spatial variation in the biological community must be evaluated prior to test mining by sampling at least three mineral deposits, if present, in the Area, each separated by a distance greater than the projected deposition of 90 per cent of the particles suspended by the mining operation. Because the populations of fauna of some deposits will be subsets of meta-populations that interact through dispersal and colonization, it is important to know the degree of isolation of populations occupying the mineral deposits that are to be removed and whether a given population serves as a critical brood stock for other populations.

34. Different kinds of sampling equipment can be used depending upon the seabed characteristics and the size of the fauna to be collected. Methods for collecting baseline biological data must therefore be adapted to each specific set of conditions. The use of multiple corers in soft sediments allows the distribution of different sampling tubes from the same station among the specialists that used different

techniques for fauna identification and counting. It should be stressed, however, that the diameter of the tubes must be adjusted to avoid excessive disturbance of the sediment or obstruction by large particles such as nodules and rock fragments and that biological samples must be large enough to generate good sample sizes in terms of abundance and biomass for robust statistical analyses.

35. Hard substrata (such as polymetallic sulphides, cobalt crusts, basalt), especially where the organisms are small, are challenging environments to sample quantitatively. Multiple collection techniques may be required, including slurp sampling and grab samples of larger organisms. Video documentation and photographic transects may be the only means suitable for developing a species-abundance matrix in some cases. Precision sampling using remotely operated vehicles is recommended for all habitats. Autonomous underwater vehicles or hybrid remotely operated-autonomous underwater vehicles may ultimately prove to be useful survey/sampling platforms. Exposed mineral surfaces may be irregular and, potentially, have steep slopes, which make them difficult to image quantitatively without the use of a remotely operated vehicle.

36. The data to be collected and the corresponding methodology for the various classes/sizes of seabed fauna should be as follows:

(a) **Megafauna**. Data on megafauna abundance, biomass, species structure and diversity should be based on video and photographic transects. Photographs need to have a sufficient resolution in order to identify organisms greater than 2 cm in their smallest dimension. The width covered by the photographs should be at least 2 m. As to sampling stations, the pattern of the photographic transects should be defined taking into account the different features of the bottom, such as topography, variability of the sediment characteristics and abundance and type of deposit. Species identification should be confirmed by collection of specimens at the site. Sampling efforts should be used to characterize the less abundant but potentially key megafauna in the system (including fish, crabs and other motile organisms). Representative samples of those organisms should be preserved for taxonomic, molecular and isotopic analyses;

(b) **Macrofauna**. Data on macrofauna (>250 μm) abundance, species structure, biomass and diversity should be obtained through a quantitative analysis of samples. In soft sediments, vertical profiles with a suitable depth distribution (suggested depths: 0-1, 1-5, 5-10 cm) should be obtained from box cores (0.25 m^2) or multiple corers, as appropriate;

(c) **Meiofauna**. Data on meiofauna (<250 μm, >32 μm) abundance, biomass and species structure should be obtained through a quantitative analysis of samples. In soft sediments vertical profiles with a suitable depth distribution (suggested depths: 0-0.5, 0.5-1.0, 1-2, 2-3, 3-4, 4-5 cm) should be obtained from cores. One multicorer tube per station could be devoted for this purpose;

(d) **Microfauna**. Microbial metabolic activity should be determined using adenosine triphosphate or other standard assay. In soft sediment vertical profiles should be obtained with suggested intervals for sampling of 0-0.5, 0.5-1.0, 1-2, 2-3, 3-4, 4-5 cm. One multicorer tube per station could be devoted for this purpose;

(e) **Nodule fauna**. Abundance, biomass and species structure of the fauna attached to the nodules should be determined from selected nodules taken from the top of box corers or sampled by remotely operated vehicle;

(f) **Demersal scavenger**. A time-lapse baited camera should be installed at the study area for at least one year to examine the physical dynamics of surface sediment and to document the activity level of surface megafauna and the frequency of resuspension events. Baited traps may be used to characterize the community species composition. Amphipod necrophage communities should be determined using short-term (24-48 hours) baited traps.

37. If there is potential for surface discharge, the plankton community in the upper 200 m of the water column should be characterized. Depending on plume modelling studies, it may be necessary to study plankton communities, especially gelatinous plankton, over a wide depth range. The pelagic community structure around the depth of the discharge plume, and at depths below, needs to be assessed prior to test mining. In addition, the pelagic community in the benthic boundary layer should be characterized using near-bottom opening/closing pelagic trawls or remotely operated vehicle techniques. Measurements should be made of phytoplankton composition, biomass and production, zooplankton composition, and biomass and bacterial plankton biomass and productivity. Temporal variation of the plankton community in the upper surface waters on seasonal and inter-annual scales should be studied. Remote sensing should be used to augment field programmes. Calibration and validation of remote-sensing data are essential.

38. Trace metals and potential toxic elements should be assessed in muscle and target organs of dominant demersal fish and invertebrate species. This should be replicated over time before test-mining operations begin (to measure natural variability) and thereafter at least annually to monitor possible changes resulting from test-mining activity. A combination of monitoring and shipboard and laboratory experimentation may be necessary to resolve, prior to test mining, potential ecotoxicological impacts, including possible impacts on phytoplankton and zooplankton if the discharge plume occurs at the sea surface or in mid-water.

39. Temporal variation must be evaluated for at least one test-mining site and the preservation reference site prior to the test-mining activity (ideally, with a minimum of annual sampling over at least three years). The temporal study should be reviewed by the Authority prior to the start of test mining. Studies of temporal variation at the seabed should be based on video and/or photographic surveys. For sulphide deposits, associated temperatures and sampling of subhabitats are required. Simple time-lapse photography seabed observatory systems recording the seabed four to five times per day over a period of a year would provide high-resolution temporal data. Where possible, ecosystem studies, such as growth rates, recruitment rates and the trophic status of dominant taxa, should be carried out. Where multiple test-mining sites are identified, the contractor must assess the degree to which temporal studies at one site are applicable to another; this assessment should also be reviewed by the Authority.

40. Taxonomic standardization should be addressed. To facilitate identification, there should be an exchange of identification codes, keys, drawings and sequences at major laboratories and collections that carry out taxonomic studies of marine organisms. Taxonomic expertise is extremely limited, even for major faunal groups (e.g. fish, molluscs, decapod crustaceans, corals, sponges and echinoderms). It will be important for all taxonomic groups to be assessed at each site. This can be accomplished most efficiently through the development of cooperative taxonomic centres or groups of experts. Taxonomy by numbers (e.g. species 1, species 2), if

consistent rules are used and vouchers maintained, is a good basis for baseline studies, but classical and molecular taxonomy must be supported, either directly by the contractor or as part of cooperative research programmes. Molecular methods continue to advance rapidly, making biotic surveys at all levels, especially the level of microorganisms, much more rapid and economically feasible than at present. Molecular sequences should be deposited in Genbank or equivalent internationally recognized sequence databases.

41. Information on faunal succession following test mining is essential to determining recovery rates of benthic populations from the effects of mining. Data should include samples from the immediate test area before and after test mining, from selected distances away from the mined area to determine the effect of the benthic plume, and at repeated intervals after test mining. Such impact experiments may be conducted collaboratively.

42. Additional information on the effects of the discharge plume on pelagic fauna may be gathered by recording unusual natural events, such as fish kills and unusually large concentrations of fish, marine mammals, turtles and birds.

43. The vertical distribution of light directly affects primary productivity in the euphotic zone. If there is surface discharge, vertical light-intensity profiles will show the effect of discharged particles on light attenuation and spectral bands over time, depth and distance from the mining ship. Those values can be used to detect any accumulation of the suspended particles at the pycnocline. In addition, any discharge plume may result in the release of large amounts of nutrients, temperature changes, the release of carbon dioxide and (at sulphide sites) potential changes in pH and ocean acidification.

44. The fifth baseline data group (bioturbation) is targeted at collecting the background “natural” rates of sedimentary processes, including “natural spatial and temporal variability”, in order to model and to evaluate the effects of mining activities on such processes. Rates of bioturbation (i.e. the mixing of sediments by organisms) must be measured to analyse the importance of biological activity prior to a mining disturbance and can be evaluated from profiles of excess Pb-210 activity from cores, taking into account the variability in the sediment. Excess Pb-210 activity should be evaluated on at least five levels per core (suggested depths are 0-0.5, 0.5-1.0, 1-1.5, 1.5-2.5 and 2.5-5 cm). Rates and depth of bioturbation are to be evaluated by standard advection or direct diffusion models.

45. The sixth baseline data group (sedimentation) is targeted at collecting data to model and evaluate the effects of the discharge plume. It is recommended that deployment of moorings with sediment traps on a mooring line be undertaken, with one trap below 2,000 m to characterize the particulate flux from the euphotic zone and one trap approximately 500 m above the sea floor to characterize the flux of materials reaching the sea floor. The bottom trap must be high enough above the bottom so as not to be influenced by sediment resuspension. Sediment traps should be installed for a suitable period of time, with samples collected monthly to examine seasonal changes in flux and to evaluate inter-annual variability, in particular between climatic event years (e.g. El Niño, La Niña). The trap installation may share the same mooring as the current meters described above. Given that the flux of materials from the upper water column into the deep sea is ecologically significant in the food cycle of bottom-dwelling organisms, an adequate characterization of the material flux in mid-water and flux to the sea floor is

necessary for a comparison with the effect of the tailings discharge. Knowledge of in situ settling velocities for test-mining discharge particles, both in mid-water and near the sea floor, will help to verify and improve the capacity of mathematical models for predicting the dispersion of the mid-water and benthic plumes. This information is relevant to the concerns expressed regarding the discharge plume and from the operation plume on the benthic biota and benthic boundary layer pelagic organisms. The temporal resolution of the particle-flux measurements must be one month or better and nephelometry time series should be recorded on the sediment traps.

46. The seventh baseline group (geological properties) is targeted at determining the heterogeneity of the environment and assisting the placement of suitable sampling locations.

47. High-resolution, high-quality bathymetric data should be collected over the area where the dispersal of test-mining by-products is expected to significantly affect the environment (i.e. over the entire region covered by the numerical circulation model).

48. As part of the high-resolution baseline survey, a suite of representative pre-mining cores of the sea floor sediment, where appropriate, should be collected and stored in a suitable repository. Sampling devices that collect undisturbed samples of the top few centimetres should be used.

49. For sulphide deposits, hydrothermal vent areas should be classified as either dormant vent sites, which are still under the potential influence of a heat source although there is no current venting of hydrothermal fluids evident at that time, or extinct sites, which are at sites remote from present-day heat sources. From an ecological point of view, these two scenarios can be considered largely equivalent. What is important biologically is whether the proposed mining site has active hydrothermal vents (case 1), inactive vents that may restart owing to mining activity (case 2) or inactive vents that will remain hydrothermally inactive even when disturbed by test mining (case 3). It is important that the baseline assessment determine which of those cases will apply.

50. Part IV of the recommendations deals with environmental impact assessment. Certain activities have no potential for causing serious harm to the marine environment and therefore do not require environmental impact assessment. Such activities are listed. With regard to activities that do require environmental impact assessment, a monitoring programme is needed before, during and after a specific activity to determine the effects of the activity on the biological activities, including the recolonization of the disturbed areas.

51. The environmental studies during exploration will be based on a plan proposed by the contractor and reviewed by the Legal and Technical Commission for completeness, accuracy and statistical reliability. The plan would then be incorporated into the programme of activities under the contract. The environmental studies to be conducted during exploration will include the monitoring of environmental parameters so as to confirm the findings that there is no serious environmental harm from any activities being conducted on the seabed, in mid-water and in the upper water column.

52. Tests of collecting systems are an opportunity to determine the environmental implications of mining. The contractor will submit to the Authority a plan for such

testing, including the details for monitoring the environment, at least one year before testing begins and at least three months in advance of the annual session of the Authority. A plan for testing of collection systems shall include provision for monitoring of those areas impacted by the contractor's activities which have the potential to cause serious environmental harm, even if such areas fall outside the proposed test site. The programme will include, to the maximum extent practicable, specification of those activities or events that could cause suspension or modification of the tests owing to serious environmental harm if the specified activities or events cannot be adequately mitigated. The programme will also authorize refinement of the test plan prior to testing and at other appropriate times, if refinement is necessary. The plan will include strategies to ensure that sampling is based on sound statistical methods, that equipment and methods are scientifically acceptable, that the personnel who are planning, collecting and analysing data are well qualified and that the resultant data are submitted to the Authority in accordance with specified formats.

53. During the mining tests, the notification of proposed impact reference zones and preservation reference zones is recommended. The impact reference zone should be selected based on the area being representative of the environmental characteristics, including the biota, of the site where test mining will take place. The preservation reference zone should be carefully located and be large enough so as not to be affected by the natural variations of local environmental conditions. The zone should have species composition comparable to that of the test area. The preservation reference zone should be outside the test area and areas influenced by the plume.

54. The monitoring programme proposed by the contractor must provide details of how the impacts of the test-mining activities will be assessed.

55. Part V of the recommendations deals with data collection and reporting. It is recommended that collection and analytical techniques follow best practices such as those developed by the Intergovernmental Oceanographic Commission of the United Nations Educational, Scientific and Cultural Organization and available at world data centres, national oceanographic data centres or those recommended by the Authority. An inventory of the data holdings from each contractor should be accessible on the World Wide Web via the Authority.

56. The environmental baseline studies and the monitoring programmes represent a significant source of data and knowledge. A data archival and retrieval scheme could assist all contractors in the search for environmentally significant indicator elements. Syntheses of data and experience can work to the advantage of all contractors. Increased data accessibility increases the likely accuracy of models and will assist in:

(a) Identification of best practices;

(b) Development of a common approach to data management;

(c) Multilateral exchange of views and data leading to international cooperation;

(d) Savings of time, effort and costs in alerting the community to failures;

(e) Savings through reduction of measurement of some parameters.

57. Models can be validated and fine-tuned by such sea-truthing of data and can then partially supplement costly data collection exercises. Some claim areas may lie adjacent to or in the vicinity of other claims, providing further justification for data accessibility and joint efforts in modelling, so that the impact of activities in neighbouring areas can be evaluated without repeating all aspects of environmental assessment.

58. Part VI of the recommendations deals with cooperative research and recommendations to close gaps in knowledge. Recent years have witnessed a revolution in the development of knowledge and technology in deep-sea science. A number of research institutes around the world are carrying out extensive research programmes. Those institutions have considerable biological and scientific expertise and could be willing to join with mining contractors in conducting some of the required environmental research. They could provide sampling equipment and expertise and would probably be eager to join the contractor's vessel and to assist in sampling remote areas.

59. Cooperative research can facilitate the establishment of baselines of natural variability on the basis of geological, biological and other environmental records acquired in selected areas.

60. A partnership between the scientific community and contractors may result in voucher collection repositories, a gene sequence database repository, stable isotope analysis and interpretation and a photographic library of species/specimens. The basic scientific information acquired in partnership should result in the cost-effective acquisition of information that will assist in development planning and decision-making and the timely recognition of any significant environmental effects or issues prior to and during test mining. This information can be used to find solutions with a minimum-conflict approach.

61. The risk of extinction for a significant fraction of a community of fauna within a test-mine site will depend largely on how localized or widespread the species are distributed. Assessment will require syntheses of the biogeography of the fauna. This assessment should be facilitated by collaboration among contractors and with the scientific community.

62. Modelling studies should be undertaken collaboratively and linked closely to the field studies so as to assess extinction risks under various management strategies, including various options for the design of protected areas. Overall conservation strategies need to take into account non-test-mining impacts on faunal communities.

63. The contractors should work together, with the Authority and with national and international scientific research agencies on cooperative research programmes to maximize the assessment of environmental impact and minimize the cost of these assessments.

64. The Convention states that the Authority shall promote and encourage the conduct of marine scientific research in the Area, and shall coordinate and disseminate the results of such research and analysis when available.

Annex II

Glossary of technical terms

Active sulphides	Polymetallic sulphides through which warm water is flowing. Active sulphides (also called hydrothermal vents) deliver reduced compounds (e.g. sulphide) to the sea floor-seawater interface where they can be oxidized or otherwise autotrophically metabolized by free-living or symbiotic microorganisms.
ATP	Adenosine triphosphate, a complex organic compound which serves for short-term energy storage and conversion in all organisms. The amount of ATP present can be used as a measure of total microbial biomass in the sediment, as it corresponds to the number of active cells, most of which are bacteria.
Bathypelagic	Pertaining to open-ocean environments at depths greater than 3,000 m, deeper than the mesopelagic zone.
Benthic	Pertaining to the ocean bottom.
Benthic boundary layer	Pertaining to the layer of water immediately above the ocean bottom water layer/sediment interface.
Benthopelagic	Pertaining to the zone very close to, and to some extent having contact with, the sea floor of deeper portions of the open ocean.
Benthos	The forms of marine life that live on, or in, the ocean bottom.
Chemosynthesis	Process by which microorganisms metabolically transform inorganic carbon to organic carbon (cells), using energy derived from oxidation of reduced compounds. Chemosynthesis is the basis for the food web associated with deep-sea hydrothermal vents. “Chemoautotrophy” is a more descriptive and precise term for the general phenomenon of chemosynthesis; the two words are often used interchangeably.
Cobalt-rich ferromanganese crusts	Ferromanganese crusts with enriched cobalt content typically formed by precipitation and found on hard substrates in the deep sea on features with significant topographic relief, such as seamounts and ridges.
CTD	Pertaining to a system for measuring conductivity (indicator of salinity), temperature and depth (defined from pressure measurements). The first two parameters are essential in oceanographic observations and the depth profile is required to delineate the vertical structure of the ocean. Additional parameters, such as pH and dissolved oxygen concentration, can be measured if optional sensors are installed.

Cumulative impacts	Impacts resulting from incremental changes caused by other past, present or foreseeable actions.
Demersal	Organisms living at, or near the bottom of, a body of water.
Diel	Involving a 24-hour period that usually includes a day and the adjoining night.
Direct impacts	Impacts caused as a direct result of an action, such as loss of habitat and populations owing to removal of sulphides or other materials.
Embolism	The blood and tissues of fish contain dissolved gases. If fish from the deep ocean are brought to the surface, the decrease in pressure allows the dissolved gas to expand in the form of bubbles (embolism), causing disfiguration and protrusion of the internal organs through the mouth and other orifices.
Endemism	The degree to which a species is restricted to a particular geographic region; usually occurs in areas that are isolated in some way. Biologists also use the term "endemic" to refer to an organism that may be geographically widespread, but is restricted to a specific habitat, e.g. hydrothermal vents.
Epifauna	Animals that live on the bottom, either attached to the sea floor or freely moving over it.
Epipelagic	Referring to the upper region of the ocean depths, above the mesopelagic and generally below the oxygen-minimum zone.
Euphotic zone	The upper section of the ocean which receives sufficient light for photosynthesis. In clear oceanic waters, the euphotic zone can extend to a maximum water depth of 150 m.
Fauna	Invertebrates and vertebrates.
Halocline	A layer of water in which there is a steep gradient in salinity.
Hard substrata	Outcrops in the form of carbonate concretions, solid material, crustal rocks or deposits of precipitated materials, metals and minerals discharged from the subsurface by hydrothermal systems.
Hydrodynamic	Referring to any event relevant to the movement of sea water.
Impact zone	Zone where impacts (direct, indirect, cumulative and/or interactive) result from the activity.

Impact reference zones	Areas used to assess the effect of activities in the Area on the marine environment; must be representative of the environmental characteristics (physical, chemical, biological) of the area to be mined.
Inactive (or dormant) sulphides	Polymetallic sulphides through which warm water is no longer flowing into the overlying seawater (i.e. they are “cold”). Disturbance of these sulphides may result in renewal of hydrothermal fluxes into the water column, turning inactive sulphides into active sulphides (hence the concept of “dormant” sulphides).
Indirect impacts	Impacts on the environment that are not a direct result of the activity, often produced away from or as a result of a complex pathway (physical, chemical and biological). Often referred to as secondary (or even tertiary) impacts.
Infauna	Organisms that live within the sediment.
Macrofauna	Animals large enough to be seen by the naked eye, up to 2 cm long.
Megafauna	Animals large enough (larger than 2 cm) to be determined in photographs, proposed as key taxon (see taxonomy) for environmental impact assessment in deep-sea mining.
Meiofauna	Animals of the benthic community that are intermediate in size between macrofauna and microfauna. Operationally defined as >32 µm and <250 µm.
Mesopelagic	Referring to the portion of the oceanic province that is below the epipelagic and above the bathypelagic, usually corresponding to the dimly lit ocean or “twilight zone”.
Microfauna	Organisms invisible to the naked eye, smaller than meiofauna. Operationally defined as <32 µm.
Microorganisms	Includes bacteria, Archaea and microscopic Eukarya.
Nekton	Fish, squids, crustaceans and marine mammals that are active swimmers in the open ocean environment.
Nematoda	The class of roundworms; a dominant meiofauna constituent.
Oxygen minimum	A water layer present in all oceans at depths between 400 and 1,000 m, caused by the sinking and degrading by bacteria of organic matter produced in the surface ocean. The oxygen scarcity can cause particulate metals to dissolve.
Pelagic	Pertaining to the open ocean environment.
pH	A measure of acidity or alkalinity.

Photosynthesis	The biological synthesis of organic material using light as energy source. Plants convert carbon dioxide and water, in the presence of chlorophyll and light energy, into carbohydrate food and oxygen.
Phytoplankton	Microscopic plants that are primary producers in the oceans.
Plankton	Passively drifting or weakly swimming organisms. This includes larval stages of benthic and pelagic organisms, phytoplankton (in surface waters), zooplankton, jellies and other drifting or weakly swimming organisms.
Plume	A dispersion of seawater that contains dense sediment particles. Benthic plume is a stream of water containing suspended particles of sea floor sediment, abraded manganese nodules and macerated benthic biota that emanates from the mining collector as a result of collector disturbance of the sea floor and spreads in a zone close to the sea floor. The far-field component of the benthic plume is termed the “rain of fines”. Surface plume is a stream of water containing suspended particles of sea floor sediment, abraded manganese nodules and macerated benthic biota resulting from the separation, on board the mining ship, of the nodules from the water carrier and spreads in a zone closer than benthic plume to the ocean surface.
Polymetallic sulphides	Hydrothermally formed deposits of sulphides and accompanying mineral resources in the Area, which contain concentrations of metals including copper, lead, zinc, gold and silver.
Pore water	The water present within the spaces between sediment particles; also called “interstitial water”.
Preservation reference zones	Areas representative of the test-mining site, but in which no test mining shall occur; used to assess changes in the biological status of the environment caused by test-mining activities.
Pycnocline	A layer of water in which there is a steep gradient in density with depth. It separates the well-mixed surface waters from the dense waters of the deep ocean. Density of the water is a function of temperature, salinity and, to a lesser extent, pressure.
Rain of fines	Far-field component of the “benthic plume” that consists mainly of fines; sedimentary particles which drift with the bottom current and slowly settle to the sea floor, generally outside the specific mining area.

Redox system	One essential chemical reaction is oxidation (giving electron) and reduction (removing electron). The chemical tendency (environmental strength) of oxidation can be expressed by redox potential (mv) that can be measured by an Eh/Ph meter. Eh is strongly correlated to the dissolved oxygen concentration in the sediment.
Scavenger	An animal that eats waste products and dead remains of other animals and plants that they did not kill themselves.
Seamounts	Isolated topographic features, usually of volcanic origin, of significant height above the sea floor.
Spatial scales	Scales characteristic of dimensions in space, as of oceanic phenomena, for example, the diameter of an eddy or the length of a wave. Also pertains to the geographical arrangement of sampling stations.
Subhabitat	A visually recognizable component of a larger habitat, e.g. tubeworm and mussel beds may be subhabitats of a specific active polymetallic sulphide field; an operational term that facilitates an understanding of the habitat as a whole.
Symbioses (chemosynthetic)	Associations between bacteria (symbionts) and invertebrates or vertebrates (hosts), in which the symbionts are chemosynthetic and provide nourishment to the host. The bacteria may be either endosymbiotic (living within the host tissues, such as tubeworms, clams, mussels) or episymbiotic (living on the outside of the host, such as bresiliid shrimp, alvinellid polychaetes).
Synoptic scales	Scales of hydrodynamic variability or events encompassing temporal scales ranging from one to two weeks to one to two months and spatial scales of one to several hundred kilometres. A typical feature is synoptic eddies 100-200 km in diameter passing through the north-east tropical Pacific from east to west and often penetrating to the sea floor.
Taxonomy	Orderly classification of animals or plants according to their presumed natural relationship.
Test mining	The use and testing of recovery systems and equipment.
Thermocline	A layer of water in which there is a rapid change of temperature with depth.
Transect	The vertical plane (reference for all the measures and sampling taken during the survey), from surface to the sea bottom, of the route of a survey oceanographic vessel, from point A to point B.

Transmissometer	Device used to measure the attenuation of light through a given path, such as of water. Data can be correlated to the amount of particles present.
Zooplankton/Animal plankton	Unlike phytoplankton, these organisms cannot produce organic matter on their own and thus feed on other organisms.