Chapter 6 Benthic Communities

6.1 INTRODUCTION

During the review of environmental documentation for the Sakhalin II development, the stakeholders to the project outlined a number of concerns and items requiring clarification as a result of reviewing the international-style Environmental Impact Assessment (EIA) report (SEIC 2003). In brief, the focus of the questions raised by interested parties regarding benthic communities included the following matters:

- Provision of additional text on the sampling and analytical methodologies used for the benthic surveys;
- Description and discussion of the site selection analysis for the disposal of dredged material in Aniva Bay;
- Clarification as to whether the reporting of any rare or endangered benthic species was undertaken;
- Clarification of the Terms of Reference for long-term monitoring in terms of how this will take into account the natural high variability in benthos;
- Clarification of the items in the discussion of benthic recovery following installation of the PA-A platform;
- Elaboration on current benthic sampling methodology and the provision of an update on any changes that have occurred since 2003.

This chapter answers these questions and concerns and as well as presenting descriptions and clarifications, offer additional information to that contained in the 2003 international-style EIA (Volume 2, Section 1.6.3). In particular, this section provides additional information on the benthic communities in the Sakhalin shelf and site-specific data on the baseline benthic environment in the vicinity of the Piltun-Astokhskoye and Lunskoye fields, associated pipeline corridors and Aniva Bay. The site selection analysis for the disposal of dredged material in Aniva Bay is elaborated upon and discussed more fully in Chapter 12 of the EIA-A.

6.2 BASELINE SURVEYS

A number of benthic surveys (as described in the following sections) have been carried out to assess the faunal species distribution and biomass in the Sea of Okhotsk and along the north-eastern Sakhalin shelf. A significant proportion of these have been undertaken specifically for characterisation and impact assessment purposes related to this project.

These included a number of site-specific surveys of the seabed around the Piltun and Lunskoye fields and, to a more limited extent, in Aniva Bay.

These surveys have been documented in a number of baseline reports during the course of the original EIA and for this Addendum, including Koblikov (1982), Dulepova and Borets (1990), Coastal Shelf Associates (CSA 1998 and

1999), DVINIGMI (2001 and 2002), SakhNIRO (1999 and 2003), Kussakin *et al.* (2001), FERHRI (2003) and FESTU (2003a). The following sections therefore provide a synopsis of the benthic communities present in each of the key project areas and reference to specific survey findings have been made where relevant. This is presented to provide a more complete description of the baseline benthic data available for each of the key project areas. Locations referred to in the text are also shown on Figure 6.1.

6.2.1 North-east Sakhalin Shelf

The benthic fauna of the shelf system of north-east Sakhalin has been investigated by a number of researchers since the early 1980s, notably Koblikov (1982), Averintsev *et al.* (1982), Borets (1985), Dulepova and Borets (1990) and Kussakin *et al*. (2001). This work indicates that the species composition and distribution of benthic communities of the shelf area are largely controlled by sediment types and water depth. Variable biomass and diversity values have been recorded in these studies. Averintsev *et al*. (1982) observed large populations of the sea urchin sand dollar *Echinarachnius parma* in water depths of 15-120m, covering an area of over 13,000km^2, (*i.e.* about 40% of the shelf area). The *E. parma* community is associated with fine sand and muddy sand, in areas of relatively high current activity with numbers decreasing as the mud content of the sediment increases towards the south of the shelf (reflecting a reduction in current strength).

Data from Dulepova and Borets (1990) and Borets (1985) shows that the shelf area of north-eastern Sakhalin differs from other parts of the Okhotsk Sea by the relatively high abundance of sand dollars and amphipods. Their survey results revealed that amphipods comprised 7.5% of total biomass, while in other parts of the Okhotsk Sea values for this group of crustaceans ranged from 0.7% (on the Pritauyiskii shelf) to 2.5% of the total biomass in Terpeniya Bay. These data compare with that published by Koblikov (1982).

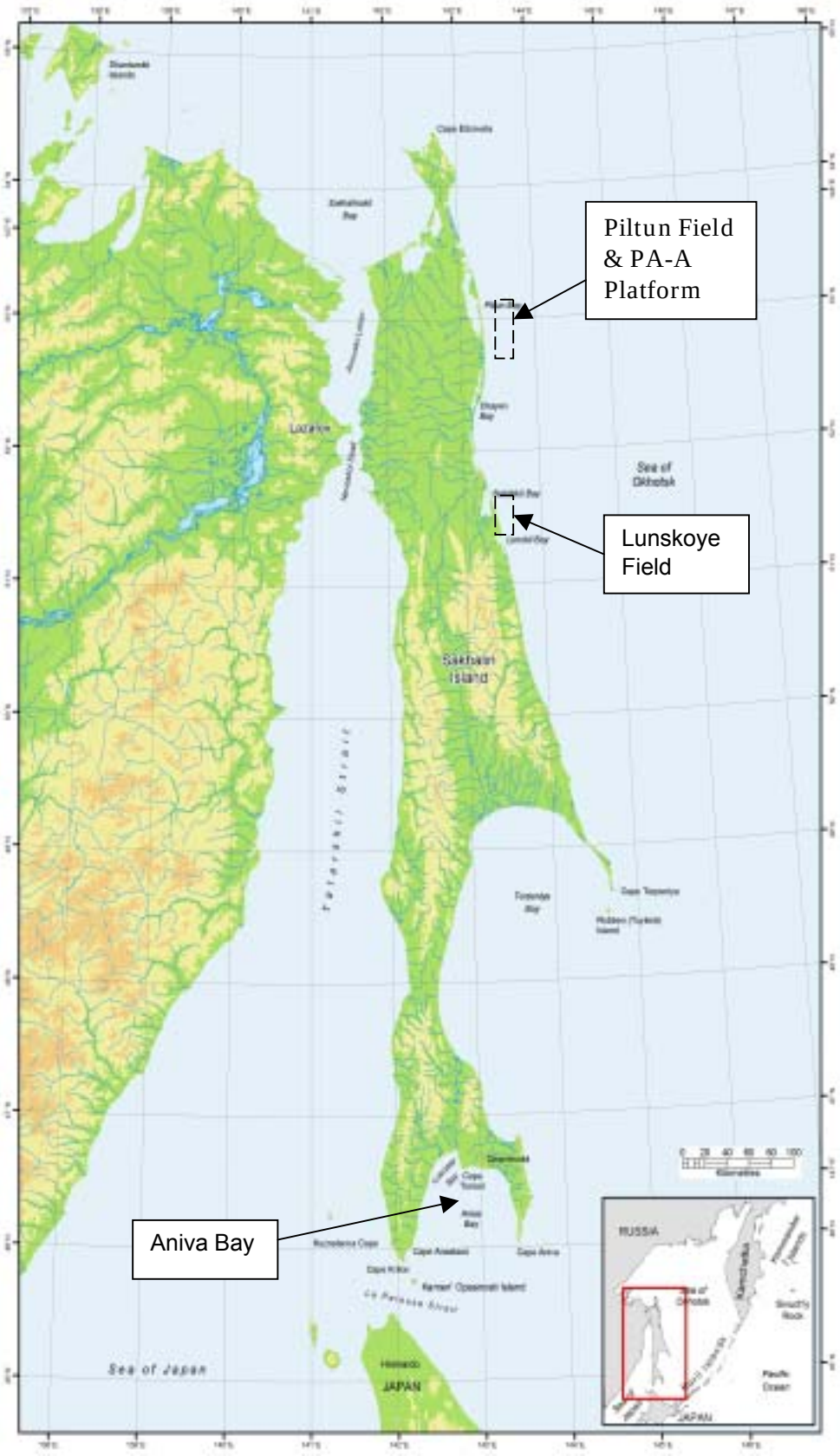

Figure 6.1 Key Areas and Locations mentioned in the text

The mean benthic biomass for the shelf area (to a depth of 100m) has been calculated as 500g/m^2 with values varying with sediment type and the presence/absence of certain key species (e.g. *E. parma*). Relatively high biomass is reported for depths to 100m in the north and central shelf. Koblikov (1982) presented a mean benthic biomass value of 428.6g/m^2 for the shelf area between Schmidt Cape in the north to the Cape of Lunskii Bay in the south. This figure is comparable with that reported by Kussakin *et al.* (2001) who quoted a range of 200 to 500g/m^2 for this area, of which sea urchins comprised 58% biomass, crustaceans 12.3%, bivalve molluscs 7.4% and polychaetes 4.9%. For the southern area from Lunskii Bay to Terpeniya Cape the mean biomass is considerably less, with a mean of 211.8 g/m^2, largely due to a decrease in the abundance of the sand dollar *E. parma*. The change in mean biomass from the north-eastern shelf southwards has been noted by a number of researchers (Koblikov 1990 and Dulepova and Borets 1990) and is clearly illustrated in Figure 6.2.

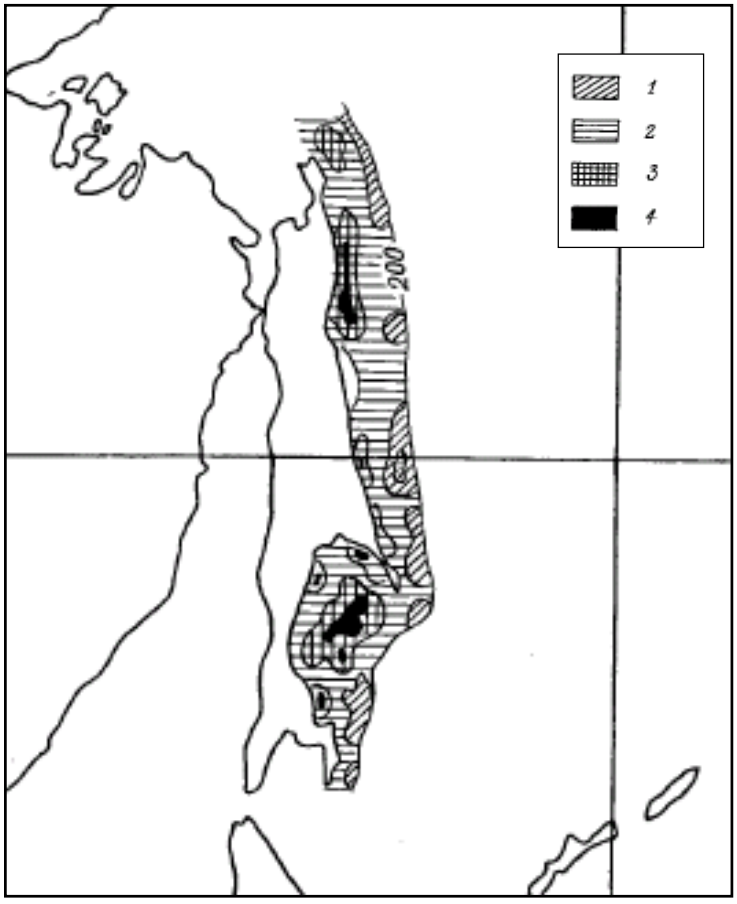

Figure 6.2 Quantitative Distribution of Benthos on the Shelf of Eastern Sakhalin (from Koblikov et al. 1990). [1 = 5-100g/m^2; 2 = 100-500g/m^2; 3 = 500-1000g/m^2 and 4 > 1000g/m^2]

Further offshore, as the water depth increases to 200m, the biomass values remain relatively high, largely due to the presence of the bivalve molluscs *Ciliatocardium ciliatum tchuktchensis* and *Liocyma fluctuosa,* the sand dollar *E. parma* and the polychaetes *Travisia forbesii* and *Praxilella praetermissa*.

6.2.2 Piltun Field

A number of specific survey programmes to determine the benthic interest of the nearshore shelf in the Piltun area have been undertaken since 1998, particularly with respect to an investigation of the benthic communities in and around the area where the Molikpaq platform (PA-A platform) has been constructed.

Data gained from these surveys indicate that the sediments within the Piltun field and along the proposed pipeline corridor primarily comprise fine to medium grain sands with areas of fine and medium gravels. A gradual decrease in particle size from platform to shore was also observed (TEOC Volume 3 Book 8: Offshore Pipelines at P-A Oil Field, 2002). Annual perturbations of the benthos from ice-scour in water depths to 20m (January to April) and storm waves create an unstable physical environment that may be responsible for the dominance of opportunistic species such as the cumacean (a group of small sediment dwelling crustaceans) *Diastylis bidentata* and suggests that the benthic fauna is adapted to physical change with annual cyclicity.

The 1998 characterisation survey (CSA 1998 and SakhNIRO 1999) obtained 67 benthic sediment samples from stations in the Piltun area and along two initially proposed pipeline routes (see Figure 6.3). The northernmost of these pipeline routes (as shown in Figure 6.3), directly from the PA-B platform to shore, was rejected in favour of a route from the PA-B platform via the PA-A (Molikpaq) platform to shore.

The most numerous taxa were amphipods (38 species) and polychaetes (31 species) and, to a lesser extent, bivalve molluscs (18 species). The total faunal density varied from 80 to 106,400 individuals per square metre (ind/m^2) with *Diastylis bidentata* being particularly abundant (contributing over 50% of the macro-infaunal abundance at 65 of the 84 stations). Bivalves accounted for 26% of the total faunal density (excluding cumaceans). By far the most numerous bivalve species was *Mysella kurilensis* (*tumida*) observed at a maximum density of 13,440 ind/m^2. The sand dollar *E. parva* accounted for 14% of the density with numbers at some stations exceeding 1,000/m^2. Polychaetes accounted for 8% of individuals while actinids (sea anemones) – the most dominant species being *Halcampa* sp. and *Epiactis lewisii* – accounted for 3% of the total benthos. The total biomass varied from 10 to 17,062g/m^2 with *E. parva* predominating (67-99% of the total biomass) followed by *D. bidentata*. These two species, along with the priapulid worm *Priapulus caudatus*, were the most frequently encountered animals in the sediment samples taken in the Piltun area.

A survey conducted in 2001 (reported in FERHRI, 2003) covered three main areas comprising the general P-A Field, and the PA-A and PA-B platform areas. In the vicinity of the platforms, stations were located along four radii - north, south, east and west – at distances of 250m, 500m and 1,000m from the platforms with the remaining stations located randomly within the

prescribed field limits. In total, 146 species of macroinvertebrates were identified during the survey work. The recorded faunal communities were similar to those reported by SakhNIRO (1999), with polychaetes (48 species) and amphipods (46 species) dominating and bivalves (17 species) also forming a significant component of the fauna. The highest species diversity was observed at the sample stations in the general P-A field area. Around the proposed PA-B platform area: 15 taxonomic groups (83 species) were found compared with ten taxonomic groups (58 species) around the PA-A platform area. Species density and biomass for the three areas are summarised in Table 6.1 below. Observed variation in biomass and distribution was attributed to the presence of mixed sediment types. The highest biomass values were recorded from areas of fine and medium sand, largely due to the presence of significant populations of the sand dollar *E. parma* and the cumacean *Diastylis bidentata*.

Table 6.1 Survey Assemblage Summary Statistics for the Piltun Field area (FERHRI 2003)

Area	Number of Samples	Mean Biomass (g/m^{-2})	Density (ind/m^2)
PA Field Stations	37	579.0	17,191.3
PA-A Platform Stations	7	262.2	8,007.2
PA-B Platform Stations	13	199.5	23,549.9

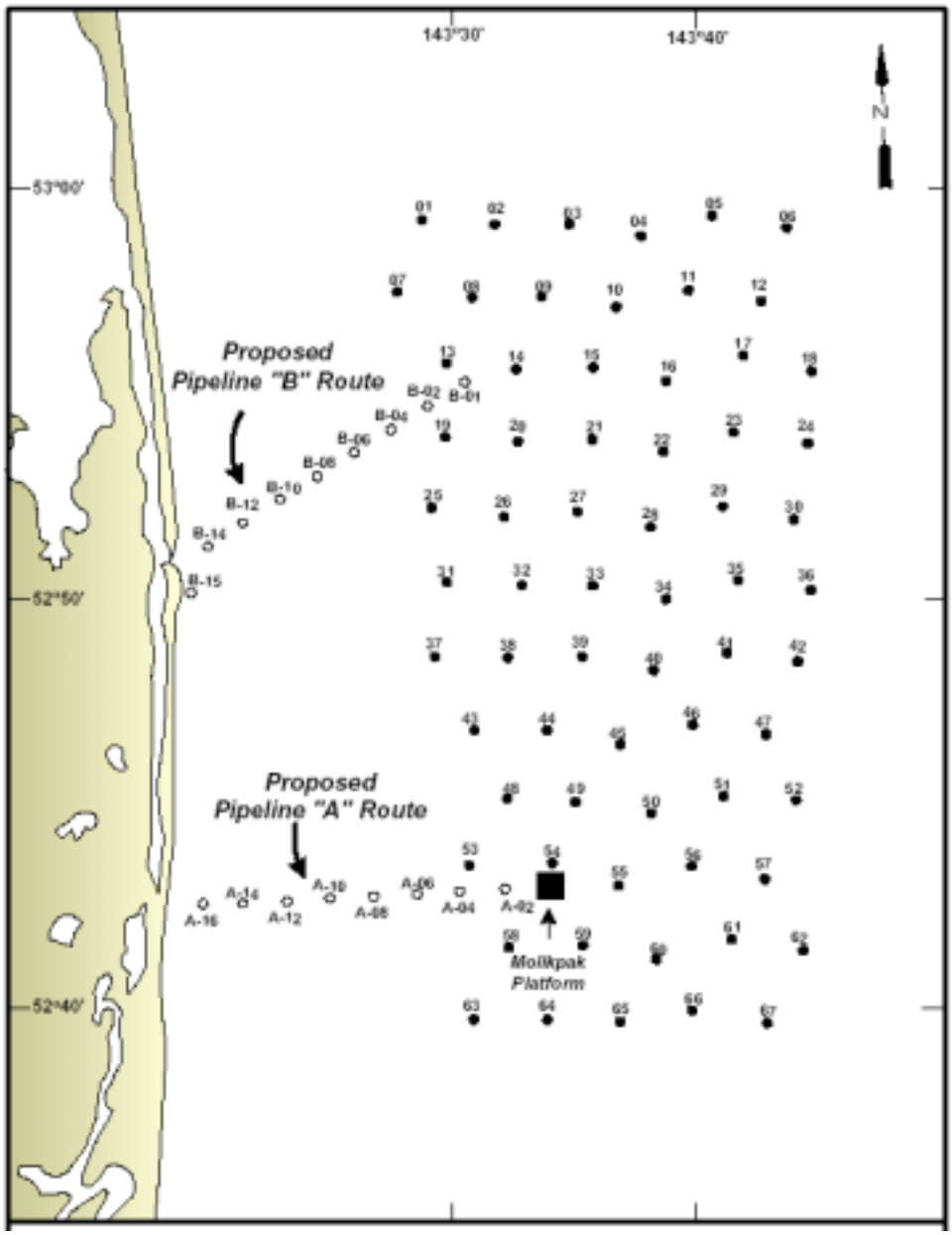

Figure 6.3 Benthic Survey Coverage of the Piltun Field for the 1998 Characterisation Survey (CSA 1998 and SakhNIRO 1999)

6.2.3 PA-A (Molikpaq) Monitoring surveys

A number of surveys in the PA-A platform area were commissioned as part of the Phase I Project to focus on determining baseline conditions before and after the installation of the platform in order to monitor changes to benthic communities and verify the previous assessment of likely impact.

In this context, the following description provides some basic knowledge of the physical environment, which is important in order to understand the context of the monitoring results. The environment into which the PA-A platform has been installed is physically highly dynamic, being affected by a strong diurnal tidal regime, heavy wave action in autumn and by sea-ice in winter. Tidal streams flood southward and ebb northward; the average resultant current is approximately 30 cms^{-1} southwards, while the maximum flows measured in the survey were 145 cms^{-1} (2.8 knots) southward and 114 cms^{-1} (2.2 knots) northward (ASL 2000). Significant wave heights of 6m in autumn and a maximum wave height of 11.75m were recorded during survey work in 1999 (ASL 2000).

The benthic communities and species occurring in the platform area (and much of the north-east shelf where these conditions predominate) are adapted to these dynamic conditions, in which perturbations and disturbance are a common and regular occurrence.

The available benthic monitoring data for the Molikpaq area covering the period 1998-2002 has been analysed by Rudall Blanchard Associates (RBA 2003). This analysis provided an overview of observed changes in the benthic communities following construction of the platform. As expected and typically of the hydrodynamic regime, the results of grain-size analysis confirm that coarse sands and gravels predominate around the platform location.

However, significant quantities of fine sand (up to 40% of sediment) and silt/clay (up to 10% of sediment) were also present. The seabed sediments are very patchy with large differences between replicate samples at a single station in one year and also large variations between average values for a station between years. This suggests that the surface sediments are highly mobile and that fine material in particular is continually deposited on the seabed and re-suspended by current and wave action.

Variations in the number of species present in the benthic community, the community diversity, biomass and other univariate statistics have been documented in the original survey report (CSA 1999) and reviewed by DVNIGMI (2002). By way of examples of these variations, Table 6.2 provides summary statistics from the pre-construction and post-construction survey work undertaken by CSA in 1998 and 1999.

Table 6.2 PA-A Platform Benthic Survey Assemblage Summary Statistics (CSA 1998 & 1999)

	PA-A Platform Stations (Pre-installation)	Reference Stations (Pre-installation)	PA-A Platform Stations (Post-installation_	Reference Stations (Post-installation)
Numbers of Taxa	22-69	27-38	21 – 73	29 – 36
Density (m^2)	2,425-103,595	17,360-37,430	3,540 - 899,940	6,170 - 108,875
Diversity (H')	0.11-2.85	0.26-0.94	0.03 - 3.20	0.12 - 0.96
Evenness (J')	0.04-0.72	0.08-0.29	0.01 - 0.75	0.04 - 0.28
Species Richness (D)	2.22-8.56	3.12-4.54	1.89 - 9.13	2.80 - 4.07

For the PA-A platform area, the data values for a range of benthic parameters are generally comparable, although a slight increase in all of the parameters following construction was observed. The situation with the reference stations was less consistent with the data showing a minor decrease in species richness, evenness and taxa number and a small increase in species density and diversity. An analysis using Tukey's HSD test (Honestly Significant Difference test) of variation in species density for the ten most abundant species from the pre- and post-installation data indicated that four species (*Crenella decussata decussata*, *Eteone longa*, *Exogone gemmifera* and *Sphaerosyllis californiensis*) decreased at all four stations within 125m of the PA-A platform area and at a limited number of other stations. Similarly, *Glycera nana* decreased at three of the four 125m stations. These results indicate that installation of the platform only affected the composition of the macroinfaunal assemblage in the near vicinity of the PA-A platform area.

The DVNIGMI (2002) review of monitoring data also concluded that observed variations in the data could not be attributed to the construction and operation of the PA-A platform. This conclusion has been further consolidated by multivariate analysis of the monitoring data covering the period 1999-2002 (RBA 2003). The results of the analysis indicate that there is no temporal trend in the data; the variation within the four-year data set being between different stations, not different years. Significantly, the results also indicate that within a single survey, there is a stronger relationship between biological communities and abiotic variables, the strongest correlation being with distance. This means that although biological communities are linked to distance, this does not prove any influence from the operations at PA-A. All of the linkages identified through the multivariate analysis could be a result of natural gradients in the environment, such as the decrease in sediment grain size from platform to shore (RBA 2003).

The monitoring data and the reviews of the results undertaken (DVNIGMI 2002 and RBA 2003) confirm and reflect important aspects of the benthic communities present in the north-east Sakhalin shelf area. Long-lived sessile species (attached or infaunal), more typical of stable substrates and/or low energy conditions, are very poorly represented in the recorded benthic communities. Virtually all of the species present are epifaunal or infaunal species with annual life-cycles or motile adults that are able to withstand the

repeated disturbance to surface sediments that result from the combined effects of ice scour, storms and current activity.

To a large extent, the disturbance to the seabed sediments associated with the construction of the PA-A platform would have mimicked the natural dynamic processes characteristic of the area. This similarity between natural and anthropogenic induced disturbance (i.e. the platform construction) to seabed sediments in the PA-A area is reflected by the lack of any significant change to the faunal characteristics, as demonstrated through the monitoring data.

6.2.4 Lunskoye Field

As is the case for the Piltun field, a number of baseline surveys have been undertaken to determine the nature of the benthic communities in the Lunskoye area.

Seabed sediments within the field and pipeline corridor are similar to those in the P-A area as discussed above and largely comprise fine sand (68%) with areas of course sands (18%) and clay-based sediments (8%) with small patchy areas of gravel to the north (reported in the EIA, Lunskoye Seismic Survey 2003 Section 4.5.2). The seabed in the area also experiences ice-scour (January to April) and storms outside the pack-ice season and therefore the seabed sediments and associated faunal communities are prone to physical disturbances.

The analysis of 50 benthic samples from the Lunskoye field in 1998 (see Figure 6.3 for survey stations) identified 172 taxa (CSA 1998, SakhNIRO 1999; TEOC Volume 2B Book 8: Appendix F1, 2002). The total benthic biomass in the Lunskoye area ranged from 0.4 to 3,510g/m^2 with an average biomass of 322g/m^2 with bivalves forming the greater part of the biomass.

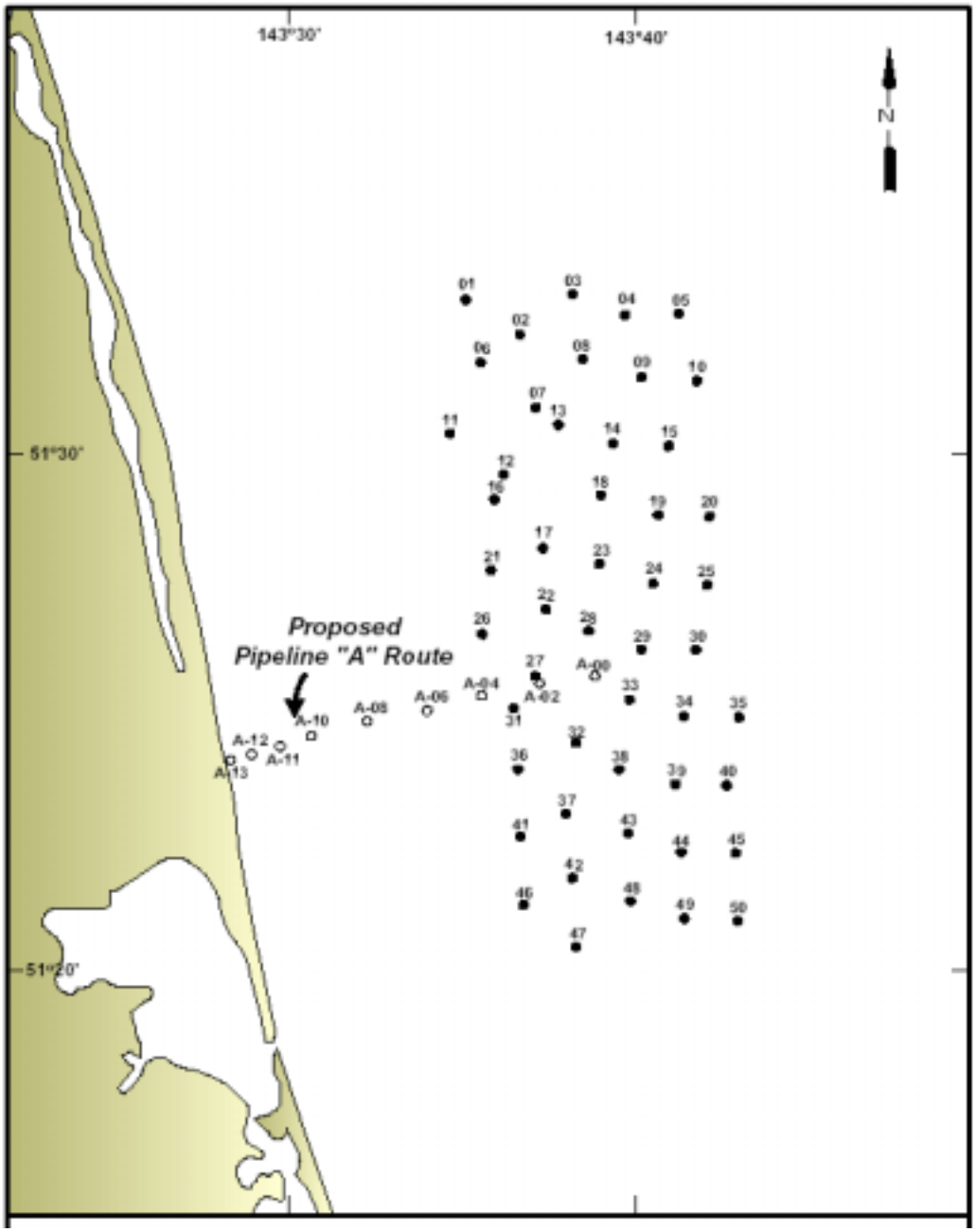

Figure 6.3 Benthic Survey Coverage of the Lunskoye Field for the 1998 Characterisation Survey (CSA 1998 and SakhNIRO 1999)

Population density ranged from 20 to 96,300 ind/m^2 with cumacean crustaceans dominating, as observed for the benthic communities present in the Piltun field. The order was represented by six species, with the most prevalent being *Diastylis bidentata*. Excluding cumaceans, the most widely distributed species were the amphipod crustaceans *Protomedeia grandimana* (with a peak population density of 2,460 ind/m^2), *Ischyrocerus commensalis* and *Pleusymtes vasinae*. Polychaetes made up 24% of the total benthic assemblage; the species *Glycera capitata*, *Chone* sp, *Nephthys caeca*, and *Chaetozone setosa* were most dominant. Bivalves comprised 8% of the total assemblage and anemones (represented by two species: *Halcampa* sp, and *Epiactis lewisi*) a further 5%.

Taxa identified to genus level were included in statistical analyses (*e.g.* cluster analysis) to examine similarities in species composition and distribution between stations. The species distribution was similar to that observed for the 1998 Piltun survey with benthic samples consisting of taxa that were more or less ubiquitous at the stations and taxa that had a more limited distribution (SakhNIRO 1999). The polychaetes *Glycera nana* and *Prionospio steenstrupi* occurred in over 80% of the samples. Other taxa present in at least half of the samples comprised: the amphipods *Pleusymptes* sp. and *Ischyrocerus anguipes*; the polychaetes *Glycinde armigera* and *Mediomastus* sp.; and *Prionospio* sp.; the bivalve *Yoldia* sp. and the cumacean *Diastylis bidentata*. The cluster analysis identified a limited grouping of sampling sites with only two groups of three sites having a similarity of more than 50%. This apparent lack of similarity is likely to be due to the low number of dominant species and a localised distribution of the less well-represented species. In general, however, the survey data indicate a homogeneity of dominant species throughout the survey area, with no evidence of areas inhabited by more localised communities.

A 2001 survey (reported in FERHRI 2003) covered two areas comprising the general Lunskoye field area and the proposed Lun-A platform area. Benthic stations locations were as per the CSA 1998 and SakhNIRO 1999. A total of 183 species were identified including polychaetes (69 species), amphipods (56 species) and bivalves (16 species). Sea anemones were represented by 12 species. The mean biomass was 279.1g/m^2 (range: 65.2 to 806.0g/m^2) in the general Lunskoye field area and 318.5g/m^2 (range: 30.4 to 809.2g/m^{-2}) in the platform area, as shown in Table 6.3). As with the 1998 survey (SakhNIRO 1999) the relatively high biomass characterising the benthic communities of the Lunskoye field was largely due to the dominance of one or two species, notably the bivalves *Serripes groenlandicus* and *Ciliatocardium ciliatum tchuktchensis*.

Table 6.3 Assemblage Summary Statistics, Lunskoye Survey (FERHRI 2003) Survey

Area	Number of Samples	Biomass (g/m^{-2})	Density (ind / m^2)
Lun-A Platform Stations	13	318.5	1,208.2
Lunskoye Field Stations	30	279.1	4,345.1

The population density range within the survey area was 1,208.2 to 4,345.1 individuals per metre square (ind/m^2) with the elevated density observed at the Lunskoye field stations attributed to large numbers of the cumacean, *D. bidentata*.

FESTU (2003b) undertook a benthic survey for the proposed pipeline corridor from the Lunskoye field to the shore. This involved the collection of samples along eight cross-sectional transects in water depths from 1m to 30m. In total, 107 species were recorded of which amphipods (46 species) and polychaetes (20 species) were the most numerous. Statistical analyses showed

community similarity in samples in water depths from 3m to 30 m with nearshore (1m depth) stations having a different fauna reflecting the higher energy conditions and greater level of sediment disturbance in this area.

6.2.5 Aniva Bay

A number of surveys have been undertaken in the northern part of Aniva Bay to characterise the marine ecology, including the benthic communities in the area where the LNG/OET facilities are to be developed. These surveys are also complemented by several studies and reviews of available information relating to commercial fisheries interests, including information on a number of benthic invertebrate species. Monitoring studies have also been initiated and detailed information on the characteristics of the communities in the vicinity of the LNG jetty and OET has been obtained.

The first comprehensive survey covering the potential area of impact in Aniva Bay was undertaken by SakhNIRO (1999). This survey comprised 31 stations (coverage shown in Figure 6.4) and the same stations were surveyed in 2001 (DVNIGMI (2001) and also reported in FERHRI 2003). The summary results of the two surveys are compared in Table 6.4.

Table 6.4. Comparative Data for Benthic Surveys Undertaken in Aniva Bay

Survey	No. of Recorded Species	Biomass in g/m^2; (Mean)	Density in ind/m^2; (Mean)
SakhNIRO 1999	174	7 - 711 (96)	140 - 4,380 (1,590)
DVNIGMI 2001	144	7 - 440 (72)	128 - 2,120 (817)

Both surveys documented that the benthic fauna of sediments (muddy sand-coarse sand) within the study area was dominated by polychaetes, amphipods and bivalves. The variation in biomass between stations was attributed to the mixed sediment types (mud, fine sand and gravel). Species inhabiting rocky areas (comprising approximately 30% of survey stations) were not represented in the faunal analysis data due to the inability to obtain samples from this substrate type (although data on the communities of this substrate is available from fisheries characterisation and monitoring surveys; see below). The same sampling and recording techniques were used in both of the surveys reported above. The difference in recorded diversity is therefore probably a function of natural variability, slight differences in the positioning of sample stations and survey timings (13^{th}-16^{th} September 1998 (SakhNIRO 1999) and 6-8^{th} July (DVNIGMI 2001)).

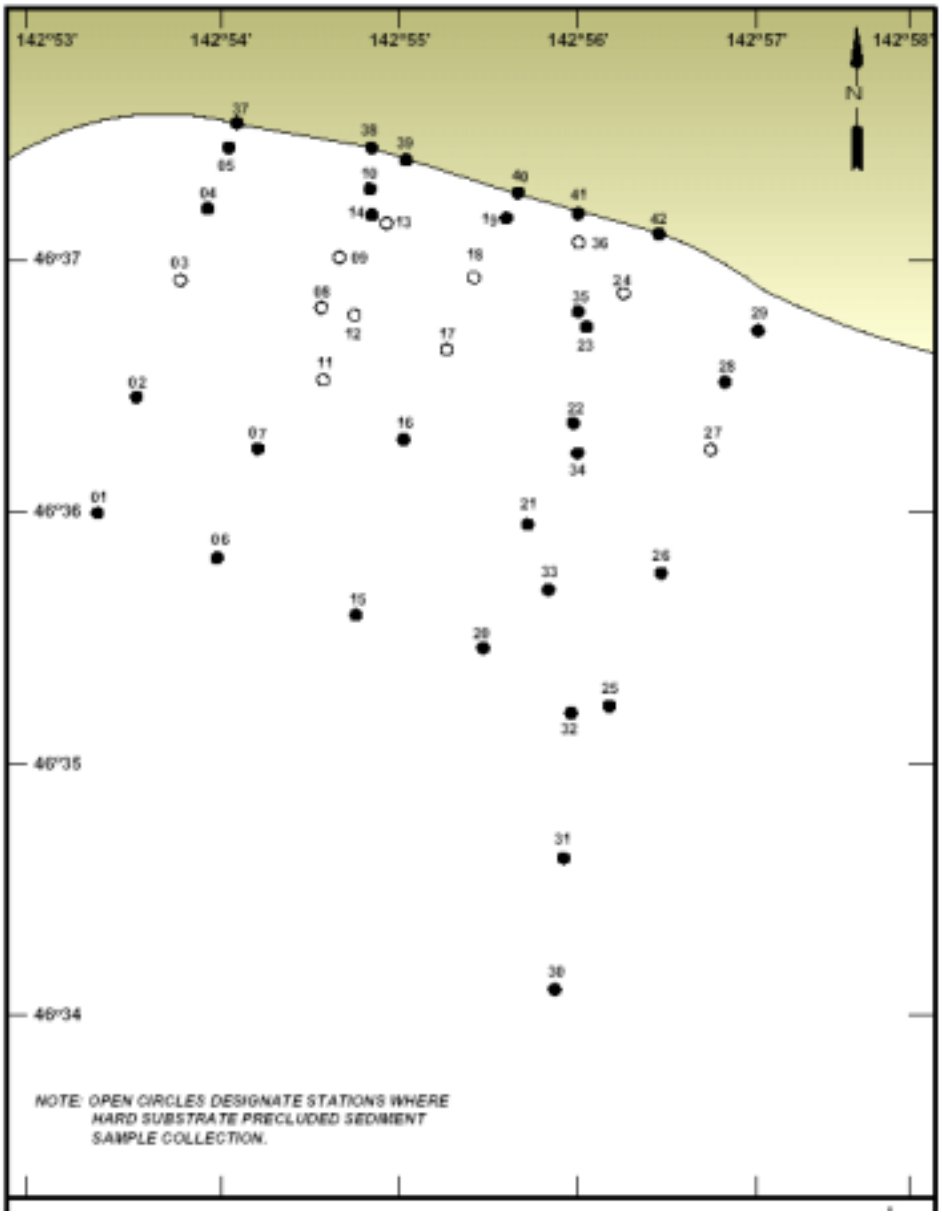

Figure 6.4 Benthic Survey Coverage for the 1998 Characterisation Survey of Aniva Bay (CSA 1998 and SakhNIRO 1999)

Statistical (cluster) analysis of the data obtained from the 2001 survey indicated seven communities with a distribution associated with water depth and sediment type (FERHRI 2003). The communities identified are summarised below:

- Community I inhabited silty substrates at 50 to 75m depth and was dominated by the bivalves *N. sachalinica*, species of the genus *Yoldia*, and *Liocyma fluctuosa;*

- Community II was represented mainly by polychaetes and amphipods;

- Community III inhabited pebbly and gravel substrate at less than 24m depth, and comprised mainly the polychaetes *Onuphis iridescens and Lumbrineris heteropoda;*

- Community IV was found on gravel substrates at 22m depth, comprising primarily of the polychaetes *Lumbrineris latreilli* and *O. iridescens* and the bivalves *Yoldia keppeliana* and *Y. seminuda;*

- Community V inhabited shallow waters (6-11m) and was dominated by brittle stars (*Amphiodia rossica* and *A. periercta*) and the polychaetes *Maldane sarsi* and *Lumbrineris longifolia;*

- Community VI inhabited silty substrate down to 19m depth and was dominated by the polychaetes *Scoloplos armiger*, *Lumbrineris longifolia* and *M. sarsi;*

- Community VII inhabited a silty substrate at 35m and was dominated by the polychaete *M. sarsi* with the subdominant bivalves *Macoma* sp. and *Yoldia seminuda*.

The ecological zonation from intertidal to mid-depth sub tidal waters (20-30m) in the Prigorodnoye area of Aniva Bay (where the LNG/OET works are located) has been described (on the basis of available survey data) as part of the assessment of fisheries interest in Aniva Bay (Regional Centre of Coastal Fishing and Commercial Exploration 2003).

This report notes that a distinctive feature of the area is the heterogeneous nature of the seabed sediments, although a basic transition from more rocky substrates through pebbly sands to fine sand/silts with depth offshore occurs. At depths of between 0 to 10m the area is characterised by outcrops of rock, which alternate with patches of pebbly sands. This zone supports dense patches of seagrass (*Zostera marina* and *Phyllospadix iwatensis*), which extend in a continuous belt of variable width (20-1000m) along the shore. The rocky substrate supports a diverse community of algae and invertebrate species. The plant/algal assemblage of the littoral zone is primarily composed of seagrass (*P. iwatensis*), brown seaweeds – *Laminaria japonica*, *Fucus evanescens*, *Pelvetia wrightii* and *Cystoseira crassipes*. A number of species of red and green algae are also present including *Laurencia nipponica*, *Corallina officinalis*, *Gloiopeltis furcata*, *Neorhodomela teres*, *Porphyra pseudocrassa*, *Ulva fenestrata* and *Chaetomorpha* sp.). The invertebrate assemblage includes: short-spined sea urchin (*Strongylocentrotus intermedius*), sea anemones, gastropods, molluscs (*Metridium senile*, *Collisella* sp., *Littorina squalida* and *Nucella* sp., the crabs *Pagurus middendorffi* and *Pugettia quadridens* and a number of species of isopods, amphipods and polychaetes.

As the depth increases (to approximately 13m), the algal community develops a three-tiered structure. The upper tier is dominated by *Laminaria japonica*, with more *occasional Laminaria cichorioides* and *Costaria costata*. The under-storey tier comprises a mixed assemblage of red, green and brown algae,

although red species such as *Chondrus pinnulatus*, *Odonthalia corymbifera* and *Neoptilota asplenioides* tend to dominate. Brown and green seaweeds that occur in this layer include *Dichloria virides*, *Ulva fenestrata*, *Monostroma crassidermum* and *Bryopsis plumosa*. The basal tier largely comprises coralline seaweeds such as *Clathromorphum circumscriptum*, *Lithothamnion phymatodeum* and *Bossiella cretacea*. The invertebrate assemblage includes *Strongylocentrotus intermedius*, *Patiria pectinifera*, *Asterias amurensis*, *Swiftopecten swifti*, *Boreotrophon candelabrum*, *Neptunea* sp., *Keenocardium californiensis*, *Telmessus cheiragonus* and *Pagurus* sp.

At depths below 10m pebbly sand starts to predominate. The replacement of bedrock outcrops by a finer-grained and more dynamic substrate leads to a significant change in the associated floral and faunal communities. The algal community primarily comprises the brown kelp *Agarum cribrosum* with an under-storey of red seaweeds (*Odonthalia corymbifera*, *O. ochotensis*) and a basal tier comprising the coralline seaweed *Bossiella compressa*. The invertebrate assemblage also demonstrates a clear change with the incoming of the Japanese scallop *Mizuhopecten yessoensis*, *A. amurensis* (which is predatory on the scallop) and a number of species of gastropod, including *Patiria pectinifera* and *Neptunea* sp. the chiton *Cryptochiton stelleri* and the sea cucumber *Cucumaria japonica*.

At water depths of 20-30m there is a gradual change in the seabed substrate from pebbly sand to fine sand and silt. Red seaweeds e.g., *Odonthalia corymbifera*, *Congregatocarpus pacificum* and *Lithothamnion* sp. dominate the algal assemblage while sponges such as *Myxilla incrustans*, *Homaxinella subdola* and *Suberites domuncula*, together with hydrozoans and polychaetes, form a significant component of the invertebrate assemblage.

The above description of the substrate conditions of Aniva Bay and associated benthic communities is also supported by video survey information. This survey work was undertaken, in part, to address the inability to collect benthic data by van Veen grab at some of the stations and was part of the characterisation survey for proposed project infrastructure locations including the Prigorodnoye area (LNG Jetty and OET pipeline) undertaken by DVNIGMI (2001). In total, five sets of video observations were made offshore of Prigorodnoye where previous surveys had identified the presence of more rocky/pebbly substrates.

Analysis of the video footage indicated that seabed conditions varied from scattered rock outcrops (with a relief up to 1m), coarse sand and gravel to fine sand with sand waves. In areas closer to the shore (transect stations 1, 3 and 4) algae (*Laminaria*) dominated, while further out in deeper water (stations 2 and 5) the more sandy substrate supported buccinid gastropods and flatfish. Table 6.5 provides an overview of the communities and species groups observed at each of the video transect stations.

Tanker Loading Unit (TLU)

Analysis of samples collected in 2003 (FESTU 2003a) from the vicinity of the Tanker Loading Unit (TLU) in Aniva Bay identified a total of 107 species. Twenty fauna groups comprising 43 species of polychaetes, 20 species of amphipods and 12 species of bivalves were represented. Other groups were represented by single species.

Abundance ranged from 178.3 to 708.3 ind m^2 with a mean of 441.7 ind m^2, with colonies of polychaetes dominating. The mean biomass was 226g/m^2, with actinids (*Metridium senile*) (14.9 %), colonial ascidians (12.4%) and bivalve molluscs (*Macoma calcarea*) (11.4%), making up the largest proportion of the total biomass, with other species comprising. less than 5 % of the total community biomass (FESTU 2003).

Table 6.5 Summary of Seabed Video Transect Observations for the Prigorodnoye Area of Aniva Bay (DVNIGMI survey 2001)

Transect Station	Substrate Conditions	Observed Communities and Species
1 (A5-20)	Scattered rocks with coarse sand	Seagrass and large algal blades evident (*Laminaria* sp.). Intermittent sponge colonies, *Metridium* sp. (stalked anemone), actinarians, ascidians, asteroids and *Potamilla* worm tubes.
2 (A3-35)	Sandy with small sand waves	Frequent flounders and cottids (sculpins). Some outcrops of yellow branching sponge, buccinid gastropods, blennoid fishes, actinarians, asteriids, *Hyas* sp. (crab) and *Potamilla* tube worms.
3 (A3-20)	Coarse sand/gravel	Dense algal growth (*Laminaria* sp.), some outcrops of yellow branching sponge, some large scallops (*Mizuhopecten yessoensis*) and large asteriids.
4 (A1-20)	Coarse sand/gravel	Dense algal growth (*Laminaria* sp. and *Agarum* sp.), some outcrops of yellow branching sponge, some large scallops *(Mizuhopecten yessoensis*), large asteriids. Many cottids, actinarians, holothuroids (sea cucumbers), anguilliform fish. Individual *Octopus* sp. and small patch of seagrass.
5 (ADD6)	Fine sand with sand waves	Many flounder, cottids. Some Zoarcidae sp. fishes (eelpouts), buccinid gastropods, *Hyas* and Paguridea crabs, few actinarians, holothuroids. Individual octopus sp.

6.3 BENTHIC COMMUNITIES OF DREDGE SPOIL DISPOSAL SITES

Work published by FESTU (2003b) compares historical survey data (pre-1982) and reports upon more recent survey data from 2003 for proposed disposal sites for dredge spoil from the P-A and Lunskoye field areas. The sites were chosen based on historical SakhNIRO data and were considered to be of low productivity both in terms of commercial fisheries value and benthic prey species for marine mammals (SakhNIRO 2003). The selection of disposal sites and characterisation has been investigated and reported by SakhNIRO (2001) and DVNIGMI (2001). This section deals solely with the characteristics of the benthic communities (i.e. the baseline) at three sites. Discussion of the impacts of dredging and disposal (for all parameters) is dealt with separately in Chapter 12 of the EIA Addendum.

6.3.1 P-A Area

The initial feasibility study for the Sakhalin II project identified that levelling and dredging work may be required for the installation of the PA-B platform. Likely volumes of material requiring disposal were not calculated, but as part of the determination process a site selection process was undertaken to identify sites where excess sediment could be disposed. Later work identified that no dredging was necessary at the PA-B site, only localized leveling of the seabed.

6.3.2 Lunskoye Area

No leveling or dredging work was required prior to the installation of the LUN-A platform.

6.3.3 Aniva Bay

The development of the LNG jetty, TLU, offshore loading facility (temporary jetty) and associated pipeline linking the TLU and OET (Offshore Export Terminal) at Prigorodnoye on the shore of Aniva Bay involves dredging activities at and around the jetties and along the pipeline. This dredging is required to deepen the approach lanes and turning basin to allow tankers to approach the LNG jetty and to allow the offloading of heavy equipment for construction of the LNG plant. It is calculated that a total of 1.4 million m^3 of dredged material will need to be removed from the area and require disposal. The dredged material will comprise uncontaminated soft sediment (silt, fine sand and sand) and rock (70% of total volume) and will not include any drill cuttings, mud, waste, or any other materials from onshore areas.

Three possible locations for the disposal of the dredged material have been identified:

- Site 1 – in shallow water (10m) West of Korsakov port (approximately 22km from the LNG terminal);

- Site 2 – in 65m deep water 25km directly south of the LNG terminal;
- Site 3 – to the south-east of Aniva Bay (110km from the LNG terminal) in a water depth of 900m.

The choice of the first two of these sites was supported by baseline studies (SakhNIRO 2001, DVNIGMI 2001 and Hydrotex2002) and the third was suggested after these baseline studies were completed.

These three potential sites are shown in Figure 6.5.

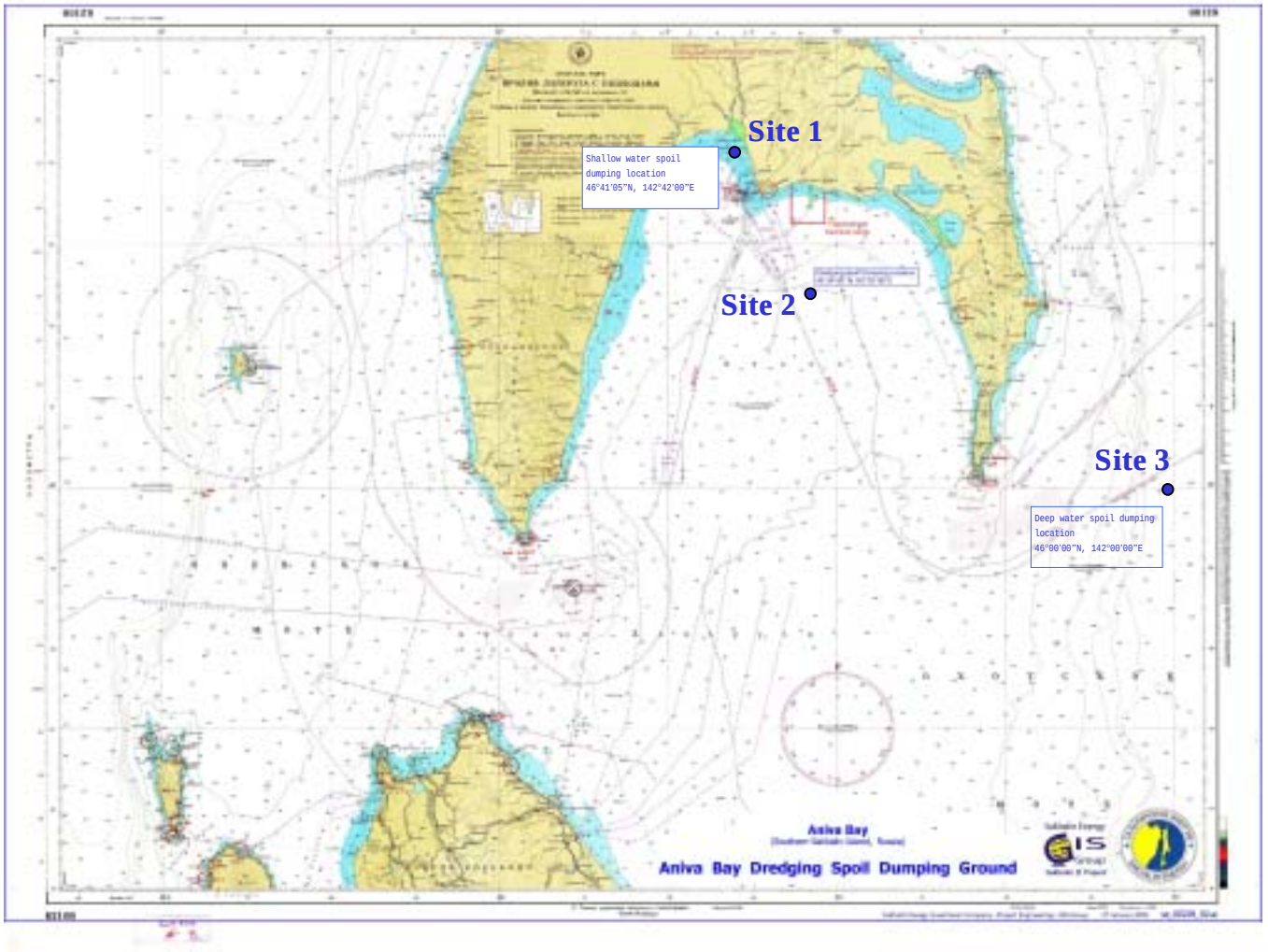

Figure 6.5 Map showing location of proposed sites for the disposal of dredged material arising from LNG associated works in Aniva Bay

Technical and environmental analysis of the disposal site options concluded that Site 2 at Aniva Bay was the preferred alternative (refer to Chapter 12 of the EIA-A for further information).

During the baseline characterisation studies, four sediment samples from around the Site 2 disposal area were collected in 2001 (DVNIGMI 2001); the locations, relative to the central position of the disposal site, are shown in the schematic on Figure 6.6. Fine sand and silt grade sediment dominated the samples while the faunal community corresponded to Community type I as described above. The bivalve species of this community type (*N.sakhalinica* and *Liocyma fluctuosa*) are characteristic of soft sediments (fine sand-silt often with admixed pebbles/gravel) and occupy a range of depths to 100m with *N. sakhalinica* inhabiting depths between 40-80m. All of the reported bivalve species are common elements of this substrate type and occur from northern Japan into the Arctic Ocean. Other than these characteristic bivalve species, the community is dominated several species of polychaete worm, notably *Praxillella praetermissa* and *Lumbrineris heteropoda*.

In comparison with the benthic samples obtained from Aniva Bay (DVNIGMI 2001), the samples from the area of the disposal ground are characterised by a relatively low biomass and density. Recorded biomass at Station ADD-6E was 7.2g/m^2 compared with an average of 71.9g/m^2 for all stations while density was 128.1 ind/m^2 at the same station compared with an average of 816.7 ind/m^2.

Further analysis of the benthic community of the Aniva Bay disposal site has been undertaken as part of a monitoring programme (SakhNIRO 2004). This data indicates that the disposal site had a higher biomass (53.7 g/m^2) than either the LNG dredge site (9.7 g/m^2) or the MOF site (6.3 g/m^2), which are characteristic of the shallower waters of Aniva Bay. Species diversity was similar to that found in the other areas (36 species, compared with 41 and 48 species respectively), while abundance was significantly lower (200 ind./m^2 compared with 1002 ind./m^2 and 945 ind/m^2 respectively). The higher biomass recorded at the disposal site during this survey was largely due to the presence of two individuals of the sipunculid worm *Golfingia*, which constituted 45% of the total biomass. Aside from differences in the recorded biomass between this 2003 survey and that undertaken in 2001, the basic community type recorded by both surveys was similar.

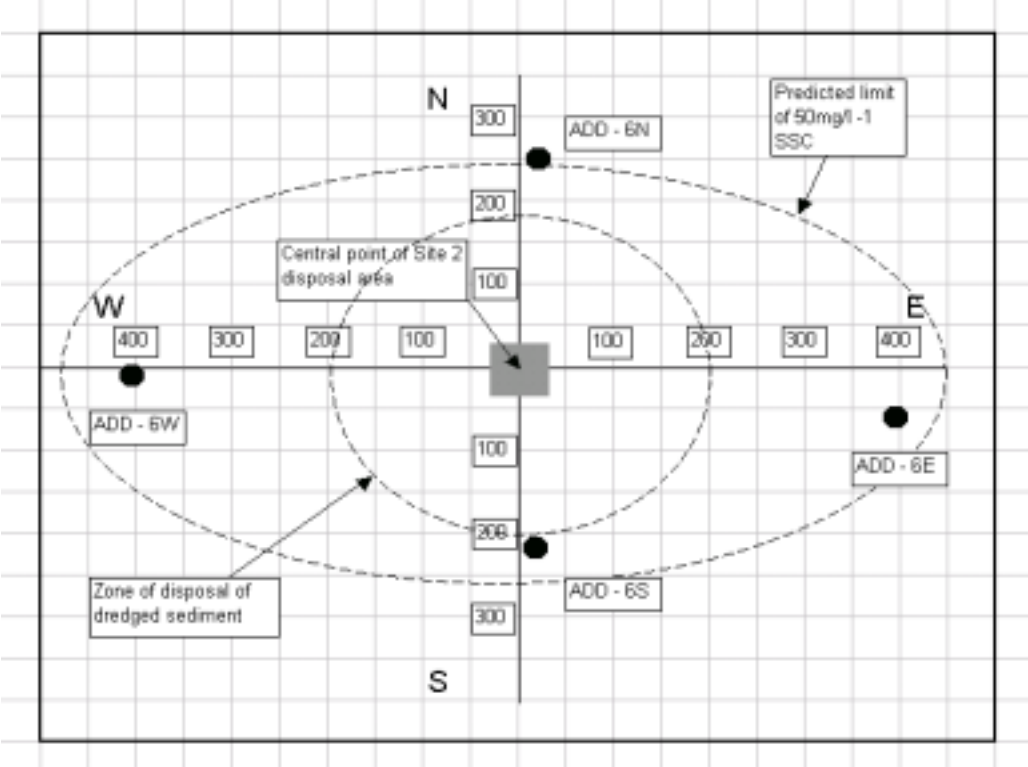

Figure 6.6 **Plot showing Location of Aniva Bay Sampling Stations ADD6 (N,S,E & W) in Relation to Site 2 Disposal Area (data from DVNIGMI 2001).** [Note: an approximation of the main area of disposal and modelled limit of 50mg/l suspended sediment concentration (SSC) is shown (derived from the EIA – Vol.5)

6.4 PROTECTED AND RARE SPECIES

For all the surveys highlighted above it was a requirement (as set out in the Scope of Works) that all rare and protected marine benthic species were recorded. None of the survey reports, however, indicated that any rare species or species of particular note were found. It should be noted that although there are a number of marine invertebrate species in the Russian Red Data Book (RDB), there are no marine benthos species listed in the Sakhalin RDB.

6.5. SAMPLING AND ANALYSIS METHODS

Sampling and analytical techniques utilised during the benthic surveys were developed on the basis of standard Russian Federation methodologies. SEIC has used a limited number of specialist offshore benthic contractors and therefore considers that sampling and analysis methodologies are generally compatible. Following the Rudall Blanchard review of Molikpaq (PA-A platform) benthic data (RBA 2003), sample techniques were reviewed across the project teams and aligned where necessary.

Reported sampling methodologies indicated that standard benthic grab sampling techniques were used for the vast majority of the survey work. Samples were taken using a 0.2m^2 van Veen grab (a hand-held 0.05m^2 grab

was used in shallow water sites when using small boats) and processed with a 1mm sieve. For some surveys, notably the initial benthic work in Aniva Bay, it was not possible to obtain representative grab samples at some of the selected sampling stations. This was due to the coarse nature of the seabed substrate. Unfortunately, in this situation, the sampling methodology utilised biased the baseline in favour of the soft sediment communities present in the study area; the results, by themselves, could therefore not be representative of the benthic diversity present in the area. Consequently, sub-aqua diving surveys and video transects were undertaken in Aniva Bay in those areas where harder and coarser substrates were identified. While this work provides a good indication of the structure and makeup of the communities in these areas, it does mean that a complete comparative analysis of the benthic communities in the entire study area using the standard analytical techniques (see below) could not be achieved in Aniva Bay.

For all of the grab samples taken (all surveys), the laboratory processing comprised determination of fauna to species level and the derivation of quantitative parameters (biomass and species abundance). All data were scaled up to $1m^2$ of the seabed area for comparative purposes. Species accounting for at least 30% of the total biomass and counts in the sample were regarded as dominant. This survey and analysis approach is repeatable and enables comparative assessment of differences and changes between sampling stations (spatially and temporally) to be made. It is, however, reliant on ensuring those repeat surveys obtain samples from the same locations and it can only be used successfully where substrate types are relatively homogeneous. For the vast majority of the project locations, this situation is applicable and it is only within parts of the study area in Aniva Bay where a different approach to data collection should be applied.

6.6 LONG-TERM MONITORING STRATEGY

The long-term offshore monitoring strategy will focus on the impacts of the project during construction and, after the commissioning phase, during the operational regime. The key objectives are listed below:

- Assess the efficiency of mitigation and reclamation programmes for all stages of project implementation;
- Identify potential sources of negative environmental impact on water quality and marine biota;
- Acquire data on the state of ambient seawater and marine biota in areas potentially affected by SEIC offshore facilities;
- Demonstrate compliance;
- Verify data predictions based on computation and modelling;
- Provide information to environmental agencies.

In order to achieve these objectives, it will be necessary to implement the following:

- An Environmental Monitoring Programme, including observations of the potential sources of impact and environmental components that may be affected;
- Introduction and management of a monitoring system for project emissions, discharges and waste;
- Make observations of the current state of ambient seawater and marine biota in areas potentially affected by facilities;
- Carry out a comparison of the state of environmental components in the areas potentially affected by facilities in comparison with background parameters.

Regarding benthic surveys, field-monitoring studies will be conducted during the open water period, including:

- Determination of benthic community characteristics, including species presence, biomass, abundance and diversity. This information will be utilised to document the changes to, and recovery of, communities following project works;
- Sediment grain size;
- Petroleum hydrocarbons;
- Metals;
- Organic carbon.

Post-dredging and post-installation monitoring will be conducted for a period that enables the temporal and spatial extent of change attributable to the works (within the context of natural dynamic change) to be established and/or within which the recovery of communities to baseline conditions can be demonstrated. After this period, maintenance monitoring surveys may be conducted every three to five years to assess general community characteristics.

The results of the PA-A post-installation monitoring work (RBA 2003) indicate that recovery of the benthic fauna on the north-east Sakhalin shelf sediments has occurred within a period of less than three years. Recovery periods vary significantly from one substrate type to the next; the recorded benthic data for the PA-A site is consistent with data obtained from other studies (Nedwell & Elliot 1998; Newell *et. al*. 1998). Table 6.6 provides international examples of the recovery periods for benthic communities following dredging activity in a range of sediment types.

Table 6.6 Summary of Recorded Recovery Rates for Benthic Communities following Dredging and Disturbance to Seabed Sediments

Location	Sediment type	Recovery time
Coos Bay, Oregon	Disturbed muds	4 weeks
Gulf of Cagliari, Sardinia	Channel muds	6 months

Location	Sediment type	Recovery time
Mobile Bay, Alabama	Channel muds	6 months
Goose Creek, Long Island	Lagoon muds	>11 months
Klaver Bank, North Sea	Sands-gravels	1-2 years
Chesapeake Bay	Muds-sands	18 months
Lowestoft, Norfolk	Gravels	>2 years
Dutch coastal waters	Sands	3 years
Boca Ciega Bay, Florida	Shells-sands	10 years

Recovery rates were most rapid in highly disturbed sediments in estuaries that are dominated by opportunistic species. In general, recovery times increase in stable gravel and sand habitats dominated by long-lived components with complex biological interactions controlling community structure. Dredging impacts are relatively short-term in areas of high sediment mobility. For example, the complete recovery of benthic animals in a channel in the estuarine Dutch Wadden Sea occurred within one year of the removal of sediments from this mobile sand environment (Van der Veer *et al* 1985).

6.7 SUMMARY

A series of offshore surveys undertaken since 1998 have documented the benthic communities of the seabed in the areas where project activities are centred (north-east Sakhalin shelf – Piltun and Lunskoye – and Aniva Bay). In combination, these surveys provide a good indication of the nature of the benthic communities, including parameters such as species presence, biomass, population density and substrate type.

The benthic data for the Piltun and Lunskoye fields indicates that variation in faunal density and biomass is linked to sediment type with high-density populations of bivalves, sand dollars and cumacean crustaceans and amphipods being present. In Aniva Bay, the recorded biomass is, on average, lower than for the north-east Sakhalin shelf. However, this may partly reflect the lack of biomass data for rocky and coarse substrates present within Aniva Bay, which support significant algal and attached communities.

The sediments within both the Piltun and Lunskoye fields and their associated pipeline corridors are relatively homogenous *i.e.*, predominantly sandy sediments mixed with varying amounts of finer and coarser grained material. Survey data indicate that species distribution within these areas is relatively evenly spread with the main difference being related to water depth. No rare species or habitats have been reported in the surveys. At water depths to 20m the seabed is subject to ice-scour and thus benthic communities are adapted to high levels of natural physical perturbation. There is greater sediment variability in Aniva Bay with a transition from rocky intertidal substrates through sand/gravel to fine sand offshore as depth increases. Faunal communities present within the bay reflect this sediment variation.

Monitoring data indicates that there was no significant effect on the

characteristics of the benthic communities as a result of installation of the PA-A platform in the Piltun Field. This reflects the fact that sediment disturbance is a natural and relatively frequent occurrence and the benthic communities present in the north-east Sakhalin shelf area are adapted to these conditions.

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