Appendix 13.4 Survey Methodology of CWD

Study Area

The Study Area for marine ecological impact assessment included the North Western Water Control Zone (WCZ), North Western Supplementary WCZ, Deep Bay WCZ and Western Buffer WCZ as designated under the Water Pollution Control Ordinance (WPCO). Two vessel survey areas were conducted. The first, covers the area of, and immediately surrounding, the footprint of the proposed reclamation for the third runway, that the second covers the region to the immediate west of the current airport platform (see **Drawing No. MCL/P132/EIA/13-011**).

Proposed Field Work

Much is known about *Sousa chinensis* (the Chinese White Dolphin [CWD], also known as the Indo-Pacific Humpback Dolphin) in Hong Kong (see review by Jefferson and Würsig, 2012), but most information is on a scale large enough that it does not provide required answers for the specific area where the proposed third runway will be situated. Thus, we need to have better information on seasonal changes in dolphin density, fine-scale distribution, individual use of the area, and the amount of time that dolphins spend within this region, as well as information on their behavior and activities while in the area. The field work for this project is designed to fill this need.

It has long been recognized that CWDs prefer brackish, estuarine waters as habitat, as dolphins virtually never occur in Hong Kong's eastern waters (which have very little freshwater input), where instead finless porpoises are common (Jefferson, 2000; Jefferson et al., 2002; Kallamaa, 2010). In many areas, there are higher dolphin densities during the wet season, possibly related to prey abundance. Dolphins tend to aggregate around islands, headlands, and areas with steep bottom slopes (Hung, 2008; Kallamaa, 2010).

The quantitative grid analysis of Hung (2008) provided empirical data to support a number of findings that had been suggested previously based on only subjective observations. High density grids only occurred in three areas of Hong Kong:

1) The entire west coast of Lantau Island,
2) The region around (and especially east of) Lung Kwu Chau Island, and
3) The region around the Brothers Islands and Sham Shui Kok.

These are clearly the preferred areas for dolphin feeding and socializing activity, and for females to rear their young calves; there has been long-term stability in the use of these high-density areas (Hung, 2008). Water temperature, clarity, and salinity were all found to be correlated with dolphin occurrence, but these factors were thought to be secondary to dolphin prey abundance. Densities were also higher along natural, rocky coastlines, than along human-modified shorelines (Hung, 2008).

The marine mammal impact assessment comprise, but not be limited to, studies of the density, abundance, movements, and behaviour of CWDs in the area of the proposed airport expansion, in Hong Kong waters and taking reference to the broader CWD population in the Pearl River Estuary (Hung, 2008; Jefferson, 2000). Studies include projects that facilitate the scientific assessment of the impacts that the project may have on the health and survivability of such marine mammals and identification of appropriate avoidance, minimisation or compensatory mitigation measures, as well as a proposed implementation plan and timeline for such identified measures.

Three major types of field work are proposed:

- small-scale vessel line transect surveys of the proposed reclamation (and surounding) area;
- land-based theodolite tracking of movements; and
- autonomous passive acoustic monitoring of the dolphins and their environment. These will occur over 10 months, so that all four seasons will be represented and seasonal differences can be examined. These are described, in turn, in more detail below.

Small Vessel Line Transect Surveys

Vessel-based CWD surveys provide data for density and abundance estimation and other assessments using distance-sampling methodologies, specifically, line-transect analysis. These surveys also included photo-identification of individual CWDs within the proposed project area to provide data on individual use of this specific area.

The surveys involved small vessel line-transect data collection and have been designed to be similar to, and consistent with, previous surveys for monitoring of small cetaceans in Hong Kong (Hung, 2008; 2012; Jefferson & Leatherwood, 1997; Jefferson, 2000; Jefferson et al., 2002). The survey was designed to provide systematic, quantitative measurements of density, abundance, and habitat use by line transect methods (Buckland et al., 2001; Buckland & York, 2002).

A 15-20m vessel with a flying bridge observation platform and a team of 3-4 observers were deployed to undertake the surveys. Two observers were on search effort at all times when following the transect lines, one using binoculars and the other using unaided eyes.

The vessel line transect survey routes are shown in **Drawing No. MCL/P132/EIA/13-011**. Generally, lines A1-P15 were surveyed first, followed by lines Q16-T18, and then survey lines P19-A23 at the end. This sequence was adopted in order to obtain a second set of coverage of the main survey area. This approach provides very fine-scale distribution information, and data of the current CWD densities in the works area. On some days, the survey routes were reversed, so that there was some variation in the timing of coverage of each part of the area. There were two survey areas for the vessel surveys. The Airport North area is the region north of the existing airport, where the 3RS will be constructed (and covering the surrounding work area as well). The Airport West area is the region directly to the west of the current airport, and was selected to prepresent the HKIA exclusion zone which restricted movements and good data on CWD use and densities in that area is currently limited.

Surveys were conducted for a 14 month period, between October 2012 and November 2013, with a total of 56 surveys undertaken. The same basic methods as current Hong Kong Cetacean Research Project (HKCRP) surveys conducted for the AFCD surveys were used, but the survey lines were spaced very close together to obtain more fine-scale information in the proposed reclamation footprint (**Drawing No. MCL/P132/EIA/13-011**).

When CWDs were seen, they were approached and photographed for photo-ID information (using a Canon 7D camera and long telephoto lens), then followed until they left the study area. At that point, the boat returned (off effort) to the next survey line and began to survey on effort again. Two complete sets of surveys of the main survey area were obtained for each day (when weather conditions allowed), which provided detailed information on how long individual dolphins remained in the area. CWD densities have been calculated using line transect methods (see Jefferson, 2000), based on only a single set of surveys from each day, using those that occurred in the best weather conditions. Seasonal differences in dolphin density and use of the study area have been examined, using both the solar seasons (Winter: Dec-Feb, Spring: Mar-May, Summer: Jun-Aug, Autumn: Sep-Nov) and oceanographic seasons (Dry: Oct-Mar, Wet: Apr-Sep (Chen et al., 2010).

Focal follows of individual dolphins were also conducted, when conditions were suitable. These involved the boat following (at an appropriate distance to minimise disturbance which is based on the observers' knowledge of CWD behaviour and disturbance responses) an identifiable individual dolphin for an extended period of time, and collecting detailed data on its location, behavior, response to vessels, and associates. This type of data allowed information to be gathered on the movement paths and travel corridors used by CWDs in the survey region. The data collected was similar to data being collected during focal follows in the AFCD-funded long-term monitoring surveys, and the combined dataset of both sets of focal follows allows the evaluation of travel corridors for the greater Hong Kong region to be undertaken, with emphasis on the proposed reclamation area. Time allocation between line transect surveys and focal follows was decided based on the desire to obtain adequate samples of both types of data.

Line Transect Analysis of Vessel Survey Data

Line transect analyses have been conducted based upon the 14-month set of survey data. The approach used conventional line-transect methods (also known as Conventional Distance Sampling or CDS) to analyse the vessel survey data (Buckland et al., 2001). Estimates of density and abundance (and their associated coefficients of variation) were calculated using the following formulae:

$$\hat{D} = \frac{n\ \hat{f}(0)\ \hat{E}(s)}{2\ L\ \hat{g}(0)}$$

$$\hat{N} = \frac{n\ \hat{f}(0)\ \hat{E}(s)\ A}{2\ L\ \hat{g}(0)}$$

$$C\hat{V} = \sqrt{\frac{\hat{\mathrm{var}}\,(n)}{n^2} + \frac{\hat{\mathrm{var}}\,[\hat{f}(0)]}{[\hat{f}(0)]^2} + \frac{\hat{\mathrm{var}}\,[\hat{E}(s)]}{[\hat{E}(s)]^2} + \frac{\hat{\mathrm{var}}\,[\hat{g}(0)]}{[\hat{g}(0)]^2}}$$

where D = density (of individuals),
n = number of on-effort sightings,
f(0) = detection function evaluated at zero distance,
E(s) = expected average group size (using size-bias correction in DISTANCE),
L = length of transect lines surveyed on effort,
g(0) = trackline detection probability,
N = abundance,
A = size of the study area,
CV = coefficient of variation, and
var = variance.

Line-transect parameters have been calculated for CWDs using the software DISTANCE 6.0, Release 2 (Thomas et al., 2010). All data collected in Beaufort sea state conditions of 0-3 has been used and the approach did not stratify estimates by sea state or other environmental parameters. Survey effort and sightings that were off-effort or in Beaufort 4+ have been used in other analyses, for example, the determination of distribution, group sizes and ranging patterns, but not in the line-transect analysis. Stratified (in terms of sighting rate and group size) estimates of density and abundance for the two main survey sub-areas and two seasons have been produced, but pooled data from all strata to produce a single estimate of the detection function, f(0). Trackline detection probability [g(0)] was assumed to be 1.0, based on the results of Jefferson (2000).

In the Airport North area, there were two transect routes surveyed on each day. This was done to collect additional information on CWD activities in this important area of the HKIAAA and project area for the 3RS. However, only the first set (Set A) **(Appendix 13.13)** of transect lines conducted in this area on each day have been used in the density and abundance estimation. In order to avoid biasing of the estimates, the other survey effort (Set B) was not used for this analysis, but again the data have been used in other analysis, notably determination of CWD distribution, group sizes and ranging patterns.

Land-based Surveys and Theodolite Tracking

Land based surveys and theodolite tracking were undertaken between October 2012 and November 2013 and a total of 105 days were spent surveying. Since surveys were conducted at two separate stations simultaneously on 22 of these days, a total of 127 surveys were undertaken.

Land-based monitoring has been able to obtain fine-scale information on the time of day and movement patterns of the CWDs within the proposed reclamation and adjacent areas. A digital theodolite (Sokkia/Sokkisha Model DT5) with 30-power magnification and 5-s precision was used to obtain the vertical and horizontal angles of each CWD and vessel position. Angles were converted to geographic coordinates (latitude and longitude) and data were recorded using *Pythagoras* software, Version 1.2 (Gailey & Ortega-Ortiz, 2002). This method delivers precise positions of multiple spatially distant targets in a short amount of time. The technique is fully non-invasive, and allows for time and cost-effective descriptions of dolphin habitat use patterns during daylight hours (Würsig et al., 1991; Piwetz et al., 2012). Examples of modern statistical techniques to describe movements relative to habitat and anthropogenic influences are described in Gailey et al. (2007) and Lundquist et al. (2012).

Land-based observation and theodolite tracking stations were set up at four locations, two stations on the northern side of the airport, one at the west side of the airport and one facing east/south/west on the southern slopes of the island of Sha Chau. Each location, A to D, is shown on **Drawing No. MCL/P132/EIA/13-012**, with position coordinates, heights of stations, and approximate distances of consistent theodolite tracking capabilities for CWDs given in **Table 1**. Approximate distances of consistent theodolite tracking capabilities were calculated post hoc based on positional fixes using ArcGIS.

Table 1: Land-based Survey Station Details

Station	Location	Geographical Coordinates	Station Height (m)	Approx. Tracking Distance (km)
A	AIRPORT NORTHEAST	22° 19' 16.86" N 113° 56' 6.3" E	11.74	1.25
B	AIRPORT NORTH	22° 19' 5.58" N 113° 54' 55.8" E	6.06	1
C	AIRPORT WEST	22° 18' 12.30" N 113° 53' 54.72" E	17.2	1.5
D	SHA CHAU	22° 20' 43.5" N 113° 53' 24.66" E	45.66	3

Note: Station B is <10 m above water level, so it is not as good as higher stations for accurate theodolite tracking >1 km distance from the station. However, it is still valuable for observations up to about 2.5 km, and theodolite tracking $\leq$ 1 km. It is at a critical location near the centre of the proposed runway.

Overall, a total of nine theodolite tracking days per month were undertaken, divided among the four stations. Surveys were undertaken during a period of about 5-6 hours per day per station, with some days longer than this but others truncated due to weather-related deterioration of sighting conditions. Observers searched for dolphins using unaided eyes and handheld binoculars (7X 50). A theodolite tracking session was initiated when an individual dolphin or group of dolphins was located. Where possible, a distinguishable individual was selected, based on colouration, within the group. The focal individual was then continuously tracked via the theodolite, with a position recorded each time the dolphin surfaced. If an individual could not be positively distinguished from other members, the group was tracked by recording positions based on a central point within the group whenever the CWDs surfaced (Bejder, 2005; Martinez, 2010). Tracking continued until animals were lost from view, moved beyond the range of reliable visibility (>1-3 km, depending on station height), or environmental conditions obstructed visibility (e.g., intense haze, Beaufort sea state >4, or sunset), after which the research effort was terminated. In addition to the tracking of CWDs, all vessels that moved within 2-3 km of the station were tracked, with effort made to obtain at least two positions for each vessel.

<u>Theodolite Tracking Data Analysis</u>

Theodolite tracking included focal dolphin groups and vessels. Focal follow data were filtered to include only CWD tracks with greater than two positional fixes and 10 minutes or greater in duration. The 10 minute window has been statistically validated for theodolite tracking analyses (Gailey et al., 2007, Lundquist, 2012), and such a logical bound is also described in Turchin (1998). If two consecutive dolphin tracks were more than 5 min apart, they were split and analysed separately. A broad time of day category was assigned for each track (morning = first position recorded before 12 pm; afternoon = first position recorded at 12 pm or later). CWD response variables that were calculated for each track included mean reorientation rate, swimming speed and linearity. Reorientation rate is the degrees per minute of changes in direction of a tracked individual or group of CWDs. Mean swimming speed has been calculated by dividing the distance travelled by the duration between two consecutive positions (Gailey et al., 2007). Linearity is an index of net movement ranging from 0 to 1, with 0 equating to no net movement and 1 equating to straight line movement. It is calculated by taking the net distance between the first and last fix of a track and dividing by the sum of distances travelled for each leg.

In order to evaluate variation in CWD movement patterns in the presence of vessels, it was necessary to establish a distance threshold. When vessels were within 500m of the focal individual or group, they were considered present. The 500m threshold was chosen since Sims et al. (2012) showed that most vessels exceeded background noise when less than 500m away, but not at greater distances. The threshold has been used in other marine mammal situations for similar reasons and direct measurement of animal reactions, such as in Lundquist et al. (2012) for southern right whales (*Eubalaena australis*). As it is not possible to record geographic locations of all targets simultaneously, positions for CWDs and vessels were interpolated *post hoc* (i.e. during analysis in the lab), allowing for a more precise estimation of vessel distances from dolphins at a given time. All types of vessels within 500m were considered, including high speed ferries. The high speed ferries travel through the area much more rapidly (up to 45 knots) than fishing, recreational, industrial vessels carrying cargo and were therefore noted and assessed as a separate category because of this.

ArcMap (v 9.3.1) was used to plot CWD and vessel positions, *Microsoft excel* 2010 was used to conduct computational analysis of leg speed, and linearity and *R* statistical software (2.14.1) was used to perform statistical analyses. Data were tested for normality and transformed if residuals were not normally distributed. Because dolphin focal follows varied in duration, each CWD track was split into 10-minute segments. In order to reduce pseudoreplication, analysis was run to determine the temporal lag at which two segments from the same focal group were no longer autocorrelated. Univariate statistical analyses (one-factor Analysis of Variance, ANOVA) were run to evaluate variation between factors.

Similar to vessel-based surveys, seasonal differences in relative CWD occurrence and use of the study area were examined for land-based surveys, using both the solar seasons (Winter: Dec-Feb, Spring: Mar-

May, Summer: Jun-Aug, Autumn: Sep-Nov) and oceanographic seasons (Dry: Oct-Mar, Wet: Apr-Sep; see Chen et al., 2010). In addition, behavioural descriptions and potential avoidance/association by CWDs relative to vessels or other on-water anthropogenic activities were analysed by multi-variate analyses as in Gailey et al. (2007) and Lundquist et al (2012). The occurrence patterns of the CWDs were assessed periodically (i.e. when feasible) with vessel-based fine scale surveys as described above, and at all times with autonomous passive acoustic monitoring devices (PAMs) located in selected areas of the research zone, as described below.

Passive Acoustic Monitoring

The passive acoustic monitoring was undertaken between December 2012 and December 2013 at a 20% duty cycle (one minute recording then 4 minutes not recording, etc.), 24 hours per day.

Acoustic data were gathered in all seasons to listen for dolphin occurrence patterns and to obtain anthropogenic noise information simultaneously. This work involved a type of Passive Acoustic Monitor (PAM) (Wiggins and Hildebrand, 2007) termed an Ecological Acoustic Recorder (EAR) (Lammers et al., 2008), with bottom-mounted broad-band recording capability operable from 20 Hz (for lower frequency anthropogenic noise) up to a flat response of 32kHz (for echolocating and communicating CWDs). A total of 5 EARs were used, with two spaced in the area with potential for reclamation (A2 and A3), another two immediately outside of this area (to the east is A4 and to the west is A1) and one north of the area, immediately south of Sha Chau Island (A5), as partial controls. All the five units were deployed using custom moorings designed specifically for this study. Data from the units was cross-validated with dolphin number and behavior patterns by simultaneous data gathering by vessel and theodolite tracking during good-weather days. The locations of the EARs are shown in **Drawing No. MCL/P132/EIA/13-013**.

Each EAR recorder was recovered after approximately 6 weeks on the sea bottom and replaced with a new digital recording unit and batteries before repositioning in the same location.

Analysis involved manually browsing through every acoustic recording and logging the occurrence of vessel transits and other unusual sounds. This approach for data analysis is adopted because generally high ambient noise conditions in these waters have meant that an automatic algorithm cannot be reliably used to detect dolphin sounds. All data therefore need to be re-played by computer and listened to by human ears for accurate assessment of dolphin group presence. Vessels were logged when discrete transits passing the EAR could be differentiated from background noise, and thus there can be more than one vessel detection per file.

Comparisons of CWD and vessel sounds during theodolite tracks of those dolphins and vessels were made *post hoc*, that is after both sets of data have been separately alalysed in the laboratory, positions are known, and the positions could be compared to loudness and frequencies of those sounds.

A review of CWD sightings from the land-based survey data in relation to five EAR devices has also been undertaken to provide data on the approximate locations of the CWDs at the time their signals are detected. Thus, overlaps of land-based CWD sightings and the EAR recorded sounds of CWDs have been analysed.

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