Census, Trend, and Status of the St Lawrence Beluga Population in 1992

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ST LAWRENCE BELUGA POPULATION IN 1992

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CONTENTS

TABLES

Page

FIGURES

Page

ABSTRACT

Kingsley, M. C. S. 1993. Census, trend and status of the St Lawrence beluga population in 1992. Can. Tech. Rep. Fish. Aquat. Sci. 1938. vi + 17 pp. + Appendices.

On 12 September 1992 a survey flight was carried out to estimate the size of the St Lawrence population of belugas (*Delphinapterus leucas*). Two aircraft, each equipped with a metric mapping camera shooting 9"x 9" frames through a 6" lens, flew at 4000 feet over a systematic grid of northwest-southeast-aligned transects that stretched from the île aux Coudres to the île du Bic. The transects were spaced 2 nautical miles apart, giving a 50% coverage of the estuary. Nine hundred and ninety-four frames were shot on colour positive aerial survey film. At the same time, another aircraft surveyed the length of the Saguenay Fjord with a single visual observer.

The film was analysed on a light table using low-power microscopy. Two hundred and twenty-seven belugas were counted on 55 frames; 45 (20%) of them appeared from their small size to be juveniles. The resulting estimate of visible belugas was 454 (S.E. 61.8). A 15% visibility correction gave an estimate of 522 (S.E. 71.1). The correction for sun glare on the photo frames was zero for all transects where belugas were seen. On the simultaneous visual survey of the Saguenay Fjord, three more belugas were seen at baie Ste-Marguerite, resulting in a total estimate of 525 for the population.

RÉSUMÉ

Kingsley, M. C. S. 1993. Census, trend and status of the St Lawrence beluga population in 1992. Can. Tech. Rep. Fish. Aquat. Sci. 1938. vi + 17 pp. + Appendices.

Un recensement aérien de la population de bélugas (*Delphinapterus leucas*) du fleuve Saint-Laurent eut lieu le 12 septembre 1992. Deux avions, chacun équipé d'une caméra de cartographie métrique prenant des clichés de 9"x 9" avec une lentille de 6", volèrent à 4000 pieds selon une grille systématique de transects orientés nord-ouest-sud-est s'étendant de l'île aux Coudres à l'île du Bic. Un transect tous les 2 milles nautiques procura un recouvrement de 50% de l'estuaire. Neuf cent quatre-vingt-quatorze clichés furent pris sur film couleur positif pour survol aérien. En même temps, un seul observateur recensait visuellement le fjord du Saguenay à bord d'un autre avion.

Le film fut analysé avec une table lumineuse et un microscope à faible grossissement. 227 bélugas furent comptés sur 55 clichés; 45 (20%), de petite taille, semblaient être juveniles. Ceci a permis un estimé de 454 (erreur type d'échantillonnage 61.8) bélugas visibles en surface. Après une correction de 15% pour les bélugas en plongée, nous obtînmes une estimation de 522 (erreur type d'échantillonnage 71.1). La correction pour les reflets solaires était de zéro pour tous les transects où des bélugas furent observés. Simultanément, lors du relevé aérien visuel du fjord du Saguenay, trois autres bélugas furent observés à la baie Ste-Marguerite, donnant ainsi une estimation de 525 pour la population totale.

PREFACE

This report describes work carried out under the Interdepartmental Plan to Favour the Survival of the Beluga of the St Lawrence, part of the St Lawrence Action Plan.

INTRODUCTION

The population of belugas (*Delphinapterus leucas*) inhabiting the St Lawrence estuary is considered to be endangered. In the earlier history of the St Lawrence, belugas were harvested, at some periods in large numbers (Reeves and Mitchell 1984, 1987; Breton 1990). In this century, belugas were not always favourably regarded, being suspected of adverse effects on stocks of commercially valuable fishes, and were for a time subject to a bounty hunt (Reeves and Mitchell 1987). Declining numbers destroyed the commerce in beluga products after the second World War, and continuing low population counts led to the legislation of an increased level of protection. The belugas of the St Lawrence River were fully protected by the Canadian government in 1979, by amendment to the Beluga Protection Regulations of the Fisheries Act.

The Committee on the Status of Endangered Wildlife in Canada approved and assigned an 'endangered' status for the belugas of the St Lawrence on 6 April 1983 (Campbell 1992). By then, the condition of the environment in general, and the prevalence in the environment of persistent artificial organochlorines—pesticides and others—had become a subject of attention. The propensity of long-lived marine mammals to accumulate lipophilic compounds led to high levels of these pollutants in the belugas of the St Lawrence, and observations of the population appeared to support the view that it was still declining in size (Béland *et al.* 1987).

The Interdepartmental Action Plan for the Survival of the Beluga of the St Lawrence included a research component designed to augment knowledge of the population in such ways as might be appropriate efficiently to direct management and protective measures. The research undertaken included aerial surveys to study the size, distribution and movements of the population. This report presents an estimation of the size of the population, carried out by aerial photographic sample survey in September 1992. It followed other census surveys carried out using the same methods in 1988 and 1990 (Kingsley and Hammill 1991).

METHODS

STUDY AREA, SURVEY DESIGN, AND FIELD METHODS

The survey area covered the middle estuary of the St Lawrence. Aerial surveys had shown that the seasonal distribution of the beluga population extended at least as far upstream as the île aux Coudres, sometimes as far as the battures des Loups Marins off St-Jean-Port-Joli (M. Kingsley, unpublished data). Surveys had also shown that there was increasing use of downstream areas along the south shore of the estuary from île Verte to the île du Bic, and that large concentrations could sometimes be found there (Kingsley and Hammill 1991).
The study area was sampled by a systematic strip transect design (Fig. 1; Appendix 1). As large counts on widely spaced transects inflate the estimate of the standard error, a uniform transect spacing was used for the whole study area, even in the downstream areas where the expected density was low. Coverage extended downstream from the transect 14.0, between Forestville and Bic, to the île aux Coudres at the upstream end, transect 29.2. The transects were spaced 2 nautical miles i.e. 3.704 km apart, and crossed the estuary on headings of 320° and 140° true.

As opposed to the remainder of the survey area, there was no photographic coverage of the Saguenay Fjord, because it is too narrow and tortuous to be satisfactorily sampled by this method. Instead, a visual overflight was made in a light high-wing aircraft (Britten-Norman 'Islander') up the entire length of the fjord from Tadoussac to La Baie and Saint-Fulgence, and back again, while the photographic survey of the St Lawrence was going on. The aircraft was flown at 2000 feet, i.e. 609.6 m, along the south-western shoreline of the fjord, so that the observer was always looking down-sun. The observer sat on the north-eastern side of the aircraft, and recorded the size and position of beluga groups as they were seen.

The photographic survey was flown using two aircraft simultaneously, in order to cover the survey area as quickly as possible and within the same day. The transects were flown from the centre outwards, i.e. in opposite directions, to reduce biases due to possible coordinated movements of belugas upstream or downstream. The work to be done by the two aircraft was as nearly as possible equalised by dividing the transect pattern at île Verte.

The observation platforms were light twin-engined aircraft: Piper 'Aztec' and Rockwell 'Commander'. The cameras were 9" x 9", i.e. 228.6 x 228.6 mm, format mapping cameras (Wild-Leitz RC10 and Zeiss A15/23), fitted with 6", i.e. 153.1-mm, lenses. The cameras were loaded with Kodak 2448 colour positive aerial survey film in 200-foot rolls.

The target survey altitude was 4000 feet, i.e. about 1200 m, giving a coverage of 50%, a nominal scale of 1:8000, and a target image size of 0.5 mm for adult belugas and 0.167 mm for neonates. As it was a clear day, this altitude was achieved for all the flying. Navigation and altitude control was by satellite-linked Global Positioning System. The

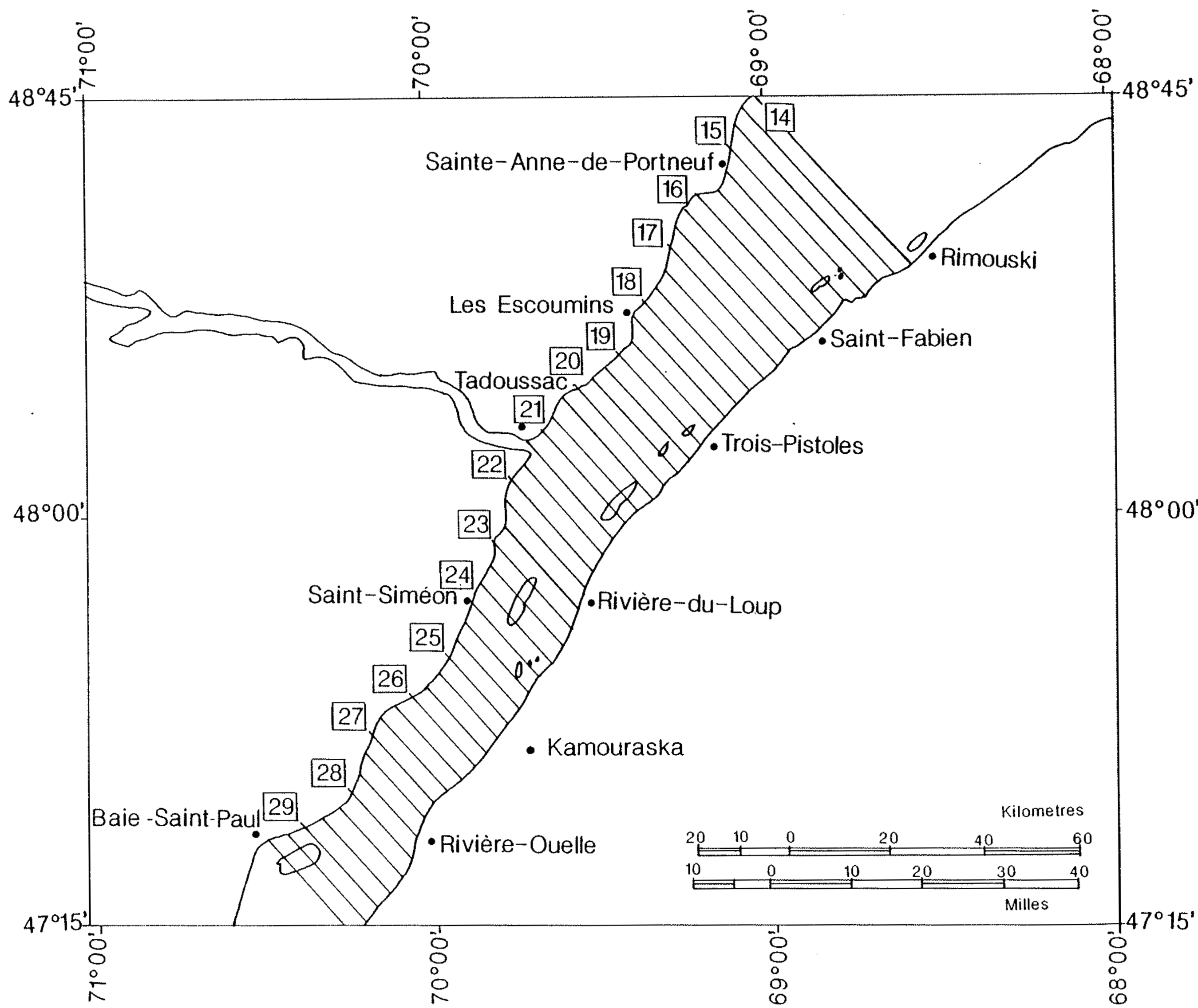

Figure 1. Transects for photographic aerial survey of the St Lawrence estuary, 12 September 1992.

target frame overlap was 20%, and frames were shot at intervals of 15–20 seconds.

FILM INTERPRETATION AND DATA ANALYSIS

Beluga images were counted by examining the film on a light table using a dissecting microscope. Low magnifications were used, as the film grain was the limiting factor in identifying whale images. The film was counted twice, by two technicians independently and without consultation, and checked again by an experienced aerial survey observer.

Some frames had areas of sun glare, a diffuse solar reflection that prevents whales being seen in part of some frames. Glare areas were searched for whales. Glare correction was checked by measuring frame overlap, and measuring the glare area not covered by the non-glared overlap of the next frame to the nearest one percent, using a ruled square grid. The distribution of belugas is known to be patchy, and the glare varied within the survey depending on the sun angle and the local wind and cloud cover. Therefore, local glare corrections would be used for those regions where belugas were seen on transects, instead of a mean glare correction over the entire survey. It was sometimes difficult to determine the overlap, owing to the lack of features on the water, and in such cases, a nearby frame was sought which showed a convergence line or front, turbidity pattern, buoy, coastline or similar feature.

For data analysis, the counts were summed over transects, omitting images that were repeated on consecutive frames. To reject an image as a repetition, the frame overlap was measured, and the position of the image relative to buoys, convergence lines, land features, or other fixed objects was checked. A group or individual would be recorded as a repetition if it was within 4 body lengths of its position on the neighbouring frame, heading in the same direction, and of a similar size. The expansion factor for the survey was calculated as

$$\begin{aligned} k &= S \,/\, W \\ &= S \,/\, (H \times B/L) \end{aligned} \qquad [1]$$

where: S = transect spacing;
W = transect width;
H = flying height;
B = photo frame breadth (228.6 mm for the metric mapping cameras used);
and L = lens focal length (153.1 mm for these lenses).

The estimate of numbers of visible whales for the area sampled by the transect grid was then given by

$$\hat{N} = k \sum_{j=1}^{J} x_j \qquad [2]$$

where: J = the number of transects;
x_j = the number of whales counted on the j^{th} transect.

The serial difference methods of Kingsley and Smith (1981) for calculating error variances for density estimates from systematic surveys were modified for this case in which the valid study area, i.e. the habitat area actually used by the population, was not precisely known and the statistic of interest was the total size of a separate population rather than the spatial density of organisms. The expression used followed equation 8.44 of Cochran (1977), and was

$$\hat{V} = \frac{k\ (k-1)\ J}{2\ (J-1)} \sum_{j=1}^{J-1} (x_j - x_{j+1})^2 \qquad [3]$$

including a correction for sampling from a finite population.

A correction for submerged animals is appropriate for photographic aerial surveys of marine mammals, but it is difficult to estimate the value of such a correction. Uncorrected estimates, i.e. of visible whales, were calculated and are presented here, and such information as is available on diving correction factors was reviewed and a correction factor applied to estimate total population.

There are two methods of classifying sightings of young belugas: by size, as they grow to adult length; and by colour, as the dark grey calves lighten gradually to the white adult coloration. We were unable to differentiate colour gradations: even the smallest calves looked white on the aerial survey film. Nor did we attempt to make precise measurements of image length on the photographs, owing to their small scale. However, we were able to make approximate length measurements, and could identify whales that were distinctly shorter than the average adult. Small whales were assigned to two classes. *Calves at heel* were defined as those that were close to an adult and shorter; *independent juveniles* were those well separated from the nearest other whale, but clearly and visibly shorter than adult images. *Unclassifiable* animals were those for which poor image quality due to distance below the surface, the attitude of the whale, or simply an intermediate size, prevented us from being sure either that they had the length and bulk of adults, or that they were definitely shorter.

Previously published estimates of the size of the population were gathered, and simple linear regression against time, in years, was used to estimate the average rate of change—the trend—in the population.

RESULTS AND DISCUSSION

POPULATION COUNTS

The weather was calm upstream of Les Escoumins, giving generally excellent conditions. Downstream of Les Escoumins, the conditions were worse, with winds over 10 knots, sea states up to Beaufort 4, and frequent whitecaps. The sky was clear, so there was sunshine to be reflected from the water. Sun glare occurred on some photo frames in the downstream part of the survey, where the water was rough, but no belugas were seen on frames where the sea state was over Beaufort 2. In the upstream part of the survey, the water was so smooth that there was little or no glare on the photos. On all frames where glare occurred and belugas were seen, all glare areas were included in the overlap. Therefore no glare correction was applied to any of the counts.

Table 3. Counts of beluga whales on photographic survey transects over the St Lawrence estuary, 12 September 1992.

Transect No	Count	Transect No	Count	Transect No	Count
S = 2 n. mi.; H = 4000 ft; k = 2					
19.2	6	22.0	13	25.0	6
20.0	14	22.1	24	25.1	10
20.1	23	22.2	5	25.2	20
20.2	13	23.1	5	26.0	2
21.0	2	23.2	22	28.1	1
21.1	3	24.1	9	29.0	3
21.2	34	24.2	12		

Note: of 48 transects flown (14.0 through 29.2), 28 on which no belugas were counted are not included in this Table.

In 1990, belugas were distributed from the île aux Coudres to St-Simon-sur-Mer (Kingsley and Hammill 1991). However, in the 1992 survey, as in 1988, the distribution observed was concentrated toward the centre of the known summer range, no belugas being recorded downstream of the île aux Pommes (transect 19.2), and very few upstream of Kamouraska (transect 25.2) (Fig. 2).

Belugas were counted on 20 of 48 transects flown (Table 1). The transect counts totalled 227. Inserting the flight parameters into Equation 1 and the transect counts into Equations 2 and 3 gave an estimate of visible whales of 454, with an estimated sampling standard error of 61.8. The transect counts were serially correlated (r = 0.39), indicating that systematic sampling was appropriate.

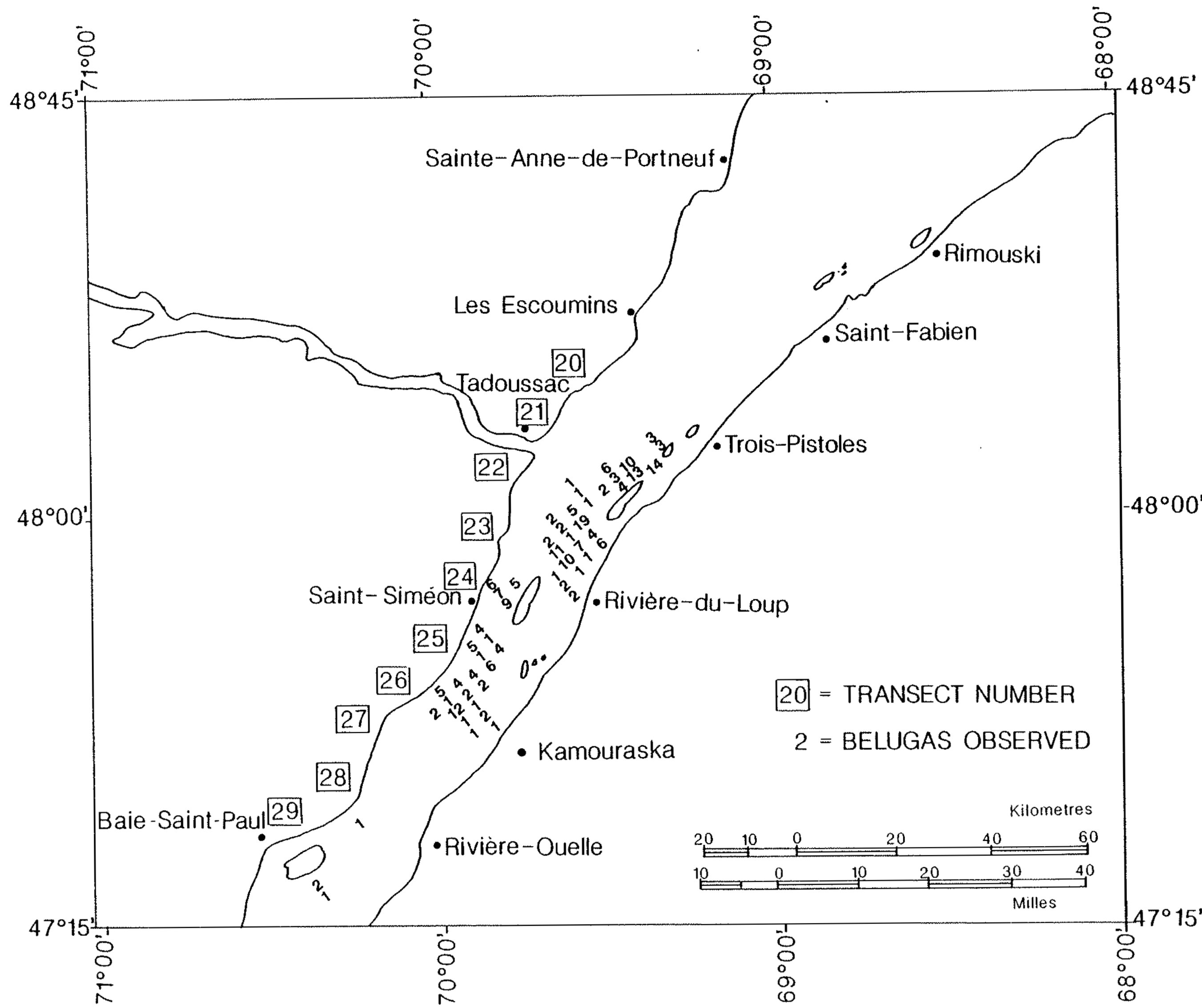

Figure 2. Observations of belugas on photographic aerial survey of the St Lawrence estuary, 12 September 1992.

There is little good information on which to base a visibility correction for photographic aerial surveys of belugas in the St Lawrence estuary. Shallowly submerged whales can be identified on aerial survey film - there are few other objects either on the surface or submerged that resemble the blurred white comma-shaped image - but the probability of detection is small and decreases rapidly with depth (Richard *et al.* in press). Furthermore, the proportion of such submerged images in the total count gives no estimate of how many more might be even deeper out of sight. Surface studies of diving behaviour are of little value in estimating the proportion of the population that is visible to an airborne camera. Sergeant and Hoek (1988), by comparing the images visible in the overlap areas in neighbouring frames in photographic surveys of St Lawrence belugas, derived correction factors of 15% and 21% for two different surveys. They noted that these values were minimum, since they did not correct for belugas underwater and out of sight in both frames. Information on dive behaviour obtained from satellite-linked time-depth recorders attached to Arctic belugas (Martin and Smith 1992) and narwhals (Martin *et al.* in press) indicates that for Arctic monodontids in deep clear water correction factors may be as high as 75%, but it is not known whether the same values would apply to the shallower, but more turbid, St Lawrence. A study in north Baffin Island on the diving behaviour of narwhal estimated a correction factor of at least 100% (Dueck 1989), but it is not clear if this is applicable to all habitat areas and behaviour patterns, or only to areas with a high proportion of feeding activity. As a standard correction factor for the estimates obtained in these surveys, we have used the least of these values, viz. 15%. A 15% correction factor was added to this estimate of 454 to yield a corrected estimate of total population in the St Lawrence estuary of 522.1 (sampling standard error 71.1).

On distribution surveys in previous years up to 59 belugas have been counted in the Saguenay Fjord (M. Kingsley, unpublished data), so it was surveyed by direct visual observation while the photographic survey was going on. Conditions in the fjord were marginal for visual aerial survey, as a north-west wind was funnelling along the length of the fjord, generating some whitecaps and many streaks of foam. No belugas were seen on the way up the fjord, but three white adults were seen close to the shelf break in Baie Ste-Marguerite on the return flight. No visibility correction factor was added to this number. The estimated total count for the population, including the Saguenay, is therefore 525.

This estimate of total population is based upon a minimal correction for animals not seen through being deep underwater when the aircraft passed overhead. Therefore, as well as the estimated sampling standard error that is attached to this estimate, there is an additional uncertainty associated with the visibility correction. Because the smallest reasonable value of the visibility correction has been used, the estimate of total population is conservative. However, population monitoring and trend estimation are, in this context, as important as knowing the absolute size of the population. For these purposes, it is advantageous to use a standard visibility correction factor.

POPULATION TREND

Other estimates of the size of the beluga population of the St Lawrence estuary with which the most recent estimate may be compared are listed in Table 2. A rate of change of the population with time—i.e. a population trend—was estimated by standard linear

Table 2. Population estimates for belugas of the St Lawrence estuary, 1973 - 1992.

Year	Method	Corrected estimate	95% confidence interval (-) or standard error (±)	Source
1973	Photo (air)	443[a]	229–658	Sergeant & Hoek (1988)
1977	Visual (air)	325[b]	300–350	Pippard (1985)
1982	Visual (air)	512[c]	360–715	Sergeant & Hoek (1988)
1984	Photo (air)	431[a]	187–773	"
1984	Visual (boat)	495[c]	±245	Lynas (1984)
1985	Visual (boat)	340		Béland *et al.* (1987)
1985	Photo (air)	530[a]	285–775	Sergeant & Hoek (1988)
1988	Photo (air)	491[a]	± 69	Kingsley & Hammill (1991)
1990	Photo (air)	606[ad]	±308	"
1992	Photo (air)	525[a]	± 71	this report

[a]corrected for visibility;
[b]the cited publication only gives a probable range; the value tabulated here as a population estimate is the midpoint of that range;
[c]uncorrected for visibility;
[d]erroneously 607 in Kingsley and Hammill (1991).

regression methods. Including all the tabulated values, the rate of change of the population was estimated at 8.6 belugas/yr (std err. 4.5 belugas/yr). If the 1990 population estimate of 606—probably biased upwards (Kingsley and Hammill 1991)—was omitted, the rate of change was 6.3 (SE 4.6) belugas/year. If the low estimates obtained by Pippard (1985) and Béland *et al.* (1987) were omitted, the rate of change became 5.9 (SE 3.0) belugas/year including the 1990 estimate and 3.9 (SE 2.4) belugas/year without it (Fig. 3). Even given the imperfections of these population estimates, it would be difficult to sustain the hypothesis that the population is decreasing, or that it is increasing, on average, by more than a small percentage every year.

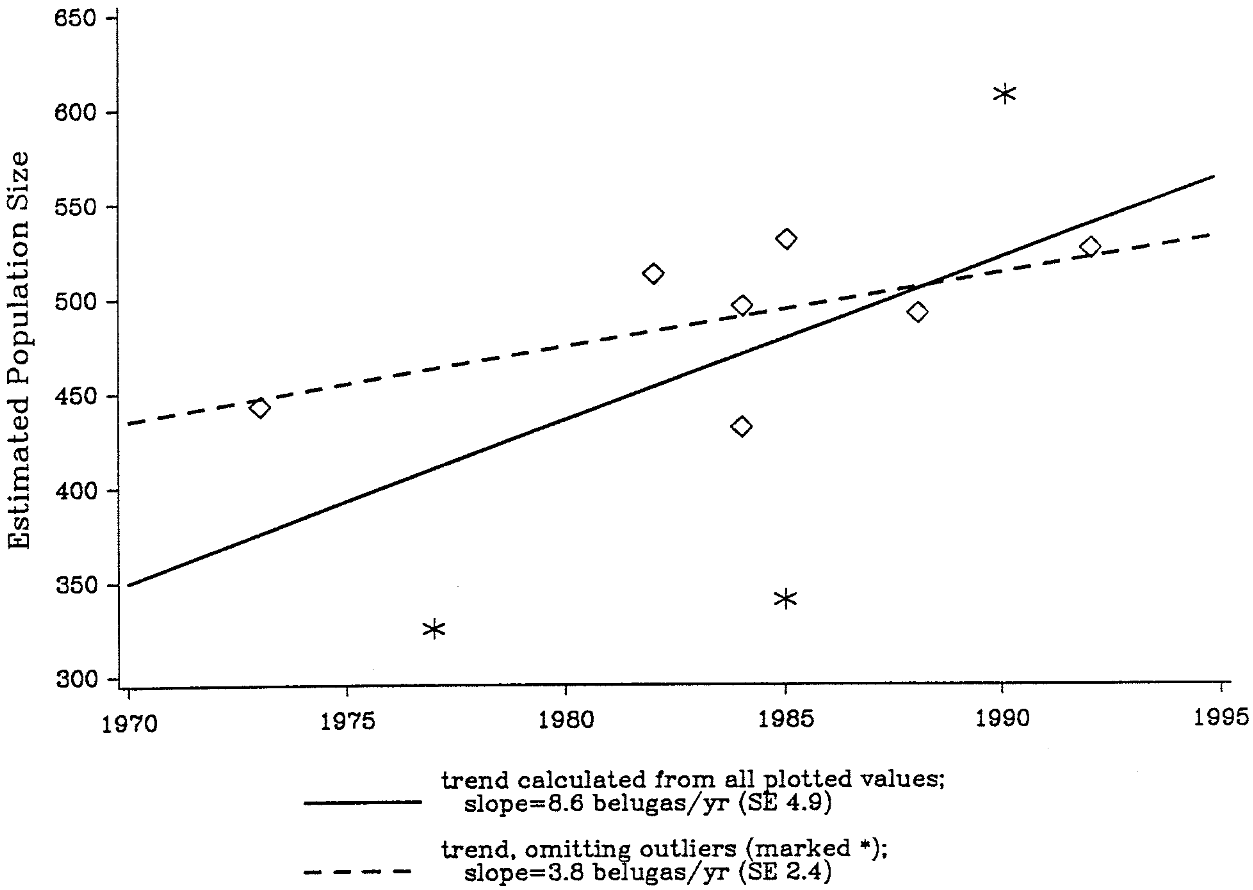

Figure 3. Trend in size of St Lawrence beluga population, estimated from published population survey results

Two caveats, in particular, must be applied to these calculations of average trend values. Firstly, the trend value was sensitive to the earliest population estimates made in 1973 and 1977, which extend the time base for calculating the rate of change to 19 years. Without them, the time base is only 10 years. Secondly, the trend calculation assumed that the population had changed at a steady rate. If it had, instead, grown more slowly in the 1970s owing to a continuing hunt at that time, it would have been growing faster in more recent years.

The population estimates obtained from some of the census surveys may be more precise than the estimated sampling standard errors or estimated confidence intervals indicate. Standard error is defined as the variation between repeated estimates of a parameter (Sokal and Rohlf 1969.) If the standard errors that are calculated for the parameter estimates do not generally approximate the variation between the estimates—i.e., the true standard error—it may be a *prima facie* indicator that the standard errors are being calculated by inappropriate methods. Although confidence bands calculated for some of the past surveys have been very wide—e.g. from 190 to 770 in 1984—the corrected estimates of total population fall in a much narrower band, and this leads us to question the reliability of the estimated standard errors that were used to calculate the confidence intervals. The calculations used to estimate standard error for some of the surveys made in the 1980s may not have factored in some of the survey characteristics that could have had the effect of reducing them, such as systematic sampling pattern and high-density coverage of beluga habitat areas.

It is emphasised that although the data available to date (subject to uncertainty in visibility correction) indicates that the population index is now probably between 500 and 600, and that it may be slowly increasing, no estimate of the rate of increase has been firmly established. To do so will require a continuation of careful survey work. A population of only several hundreds of a large mammal with a low reproductive rate, isolated from its conspecifics, and inhabiting a restricted area in a heavily travelled estuary where individuals have become highly contaminated with persistent organochlorines and heavy metals (Martineau *et al.* 1987), must be regarded as still being in a precarious situation.

PROPORTION AND DISTRIBUTION OF YOUNG BELUGAS

The St Lawrence population has been said to have a reproductive rate which at 8–9% per year is low compared with that estimated for Arctic populations at 14.5% (Sergeant 1986). However, other analyses of monodontid population dynamics (Burns and Seaman 1985) show that the gross population annual birth rate should be 9--10 %, and after calving, the first four age classes, aged 0--3 years, would sum to about 27% of the population. Young belugas grow slowly, and even at three years of age are still only 70% of the length of the female (Doidge 1990).

In the 1988 survey, there were few beluga calves definitely identified on the film. Nineteen juveniles were counted, but half of these were rated as 'questionable', and there were only three that were counted as 'calves at heel' (Table 3). This would support the

Table 3. Juvenile belugas counted from photographic aerial surveys of the St Lawrence in 1988, 1990, and 1992.

Year	Total count	Juveniles				
		At heel	Independent	Questionable	Total	as % of total count
1988	152	3	6	10	19	12.50
1990	148	23	4	-	27	18.24
1992	227	33	12	-	45	19.87

conclusion that the birth rate was low. In that year, colour negative film was used, and proved difficult to interpret. It was carefully searched for small beluga images, but they were not found. In 1990, no juveniles rated as 'questionable', and the total count of juveniles was higher. Juveniles were 18% of the population in 1990, and 'calves at heel' accounted for 88% of all juveniles.

In 1992, 33 cow-calf pairs and 12 independent juveniles were recorded in a total count of 227 (Table 3); 74, or 32.6%, were unclassifiable. Not all the calves counted in cow-calf pairs were young of the year: assuming normal reproduction, only 23 young of the year would be expected in a total count of 224, and the newborn young of the year are particularly likely not to be visible on high-altitude aerial survey film because they are so small. There was considerable variety in the lengths of the small belugas counted close to larger animals, which were considered calves at heel. Calves over 2 years old may be likely to separate from their mothers and be considered unclassifiable, not being accompanied by a larger animal. However, 20% identified juveniles, compared with an expected 27% (Burns and Seaman 1985) for the first four age classes, supposes a 74% relative detectability for juveniles, compounded of visibility and classifiability. If unclassified animals are left out, the identified juveniles become 29% of the remaining count of adults plus juveniles. The 1990 and 1992 results do not indicate depression of the reproductive rate in this population.

Most of the sightings made in 1992 were upstream of the mouth of the Saguenay Fjord (Fig. 4). The proportion of young in that upstream sector was estimated at 20% (Table 4). Of the much smaller number of belugas downstream of the Saguenay, the

Table 4. Distribution of juvenile belugas in the St Lawrence estuary determined from photographic aerial surveys in 1988, 1990, and 1992.

	Upstream of Saguenay			Downstream of Saguenay		
Year	Calves	Others	%	Calves	Others	%
1988	15	53	22.1	4	80	4.8
1990	24	76	24.0	3	45	6.1
1992	36	135	21.1	9	49	18.4

proportion of juveniles was similar at 18%. The observations in the downstream area tended to be toward the south side of the estuary. It has been considered in the past that groups of females and calves have a distribution that favours the upstream end of the range of the population, i.e. the estuary upstream of the mouth of the Saguenay Fjord

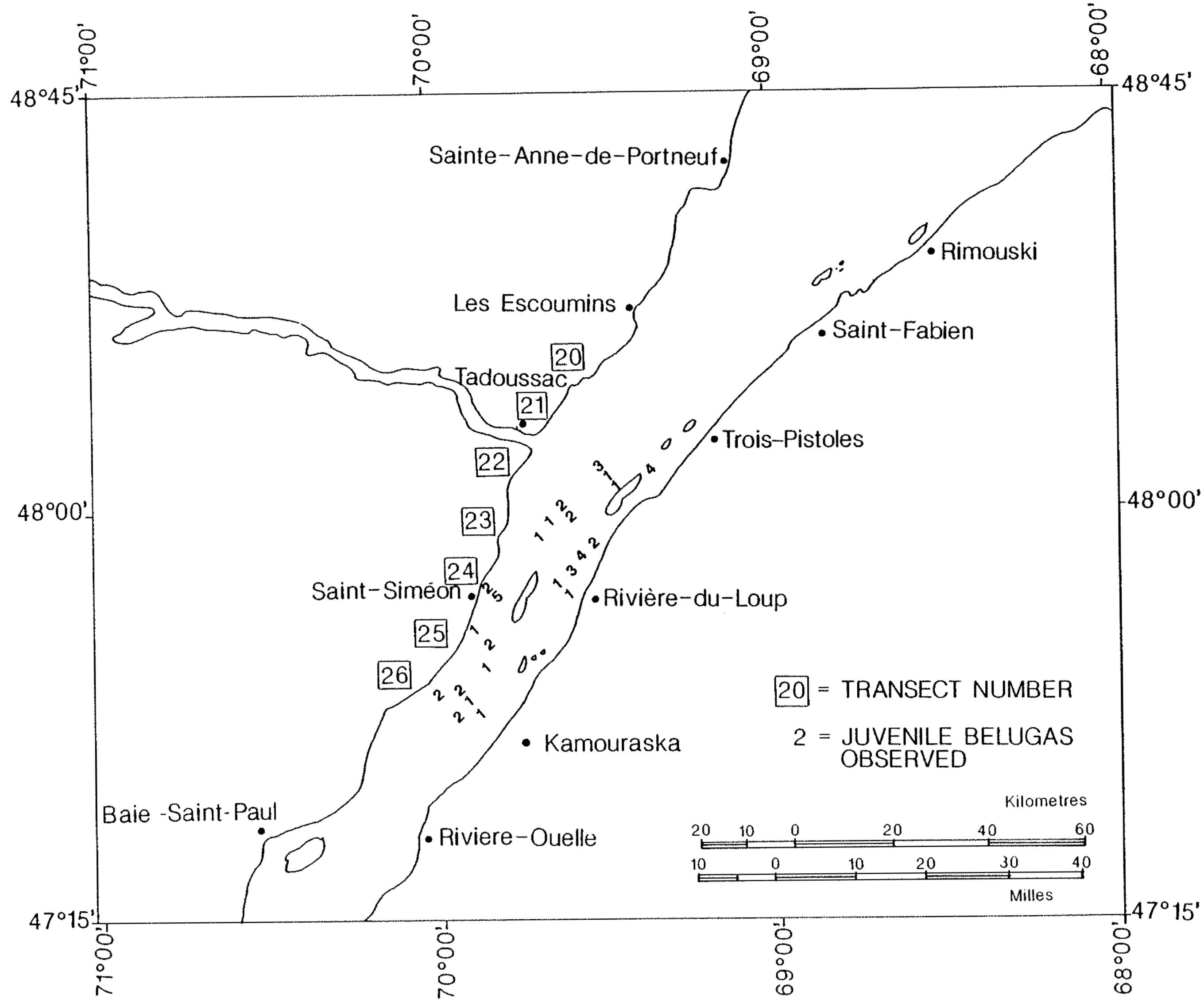

Figure 4. Distribution of juvenile belugas in the St Lawrence estuary determined from photographic aerial survey, 12 September 1992.

(Sergeant 1986; Sergeant and Hoek 1988: Fig. 4), while belugas found downstream of the Saguenay are usually all adults, and presumably adult males. A separate herd of large white adults is typically seen in the deep water of the Laurentian Channel off the north shore of the estuary between Les Escoumins and Grandes Bergeronnes. This distribution was also observed in the 1988 and 1990 surveys (Kingsley and Hammill 1991: Table 6, Fig. 5, Fig. 6). In both those surveys, the proportion of juveniles upstream of the Saguenay was over 20%, while downstream it was 4 - 6%. The larger number of juveniles in 1990, almost all upstream of the mouth of the Saguenay Fjord, was associated with a larger count of accompanying adults in the upstream area, in such a way that the proportion of juveniles in that area remained nearly constant. This supported Sergeant's (1986) suggestion of a segregation of lactating females with calves in the île aux Lièvres area. However, in recent years, crews flying visual aerial surveys to estimate the distribution of the population, and boat crews carrying out studies of the composition of groups in different parts of the range, have noticed an increased frequentation of the southern part of the estuary downstream of île Verte, which is opposite the mouth of the Saguenay, by groups of females with young (Michaud 1993).

CONCLUSION ON THE STATUS OF THE POPULATION

Using a conservative value of the factor to correct for visibility, the size of the St Lawrence population of belugas is estimated at 525, and under the same assumption a probable range is between 500 and 600. If the proportion of belugas not visible to aerial photographic surveys were to be assumed greater than about 13%, the population estimate would increase. The population trend is at worst stable; it is possible that it may be increasing, but the rate of increase, if any, is very small. The juvenile proportion of the aerial film counts in 1992 is consistent with a normal rate of reproduction, allowance being made for the difficulty of both seeing juveniles on the film, and confidently identifying them as such when they are seen. More significantly, the proportion of juveniles appears, if anything, to be increasing, and may possibly affect the future rate of growth of the population.

However, the population is still isolated from its conspecifics, no significant immigration or regular exchange with other beluga groups being known. This, combined with its low numbers, will continue to render its situation precarious for the foreseeable future.

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Appendix I. Coordinates of transects for systematic sample survey of the St Lawrence estuary.

Of these transects, numbers 14 through 29+2 were flown for the photographic census survey of the St Lawrence beluga on 12 September 1992. The others are included as a matter of record.

Transect number	North end latitude	North end longitude	South end latitude	South end longitude
1	49°24.2'	67°20.0'	49°1.8'	66°51.6'
1+1	49°22.4'	67°21.0'	49°1.5'	66°54.5'
1+2	49°20.5'	67°22.9'	49°0.0'	66°56.6'
2	49°20.0'	67°26.5'	48°59.4'	67°0.0'
2+1	49°20.3'	67°30.0'	48°58.2'	67°2.4'
2+2	49°20.0'	67°34.0'	48°57.2'	67°5.0'
3	49°20.0'	67°38.5'	48°56.5'	67°8.3'
3+1	49°18.8'	67°40.3'	48°55.7'	67°11.3'
3+2	49°19.0'	67°44.6'	48°54.8'	67°14.2'
4	49°17.8'	67°47.5'	48°53.8'	67°16.9'
4+1	49°17.0'	67°50.0'	48°53.5'	67°20.2'
4+2	49°17.8'	67°55.3'	48°52.7'	67°23.0'
5	49°17.9'	68°0.0'	48°51.5'	67°25.9'
5+1	49°18.2'	68°3.7'	48°50.7'	67°28.5'
5+2	49°16.2'	68°5.3'	48°50.4'	67°32.0'
6	49°15.6'	68°8.7'	48°49.0'	67°34.6'
6+1	49°13.3'	68°9.5'	48°48.2'	67°37.3'
6+2	49°12.5'	68°12.3'	48°47.2'	67°40.0'
7	49°8.3'	68°11.4'	48°46.1'	67°43.0'
7+1	49°6.5'	68°12.9'	48°45.5'	67°45.8'
7+2	49°6.0'	68°16.0'	48°44.7'	67°48.8'
8	49°6.1'	68°20.0'	48°43.8'	67°51.9'
8+1	49°4.6'	68°22.2'	48°42.4'	67°54.0'
8+2	49°3.3'	68°24.4'	48°41.1'	67°56.1'
9	49°4.8'	68°30.4'	48°40.0'	67°58.5'
9+1	49°4.2'	68°33.4'	48°39.8'	68°2.5'
9+2	49°3.3'	68°36.1'	48°38.3'	68°4.3'
10	49°1.8'	68°38.0'	48°37.3'	68°6.9'
10+1	48°59.3'	68°38.9'	48°37.2'	68°10.8'
10+2	48°56.6'	68°39.2'	48°36.2'	68°13.3'
11	48°54.1'	68°40.0'	48°35.0'	68°15.6'
11+1	48°54.7'	68°44.6'	48°33.7'	68°18.0'
11+2	48°53.8'	68°47.4'	48°32.5'	68°20.4'
12	48°52.4'	68°49.5'	48°31.8'	68°23.5'
12+1	48°51.0'	68°51.8'	48°31.0'	68°26.6'
12+2	48°50.0'	68°54.5'	48°29.2'	68°28.7'

Transect number	North end latitude	North end longitude	South end latitude	South end longitude
13	48°49.2'	68°57.4'	48°27.7'	68°30.9'
13+1	48°47.2'	68°59.0'	48°26.2'	68°32.8'
13+2	48°46.8'	69°2.2'	48°25.2'	68°35.4'
14	48°44.9'	69°3.8'	48°24.0'	68°37.9'
14+1	48°43.3'	69°5.7'	48°23.0'	68°40.3'
14+2	48°40.4'	69°6.1'	48°22.0'	68°42.8'
15	48°37.2'	69°6.0'	48°21.8'	68°46.3'
15+1	48°35.8'	69°8.3'	48°20.3'	68°48.4'
15+2	48°35.1'	69°11.2'	48°18.8'	68°50.7'
16	48°34.3'	69°14.0'	48°18.5'	68°54.1'
16+1	48°33.2'	69°16.1'	48°17.0'	68°56.0'
16+2	48°31.3'	69°17.6'	48°15.7'	68°58.2'
17	48°28.1'	69°17.8'	48°14.0'	69°0.0'
17+1	48°26.3'	69°19.5'	48°13.3'	69°3.0'
17+2	48°24.4'	69°20.7'	48°11.8'	69°5.0'
18	48°22.5'	69°22.2'	48°10.3'	69°7.0'
18+1	48°20.8'	69°23.8'	48°8.7'	69°8.9'
18+2	48°19.0'	69°25.3'	48°7.4'	69°11.2'
19	48°17.3'	69°27.0'	48°5.9'	69°13.2'
19+1	48°16.2'	69°29.8'	48°4.7'	69°15.7'
19+2	48°14.4'	69°31.6'	48°3.1'	69°17.6'
20	48°13.4'	69°34.3'	48°2.0'	69°20.0'
20+1	48°11.9'	69°36.4'	48°1.4'	69°23.1'
20+2	48°10.4'	69°38.6'	48°0.0'	69°25.3'
21	48°8.9'	69°40.4'	47°58.5'	69°27.2'
21+1	48°8.8'	69°44.2'	47°56.6'	69°28.6'
21+2	48°5.2'	69°43.6'	47°54.8'	69°30.3'
22	48°3.9'	69°45.7'	47°53.1'	69°32.2'
22+1	48°1.4'	69°46.3'	47°51.1'	69°33.6'
22+2	47°58.5'	69°46.8'	47°48.8'	69°34.4'
23	47°56.5'	69°48.0'	47°46.8'	69°35.7'
23+1	47°54.5'	69°49.4'	47°45.0'	69°37.3'
23+2	47°52.7'	69°51.2'	47°43.5'	69°39.3'
24	47°51.0'	69°52.8'	47°42.3'	69°41.7'
24+1	47°48.9'	69°53.9'	47°40.4'	69°43.3'
24+2	47°46.4'	69°54.8'	47°38.5'	69°44.8'
25	47°45.8'	69°57.8'	47°37.0'	69°46.8'
25+1	47°43.7'	69°59.0'	47°35.6'	69°48.8'
25+2	47°42.1'	70°0.8'	47°34.4'	69°51.3'
26	47°41.0'	70°3.4'	47°32.6'	69°52.9'
26+1	47°40.0'	70°6.0'	47°31.1'	69°54.7'
26+2	47°39.5'	70°9.2'	47°30.1'	69°57.3'
27	47°36.7'	70°9.5'	47°29.4'	70°0.5'

Transect number	North end latitude	North end longitude	South end latitude	South end longitude
27+1	47°35.4'	70°11.8'	47°27.1'	70°1.4'
27+2	47°32.9'	70°12.4'	47°25.0'	70°2.6'
28	47°30.5'	70°13.3'	47°22.4'	70°3.3'
28+1	47°29.3'	70°15.7'	47°20.8'	70°5.2'
28+2	47°28.2'	70°18.1'	47°19.5'	70°7.5'
29	47°27.8'	70°21.5'	47°18.7'	70°10.3'
29+1	47°26.8'	70°24.0'	47°17.5'	70°12.6'
29+2	47°25.9'	70°26.7'	47°15.4'	70°14.0'
30	47°25.4'	70°30.1'	47°13.4'	70°15.3'

Appendix II. Counts of beluga whales on aerial photography of the St Lawrence estuary, 12 September 1992.

Roll and frame numbers referenced in this Appendix are the same as those appearing in Appendix III. Transect numbers are not; instead, they are those referenced in Appendix I, Table 1 and Figure 1 of this report.

The film was read on a light table, emulsion side up, i.e. reversed, with the start of the film (lower-numbered frames) to the reader's right. For north-bound transects, South was to the reader's right, North to his left, West at the top of the table, and East at the bottom. On south-bound transects, South was to the left, North to the right, West at the bottom, and East at the top. Images were located on the film on a grid of 10 squares each way. The rows were numbered 00 at the top to 90 at the bottom of the light table, the columns were numbered 00 at the left and 09 at the right. Square 00 was at the top left, 09 at the top right, 90 at the bottom left, and 99 at the bottom right.

Roll	Transect	Frame	Position (Lat. N; Long. W)	Grid	Observations
31621	17.2	188	48°23.59' - 69°19.43'	35	blue whale
31621	18.2	138	48°16.00' - 69°17.00'	23	fin whale
31621	18.2	106	48°17.72' - 69°25.75'	66	blue whale
31621	19.2	46	48°07.28' - 69°23.26'	21	A/n
31621	19.2	46	"	22	A
31621	19.2	46	"	23	A
31621	19.2	47	48°08.50' - 69°24.53'	39	A/p
31621	19.2	47	"	44	[3A]
31621	20.0	34	48°04.05' - 69°22.49'	11	Cc/n
31621	20.0	34	"	33	J
31621	20.0	34	"	34	Cc
31621	20.0	34	"	52	[2A]
31621	20.0	34	"	62	[2A + U] U
31621	20.0	34	"	82	[Cc + U]
31621	20.0	35	48°03.58' - 69°21.81'	19	Cc/p
31621	20.1	07	48°04.40' - 69°26.70'	65	[5A + 8U]
31621	20.1	08	48°04.87' - 69°27.38'	03	[2A]

Observations: [ ] = close group; Cc = ♀ with calf at heel; A = adult; J = juvenile; U = unclassified; /p (n) = also on previous (next) frame.

Roll	Transect	Frame	Position (Lat. N; Long. W)	Grid	Observations
31621	20.1	08	"	28	[4A + 4U]
31621	20.1	16	48°09.97' - 69°33.95'	42	fin whale
31621	20.1	17	48°10.63' - 69°33.74'	94	fin whale
31616	20.2	02	48°02.35' - 69°30.21'	33	Cc
31616	20.2	02	"	93	[A + U]
31616	20.2	03	48°02.69' - 69°30.84'	26	[Cc + U]
31616	20.2	06	48°04.04' - 69°33.20'	60	[2C + 3c + U]/n
31616	20.2	07	48°04.49' - 69°33.99'	68	[Cc + Cc + 2U]/p
31616	21.0	27	48°02.85' - 69°34.31'	31	[2U]
31616	21.1	44	48°02.55' - 69°36.69'	86	U
31616	21.1	45	48°03.11' - 69°37.37'	30	U
31616	21.1	47	48°04.35' - 69°38.81'	52	A
31616	21.2	65	47°59.15' - 69°35.42'	42	[Cc + Cc + A]/n
31616	21.2	66	47°58.63' - 69°34.79'	00	A
31616	21.2	66	"	41	A
31616	21.2	66	"	42	[2U]
31616	21.2	66	"	59	[2U]/p
31616	21.2	66	"	73	U
31616	21.2	66	"	76	U
31616	21.2	66	"	81	Cc/n A
31616	21.2	66	"	82	[2A]/n [2U]/n [2U]
31616	21.2	66	"	85	[A + U]
31616	21.2	66	"	86	U
31616	21.2	66	"	97	J
31616	21.2	67	47°58.10' - 69°34.16'	49	[A + 2U]
31616	21.2	67	"	69	A
31616	21.2	67	"	88	Cc/p
31616	21.2	67	"	99	[2A]/p [2A]/p
31616	21.2	71	47°55.22' - 69°30.79'	31	[Cc + Cc] A/n

Observations: [ ] = close group; Cc = ♀ with calf at heel; A = adult; J = juvenile; U = unclassified; /p (n) = also on previous (next) frame.

Roll	Transect	Frame	Position (Lat. N; Long. W)	Grid	Observations
31616	21.2	71	"	51	A
31616	21.2	72	57°53.22' - 69°31.96'	48	A/p
31616	22.0	76	47°55.42' - 69°34.82'	11	U/n
31616	22.0	77	47°55.96' - 69°35.44'	12	Cc/n
31616	22.0	77	"	18	U/p
31616	22.0	77	"	25	Cc J Cc-deep
31616	22.0	78	47°56.55' - 69°36.03'	19	U Cc/p
31616	22.0	79	47°57.00' - 69°36.70'	17	U
31616	22.0	79	"	36	U-deep
31616	22.0	84	47°59.33' - 69°39.34'	97	Cc
31616	22.1	101	47°57.26' - 69°40.91'	73	Cc
31616	22.1	106	47°56.20' - 69°38.18'	12	A/n
31616	22.1	106	"	33	A
31616	22.1	106	"	32	[2U]/n-deep
31616	22.1	106	"	51	U
31616	22.1	106	"	52	[2A + 2U]/n
31616	22.1	106	"	82	U
31616	22.1	106	"	93	A
31616	22.1	107	47°54.42' - 69°37.69'	19	A
31616	22.1	107	"	29	A/p
31616	22.1	107	"	49	[2U]/p-deep
31616	22.1	107	"	57	[Cc + A]
31616	22.1	107	"	69	[3U]/p
31616	22.1	107	"	73	Cc Cc A U
31616	22.1	108	47°53.25' - 69°36.35'	13	U
31616	22.2	125	47°53.79' - 69°40.80'	77	Cc
31616	22.2	129	47°55.39' - 69°42.89'	40	Cc
31616	22.2	130	47°55.83' - 69°43.46'	46	A
31616	23.1	171	47°52.78' - 69°47.22'	15	A

Observations: [ ] = close group; Cc = ♀ with calf at heel; A = adult; J = juvenile; U = unclassified; /p (n) = also on previous (next) frame.

Roll	Transect	Frame	Position (Lat. N; Long. W)	Grid	Observations
31616	23.1	171	"	43	[4U]
31616	23.2	177	47°51.61' - 69°49.13'	03	[Cc + Cc + 2U]
31616	23.2	178	47°50.98' - 69°48.41'	27	A
31616	23.2	178	47°50.98' - 69°48.41'	48	[3J]
31616	23.2	178	"	59	[2J]
31616	23.2	178	"	71	A/n
31616	23.2	179	47° 48.21' - 69°45.11'	68	A/p
31616	23.2	184	47° 47.66' - 69°44.45'	02	A
31616	23.2	184	"	51	A
31616	23.2	184	"	71	A/n U
31616	23.2	184	"	90	[A + 3U]/n
31616	23.2	185	47°47.09' - 69°43.74'	68	A/p
31616	23.2	185	"	97	[A + A/p + 3U/p]
31616	24.1	212	47°48.24' - 69°52.67'	22	[C/nc + 2U/n]
31616	24.1	213	47°47.14' - 69°51.36'	29	[A + 2U]/p deep
31616	24.1	214	47°46.83' - 69°50.96'	27	A
31616	24.1	215	47°46.52' - 69°50.57'	86	[Cc + J]
31616	24.1	215	"	87	U
31617	24.2	10	47°44.24' - 69°51.75'	26	J
31617	24.2	10	"	27	A
31617	24.2	10	"	32	A
31617	24.2	10	"	55	A
31617	24.2	10	"	60	U/n
31617	24.2	10	"	84	A
31617	24.2	11	47°44.94' - 69°52.59'	67	A U/p
31617	24.2	14	47°46.42' - 69°54.74'	52	A
31617	24.2	14	"	61	A 2A/n
31617	24.2	14	"	73	A
31617	24.2	15	47°47.12' - 69°55.58'	68	A/p

Observations: [ ] = close group; Cc = ♀ with calf at heel; A = adult; J = juvenile; U = unclassified; /p (n) = also on previous (next) frame.

Roll	Transect	Frame	Position (Lat. N; Long. W)	Grid	Observations
31617	24.2	15	"	69	A/p
31617	25.0	19	47°42.89' - 69°54.10'	03	A
31617	25.0	19	"	91	[2U/n] U/n
31617	25.0	20	47°42.33' - 69°53.41'	07	U
31617	25.0	20	"	75	A
31617	25.0	20	"	98	A/p 2U/p
31617	25.1	35	47°38.39' - 69°52.28'	07	A
31617	25.1	36	47°39.05' - 69°53.07'	36	Cc
31617	25.1	41	47°41.86' - 69°56.32'	16	A
31617	25.1	42	47°42.44' - 69°57.04'	71	Cc
31617	25.1	43	47°42.96' - 69°57.76'	13	Cc
31617	25.1	43	"	82	Cc/n
31617	25.1	44	47°43.51' - 69°58.48'	89	Cc/p
31617	25.2	47	47°41.12' - 69°59.63'	24	A
31617	25.2	47	"	35	U
31617	25.2	47	"	36	Cc
31617	25.2	47	"	42	J/n
31617	25.2	48	47°40.54' - 69°58.94'	15	U
31617	25.2	48	"	59	J/p
31617	25.2	54	47°37.23' - 69°54.96'	01	[2U] U
31617	25.2	54	"	02	A
31617	25.2	54	"	11	J
31617	25.2	54	"	24	A
31617	25.2	54	"	25	A
31617	25.2	54	"	35	Cc A
31617	25.2	54	"	45	A
31617	25.2	54	"	54	A
31617	25.2	55	47°36.72' - 69°54.32'	23	A
31617	25.2	56	47°36.11' - 69°53.57'	04	A

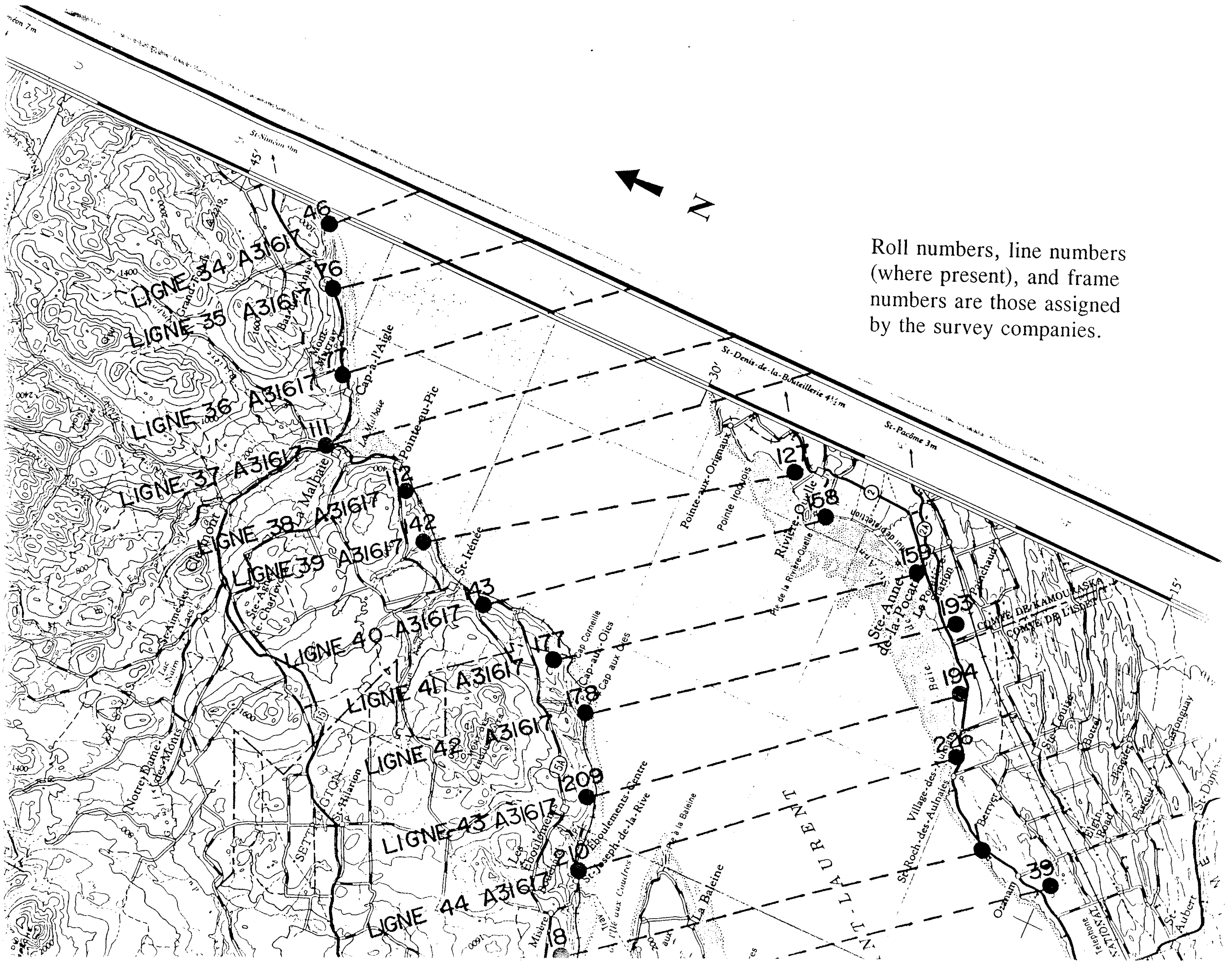
Observations: [ ] = close group; Cc = ♀ with calf at heel; A = adult; J = juvenile; U = unclassified; /p (n) = also on previous (next) frame.

Roll	Transect	Frame	Position (Lat. N; Long. W)	Grid	Observations
31617	26.0	74	47°40.35' - 70°02.48'	84	U
31617	26.0	74	"	95	U
31617	28.1	180	47°27.50' - 70°12.50'	66	U
31618	29.2	28	47°21.05' - 70°20.53'	01	U Udeep
31618	29.2	29	47°20.05' - 70°20.05'	08	A

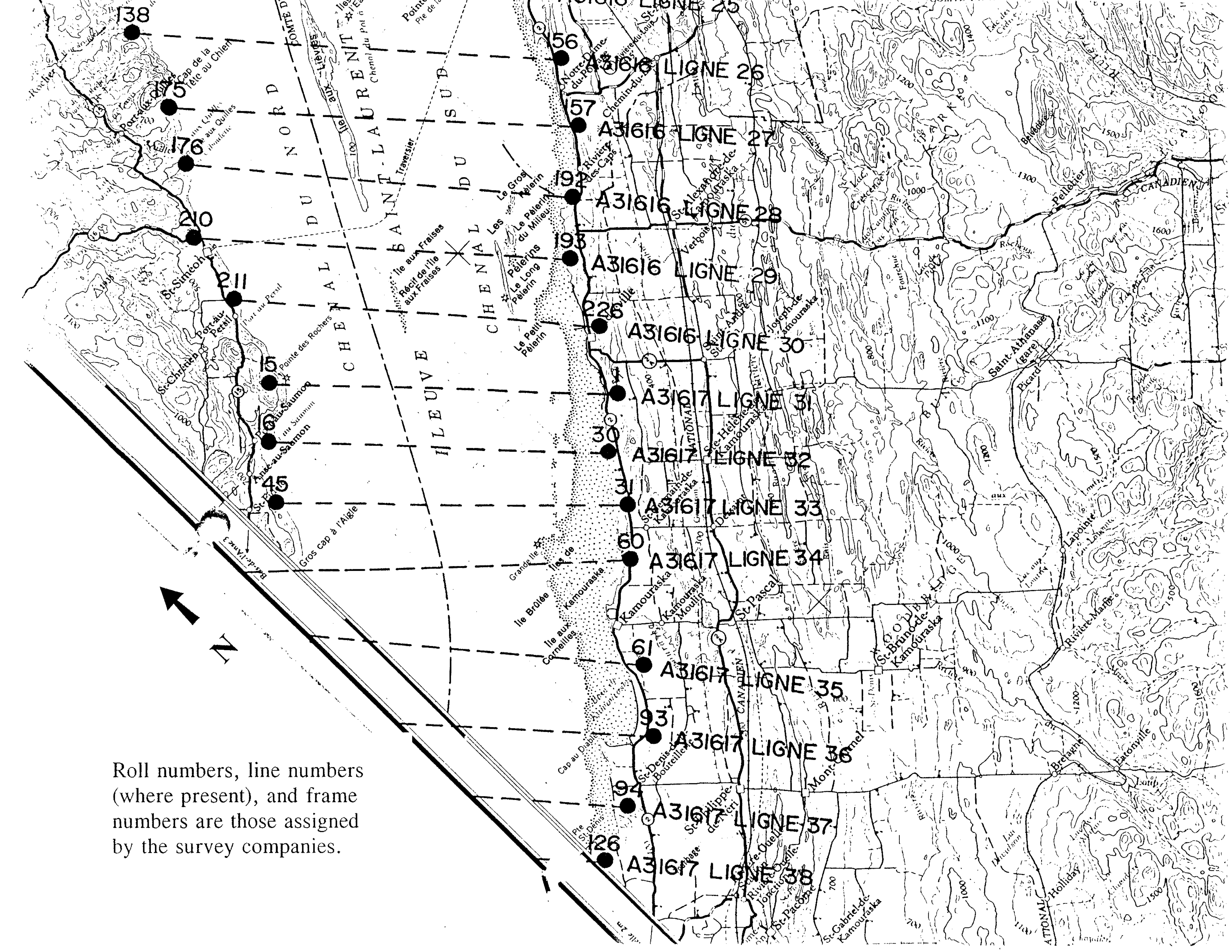
Observations: [ ] = close group; Cc = ♀ with calf at heel; A = adult; J = juvenile; U = unclassified; /p (n) = also on previous (next) frame.

Appendix III. Index maps of aerial photography transect and frame locations.

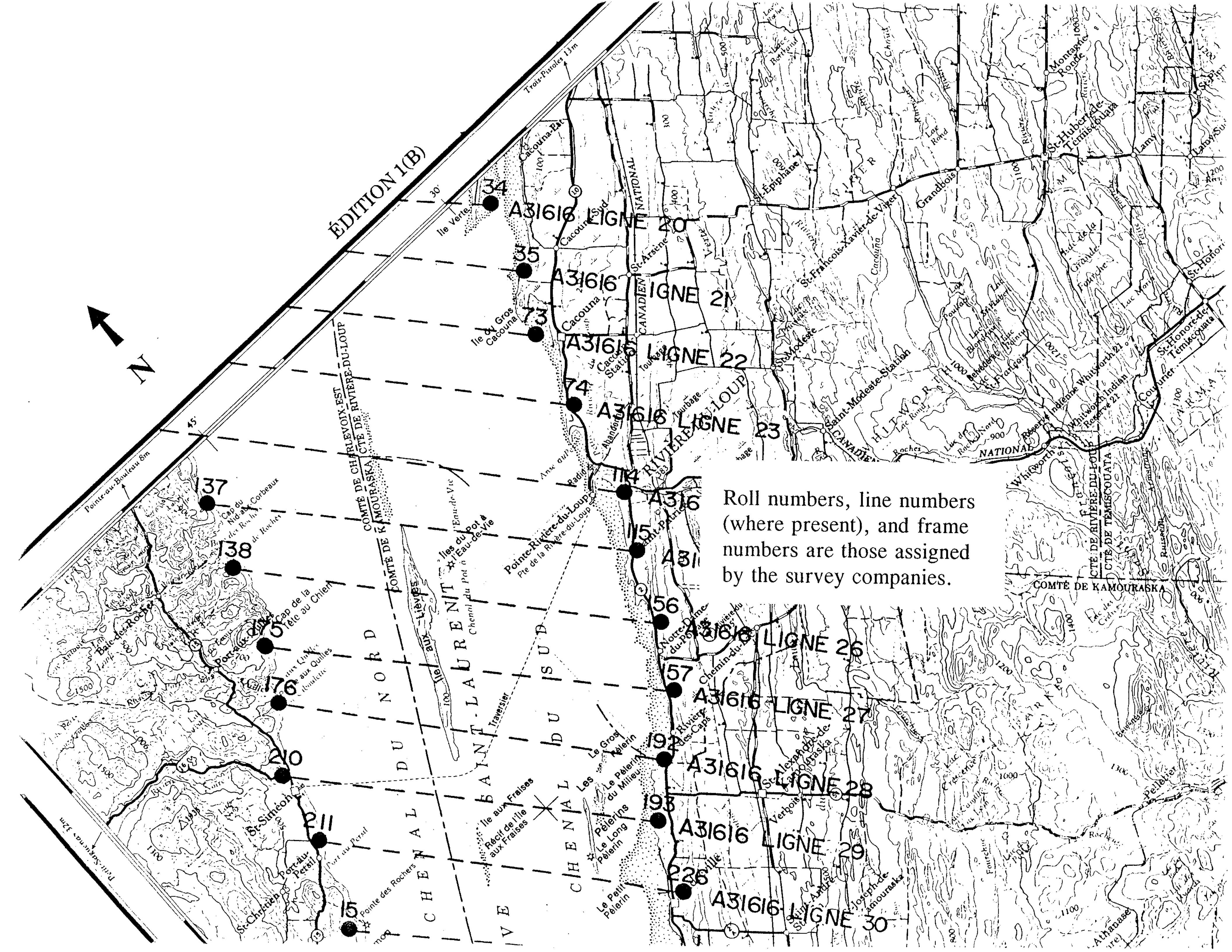
The maps reproduced in this Appendix are copies of those furnished by the aerial survey companies. They provide the best information on the actual location of the transects as flown. The film roll numbers are the standard roll numbers assigned by the National Air Photo Library, Dept of Energy Mines and Resources, where this film is deposited. These roll numbers are referenced in Appendix II. The transect numbers are those assigned by the aerial survey companies, and are not necessarily the same as those referenced in the text or tables of this report, or in Appendix II. The frame numbers, which start afresh for each roll and are consecutive within film rolls, are those assigned by the survey companies, and are referenced in Appendix II. They are not the same as the camera counter numbers automatically registered on each frame.



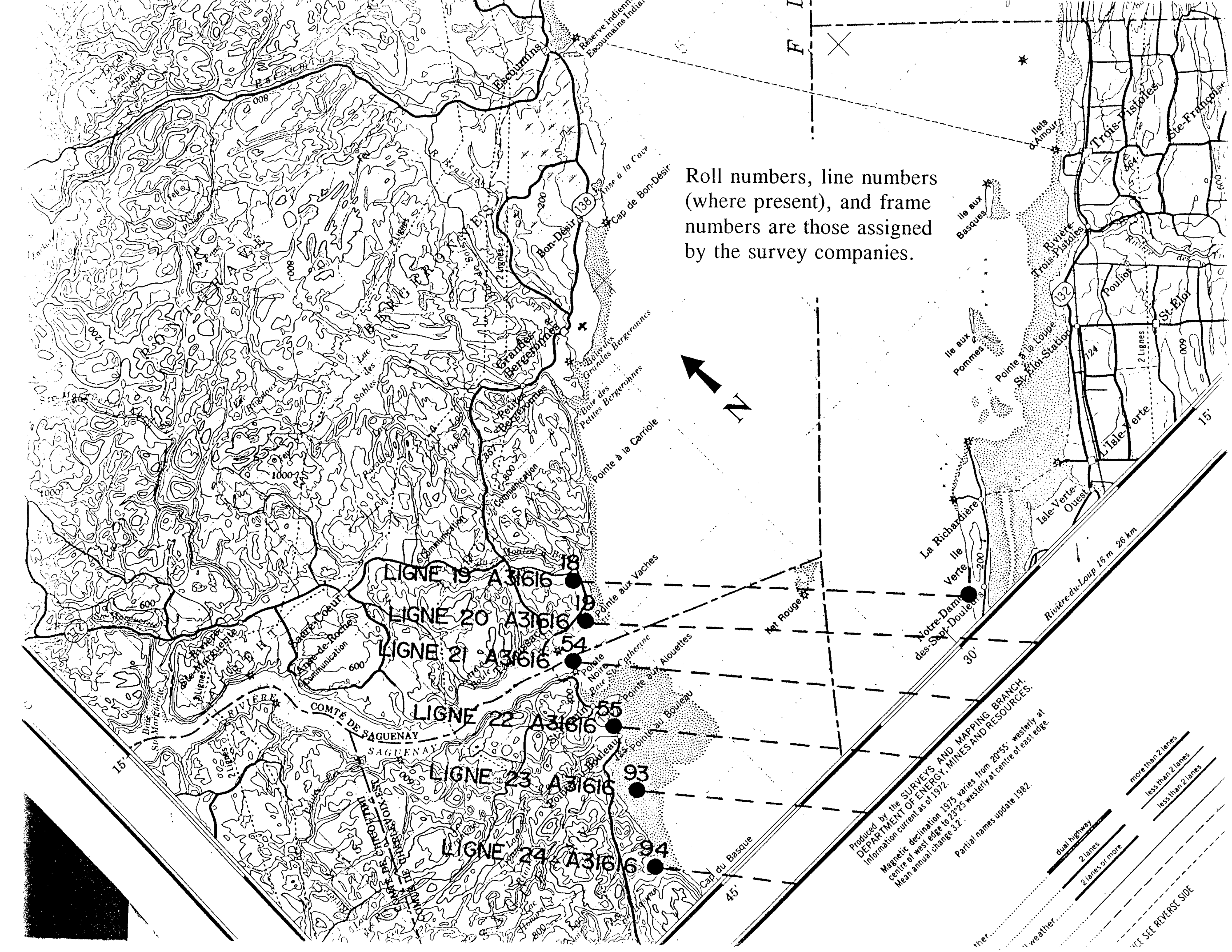
Roll numbers, line numbers (where present), and frame numbers are those assigned by the survey companies.

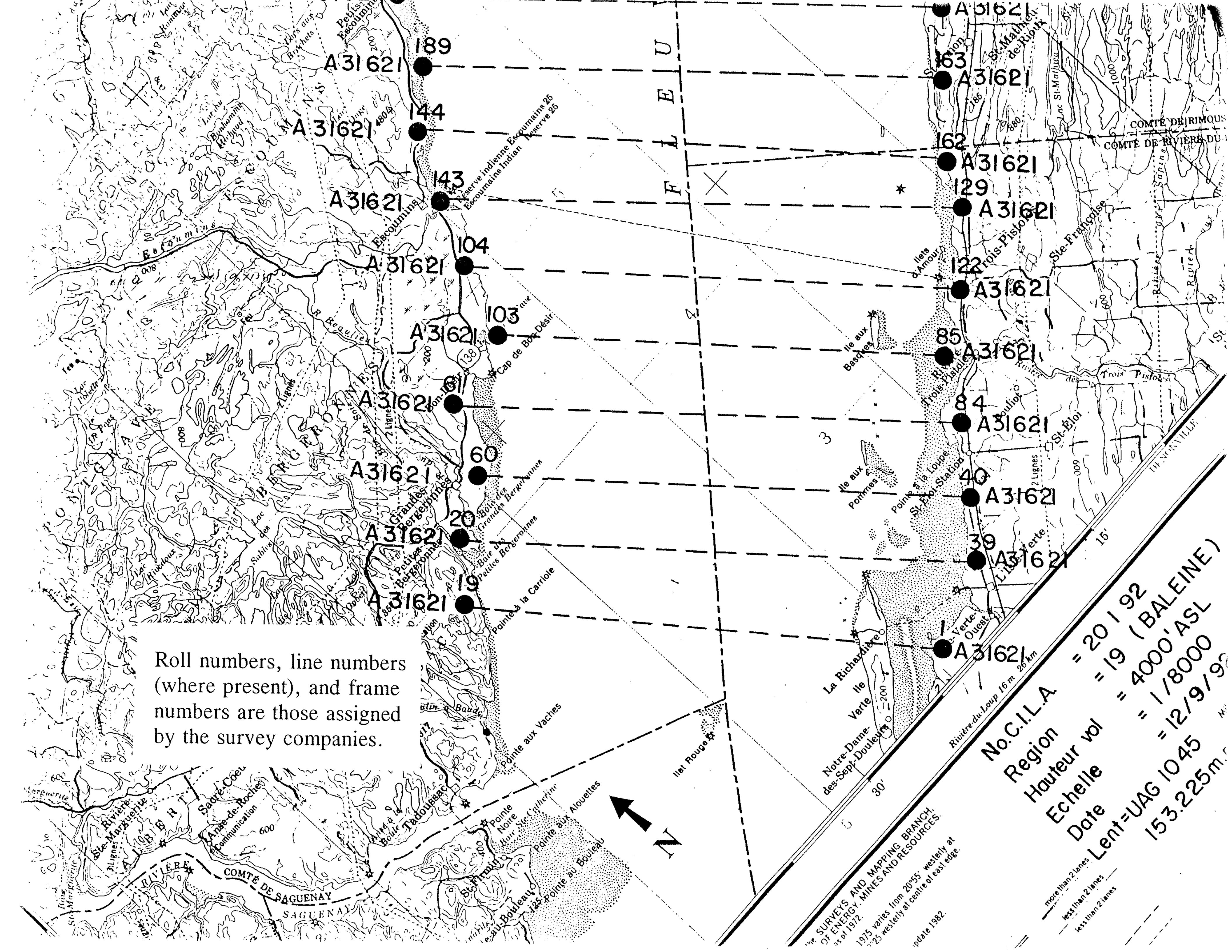


Roll numbers, line numbers (where present), and frame numbers are those assigned by the survey companies.

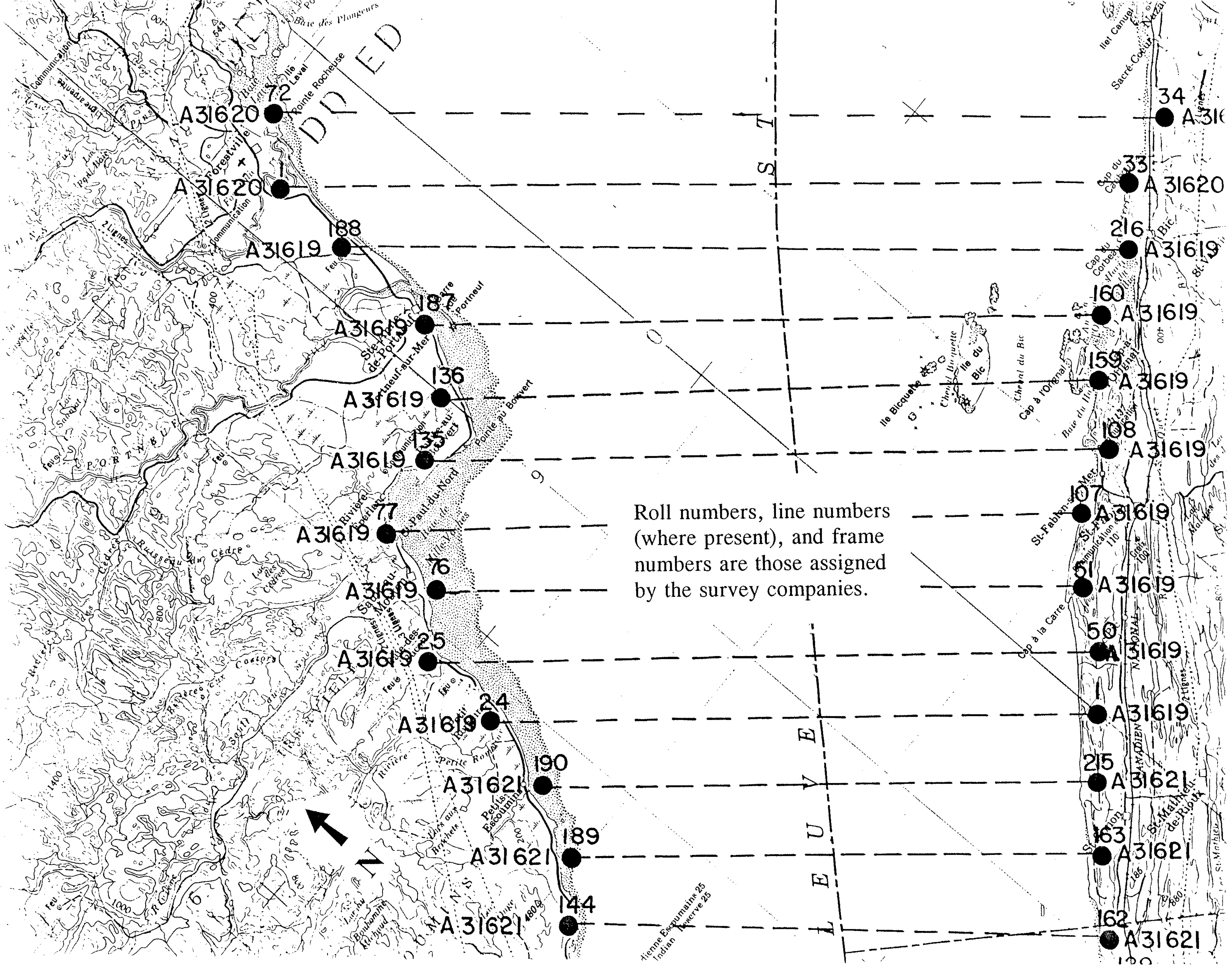


Roll numbers, line numbers (where present), and frame numbers are those assigned by the survey companies.
ÉDITION 1(B)
N
A31616 LIGNE 20
A31616 LIGNE 21
A31616 LIGNE 22
A31616 LIGNE 23
A31616 LIGNE 26
A31616 LIGNE 27
A31616 LIGNE 28
A31616 LIGNE 29
A31616 LIGNE 30
34
35
73
74
114
115
156
157
192
193
226
137
138
175
176
210
211
15
FLEUVE SAINT-LAURENT
CHENAL DU NORD
CHENAL DU SUD
Île aux Lièvres
COMTÉ DE CHARLEVOIX-EST
COMTÉ DE KAMOURASKA
CTÉ DE RIVIÈRE-DU-LOUP
CTÉ DE TEMISCOUATA
COMTÉ DE KAMOURASKA
RIVIÈRE-DU-LOUP
Pointe-Rivière-du-Loup
Cacouna
St-Arsène
St-Épiphane
St-François-Xavier-de-Viger
Grandbois
St-Hubert-de-Témiscouata
Saint-Modeste-Station
St-Modeste
Whitworth
Notre-Dame-du-Portage
Rivière-des-Caps
St-Alexandre-de-Kamouraska
St-André
St-Joseph-de-Kamouraska
Île Verte
Île du Gros Cacouna
Île aux Fraises
Les Pèlerins
Port-au-Persil
St-Siméon
Baie-des-Rochers
Port-aux-Quilles
St-Chrétien
Pointe des Rochers
Cap du Nid aux Corbeaux
Cap de la Tête au Chien
Trois-Pistoles 13m
Pointe-au-Bouleau 8m
Petit-Saguenay 32m


Roll numbers, line numbers (where present), and frame numbers are those assigned by the survey companies.
LIGNE 19 A31616
18
LIGNE 20 A31616
19
LIGNE 21 A31616
54
LIGNE 22 A31616
55
LIGNE 23 A31616
93
LIGNE 24 A31616
94
N
Escoumins
Réserve indienne Escoumains Indian
Bon-Désir
Cap de Bon-Désir
Anse à la Cave
Grandes-Bergeronnes
Baie des Grandes Bergeronnes
Petites-Bergeronnes
Baie des Petites Bergeronnes
Pointe à la Carriole
Pointe aux Vaches
Sacré-Coeur
Anse-de-Roche
COMTÉ DE SAGUENAY
SAGUENAY
Pointe Noire
Baie Ste-Catherine
Pointe aux Alouettes
Pointe au Bouleau
Cap du Basque
Îlet Rouge
Île Verte
La Richardière
Notre-Dame-des-Sept-Douleurs
Isle-Verte-Ouest
L'Isle-Verte
Île aux Pommes
Île aux Basques
Îlets d'Amour
Trois-Pistoles
Rivière Trois-Pistoles
Ste-Françoise
St-Éloi
St-Éloi-Station
Pointe à la Loupe
Rivière-du-Loup 16 m 26 km
138
132
15'
30'
45'
Produced by the SURVEYS AND MAPPING BRANCH, DEPARTMENT OF ENERGY, MINES AND RESOURCES.
Information current as of 1972.
Magnetic declination 1975 varies from 20°55' westerly at centre of west edge to 23°25 westerly at centre of east edge. Mean annual change 3.2'.
Partial names update 1982.
dual highway
2 lanes
2 lanes or more
more than 2 lanes
less than 2 lanes
less than 2 lanes



Roll numbers, line numbers (where present), and frame numbers are those assigned by the survey companies.



Roll numbers, line numbers (where present), and frame numbers are those assigned by the survey companies.