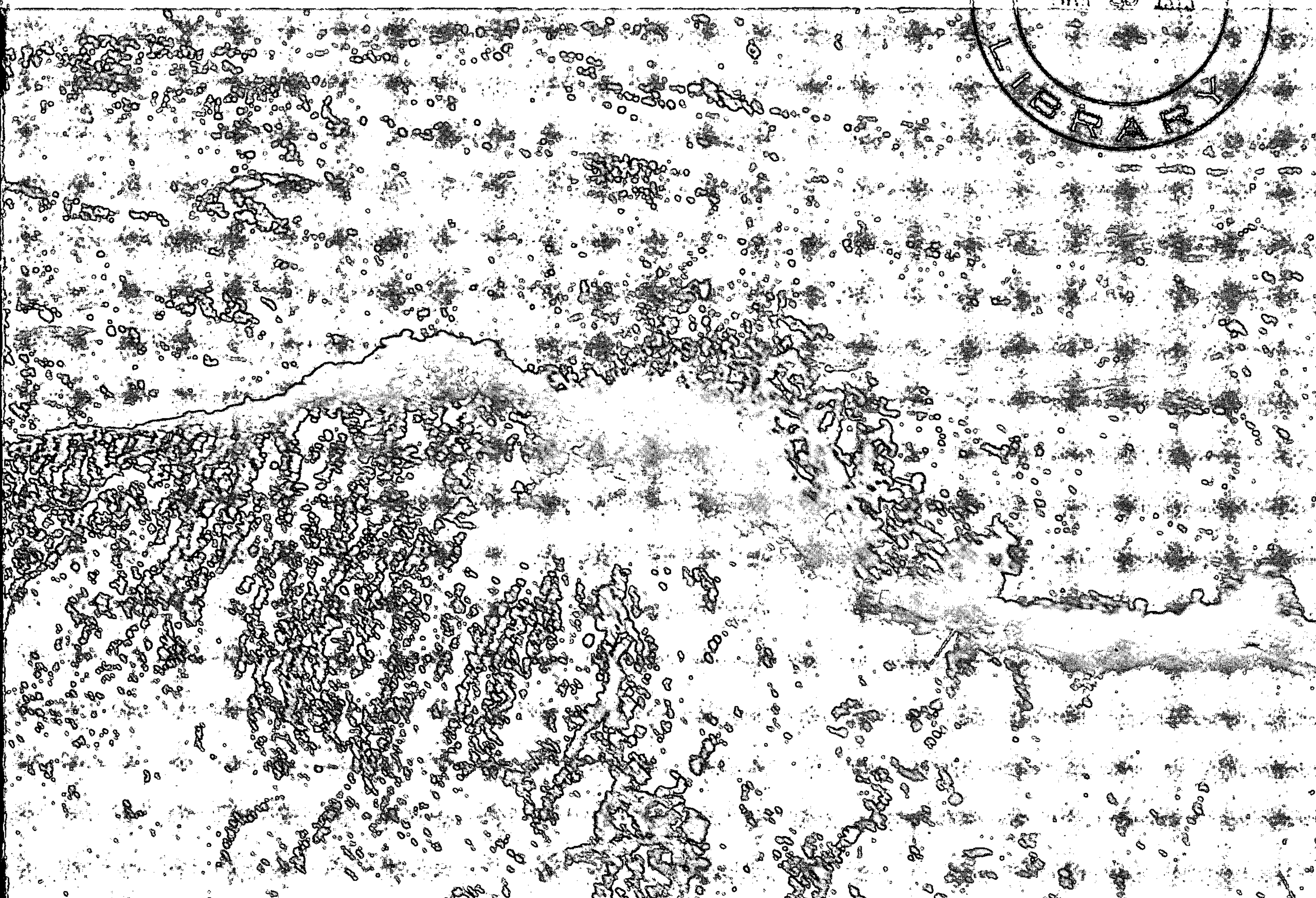
Environment Canada
Water Management

Environnement Canada
Gestion des Eaux

Investigation of Infrared Anomalies in the Lac des Deux Montagnes Area, Quebec

P. A. Carr and H. Gross



SCIENTIFIC SERIES NO. 19
(Résumé en français)

INLAND WATERS DIRECTORATE,
WATER RESOURCES BRANCH,
OTTAWA, CANADA, 1972.

Environment Canada
Water Management

Environnement Canada
Gestion des Eaux

Investigation of Infrared Anomalies in the Lac des Deux Montagnes Area, Quebec

P. A. Carr and H. Gross

SCIENTIFIC SERIES NO. 19
(Résumé en français)

INLAND WATERS DIRECTORATE,
WATER RESOURCES BRANCH,
OTTAWA, CANADA, 1972.

Cat. No.: En36-502/19

Contents

Illustrations

Tables

Abstract

In October 1965, as an introduction to the use of infrared scanners in Canada, certain areas were selected for investigation of infrared anomalies related to groundwater discharge into the Ottawa River. On the basis of this survey, the Lac des Deux Montagnes area, on the Ottawa River just above its junction with the St. Lawrence River, was selected for more intensive study in 1968 and 1969.

Comparison of imagery and published geological work led to the conclusion that no positive identification of groundwater discharge was made; however, it is possible that one anomaly, just southeast of Pointe Cavagnal, is caused by groundwater influx into the river along its bottom.

Résumé

L'introduction des détecteurs d'émissions infrarouges fut apportée au Canada en octobre 1965. Afin d'arriver à bien utiliser cet instrument, certaines régions ont été choisies pour étudier les anomalies causées par l'émergence des eaux souterraines dans la rivière Ottawa. Les résultats de cette étude nous indiquèrent que la région du Lac des Deux Montagnes, située sur la rivière Ottawa, en amont de l'embranchement de celle-ci avec le fleuve St-Laurent était le lieu le plus propice pour effectuer une étude détaillée durant les années 1968 et 1969.

La comparaison des images obtenues et des études géologiques publiées à ce sujet nous conduit à conclure qu'aucun déversement catégorique d'émergence des eaux souterraines a été observé, toutefois, il est possible qu'une anomalie se trouvant juste au sud-est de Pointe-Cavagnal soit dûe à l'affluence des eaux souterraines le long du fond de la rivière.

Acknowledgments

We wish to acknowledge the help of the National Aeronautical Establishment staff, especially Mr. Errol Stewart for the scanner operation, Captain Norman Pool and his aircrew for excellent navigation, and Mr. Peter Holman for the preliminary drafting and aid in interpretation.

Investigation of Infrared Anomalies in the Lac des Deux Montagnes Area, Quebec

P. A. Carr and H. Gross

INTRODUCTION

An airborne infrared scanner maps the distribution of the energy radiated by a surface. This distribution is determined by the surface temperature and emissivity, and is modified by the intervening atmosphere. The scanner does not detect absolute temperature directly, but gives an indication of differences in relative energy radiated over small areas of the surface.

Flying the infrared scanner over water has a unique advantage; since the emissivity of water is nearly uniform and near unity, small changes in surface temperature can be mapped. Thus contrasting tones of the imagery indicate differences in temperature of the water surface. Only apparent temperature contrasts are detected, not absolute temperature contrasts. The warmer temperatures appear as lighter areas and the cooler temperatures as darker areas on the imagery positive.

The infrared scanner has been very useful in detecting thermal pollutants in lakes and rivers (Slaney *et al.*, 1967), and in detecting shoreline springs (Lee, 1969). Also, Fischer *et al.*, (1964) used the scanner to study the thermal regime of volcanoes on the Island of Hawaii; in this survey the scanner also detected groundwater outflow off the coast of Hawaii.

The purpose of this work is to determine if the infrared scanner can be used as a tool for detecting groundwater outflow into a river. The results of the imagery obtained from scanning the Ottawa River just west of Montreal are presented (Figure 1). Here, a confined sand aquifer is situated in a buried valley and is known to discharge groundwater into the Ottawa River. The major part of the imagery was obtained by flying over water. Thus the methodology and results apply to detecting anomalies over water rather than over land.

CONDITIONS NECESSARY FOR FLIGHTS

If weather conditions such as humidity, wind, and cloud cover are taken into consideration, better infrared imagery can be obtained. The atmospheric absorption of infrared radiation determines the energy loss between the ground and the detector. Since water vapor is the primary varying attenuator of infrared imagery at normal survey altitudes, the scanner should be flown at times of low humidity.

Energy is absorbed and reradiated by the surface of the water. During the day it responds very rapidly to transient conditions such as clouds or shadows, so by flying at night, this effect and reflection are eliminated. A cloud layer above the aircraft will reradiate energy to the ground and reduce the thermal contrast. Infrared surveys should therefore be conducted under cloudless conditions whenever possible. Evening flights have added advantages for the pilot, for the air is usually calm and often some moonlight is present for visual navigation.

The effect of wind reduces the thermal contrast by removal and redistribution of the thermal energy. Navigation can be a major problem, with the pilot finding it more difficult to maintain a constant course and heading. The latter effect will show up in a mosaic as scale changes in the along-track scale of adjacent strips, and in feature mismatching at edges.

Taking all these factors into consideration, the flights were flown during the evening in late October and early November under the best weather conditions that coincided with the availability of the aircraft.

The first flights, (Table 1, Flights A and B) were flown in October 1965. At this time some anomalies were detected (Ory and Stingelin, 1966); these anomalies then became the basis for further research and flights (C, D and E) were flown in August and November 1968, and November 1969.

EQUIPMENT USED AND ITS LIMITATIONS

Infrared principles have been described previously by many authors (for example Holter, *et al.* 1962; Wolfe,

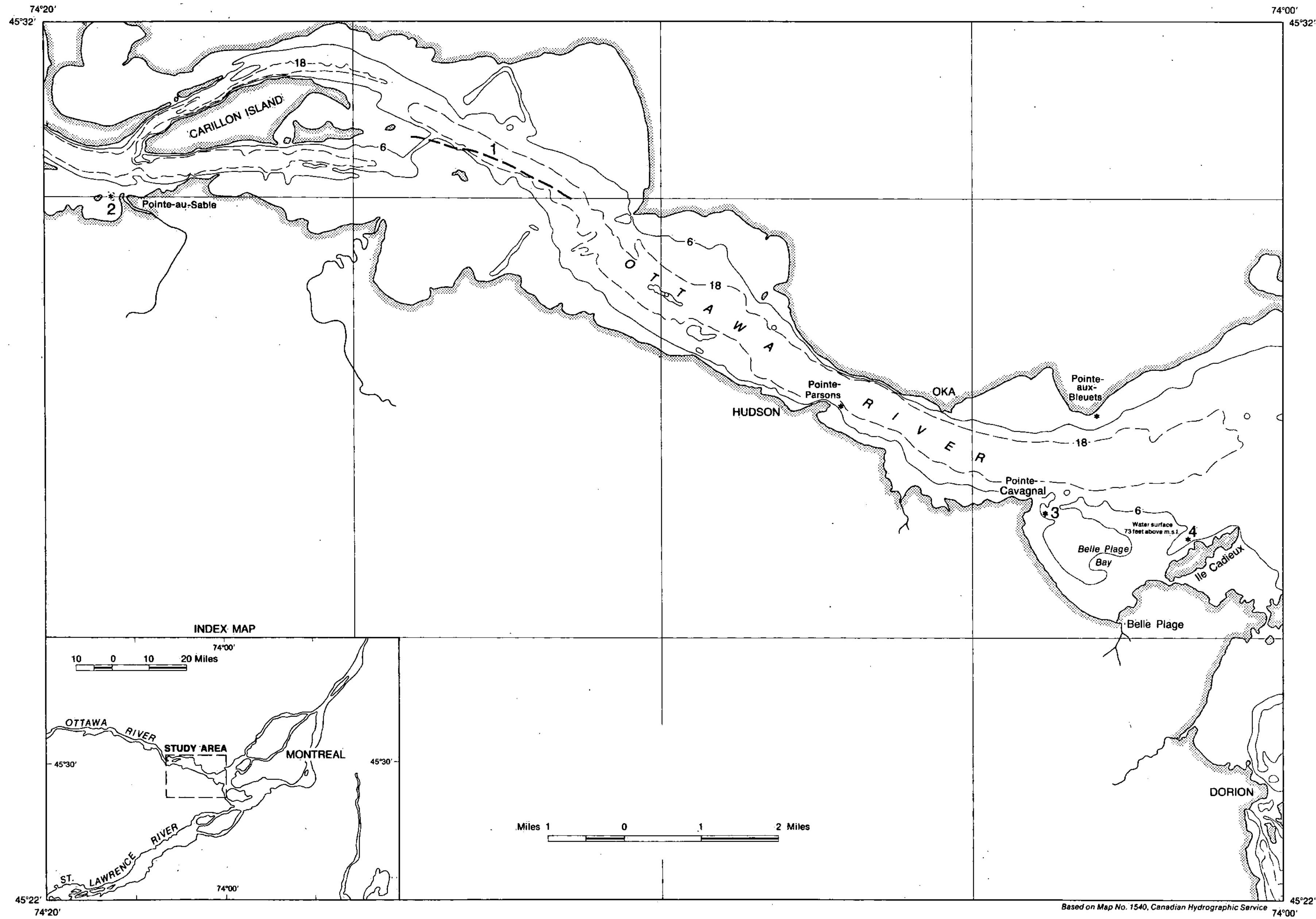


Figure 1. Location of the infrared anomalies.

Table 1 - Flight Conditions and the Equipment Used

Flight	Date of Flight	Time (EST)		Altitude (Feet)	Scanner Used	Detector		Field of View (Degrees)	Thermal Sensitivity Unit (Degrees, Kelvin)	Film Roll Reference
		Started	Ended			Size	Type			
A	Oct. 27, 1965	2130	2330	5,000	Reconofax	23mr 13mr	In:Sb Ge:Hg	80	0.01	941-2
					V					
B	Oct. 29, 1965	2030	2145	9,000	Dual Channels		In:Sb Ge:Hg	80	0.01	941-5
C	Aug. 12, 1968	2130	2250	5,000	Reconofax		Ge:Hg	120	0.1	RS-11
					IV					
D	Nov. 14, 1968			5,000	Single Channel		Ge:Hg	120	0.1	RS-14
E	Nov. 24, 1969	1613	1645	1,000			Ge:Hg	120	0.1	RS-69/96

Detector 1 – In:Sb 23 milliradian, 3 to 5 micron band with a 4.5 micron cut-on filter
Detector 2 – Ge:Hg 13 milliradian, 8 to 14 micron band
Detector 3 – Ge:Hg 15 milliradian, 8 to 14 micron band, with a 8.0 micron cut-on filter

1965); only the pertinent aspects of the instrumentation that affect the imagery obtained, are discussed here.

The first flights (A and B) of the project were done under contract by the. H.R.B. Singer Corporation, using a Singer Reconofax V scanner. Later work in 1968 and 1969 was done using the Singer Reconofax IV scanner which has been acquired by the Department of Energy, Mines and Resources. These two scanners have different sensitivities (Table 1) and circuitry and thus produce different tonal effects on the imagery.

Reconofax V

The Reconofax V is a dual channel D.C. coupled scanner which contains an indium-antimonide and a mercury-doped germanium detector. Thus two strips of infrared imagery showing the same area are obtained simultaneously. In general, little information was provided by the long wavelength (Ge:Hg) detector that was not also recorded by the short wavelength (InSb) detector. However, when these highly sensitive detectors (0.01°C) were used in the cold, ambient temperatures that occurred on Flights A and B, spurious thermal gradients were produced within the scanner housing. These gradients produce dark zones at the edges of the imagery (Figures 2A, 2C, 2D, 2E and 2F) which obscure all the detail and look like large anomalies. This effect is called "electronic humping" and can be reduced or eliminated by insulating the housing, careful optical alignment, and a lower gain setting.

This scanner has a linear amplifier and whenever a very strong signal with a high rate of change strikes the detector, there is a possibility of amplifier saturation and a momentary overexposure of the film. Sharp boundaries between areas such as land and water that have large radiation contrast frequently meet these conditions. The amplifier becomes saturated and there is a loss of infrared data for a short distance past the boundary until the amplifier recovers. Thus small areas on the imagery are blanked out (Figures 2C, 2E and 2F).

The overall contrast of the imagery and the extent to which small changes in the signal will be expressed are controlled by the amplifier gain setting. Since the Reconofax V scanner does not have an automatic gain control, the setting is adjusted manually at the beginning of the flight. Flights A and B were carried out using a gain setting that was far too high. This produced imagery that has a strong predominance of white and black tones, and lacks many of the intermediate grey tones that were produced on the later imagery. The effect can be seen by comparing Figures 2A, 2C, 2D, 2E and 2F with Figures 2B and 2G.

Reconofax IV

Flights C, D and E were made using the Reconofax IV scanner. This is a single channel scanner having a Ge:Hg detector with a sensitivity of about 0.1°C. The film is unable to record the full range of data present at the

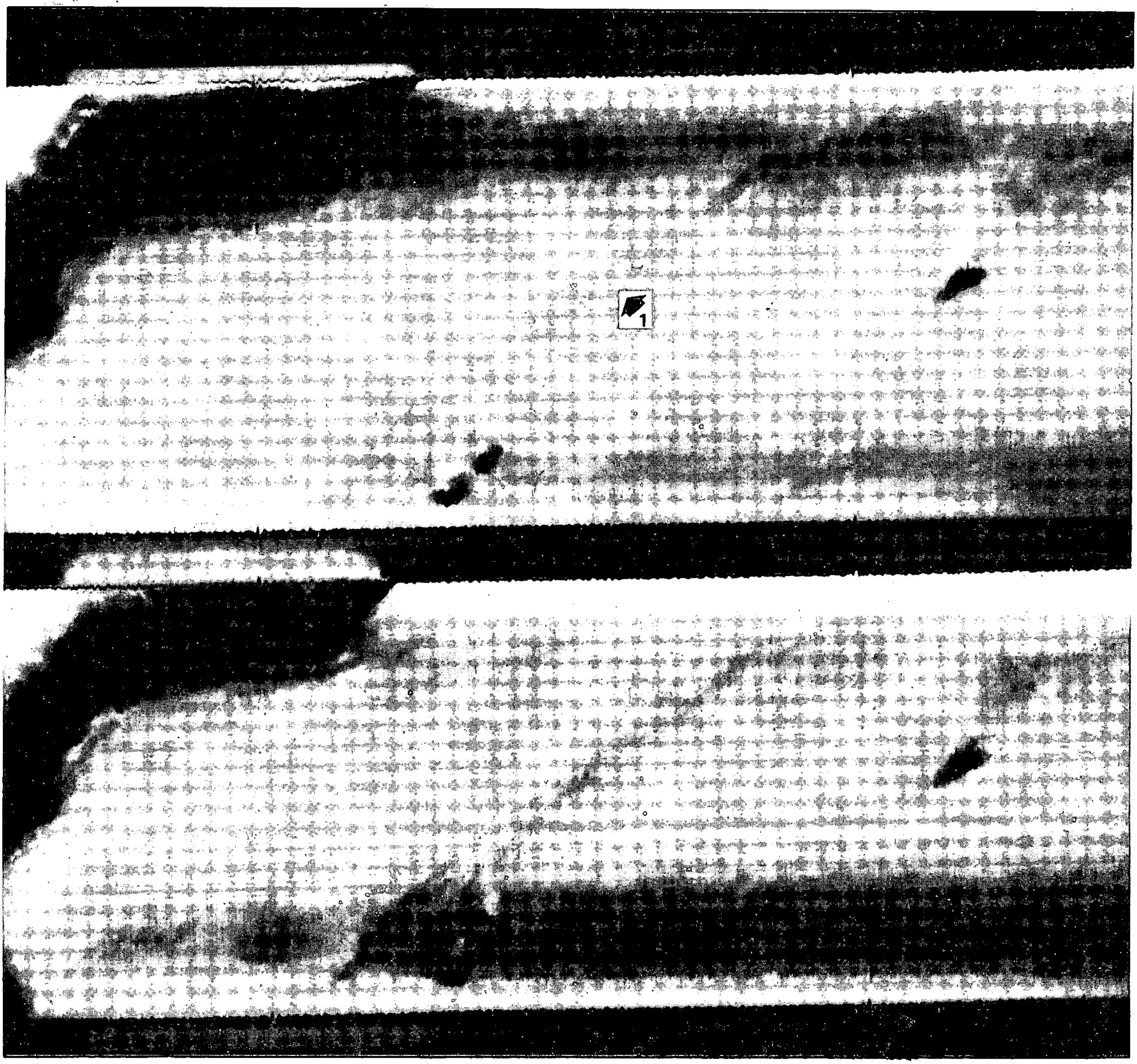


Figure 2A. Linear current feature near Carillon Island. Flight A, October 27, 1965, at 5,000 feet.

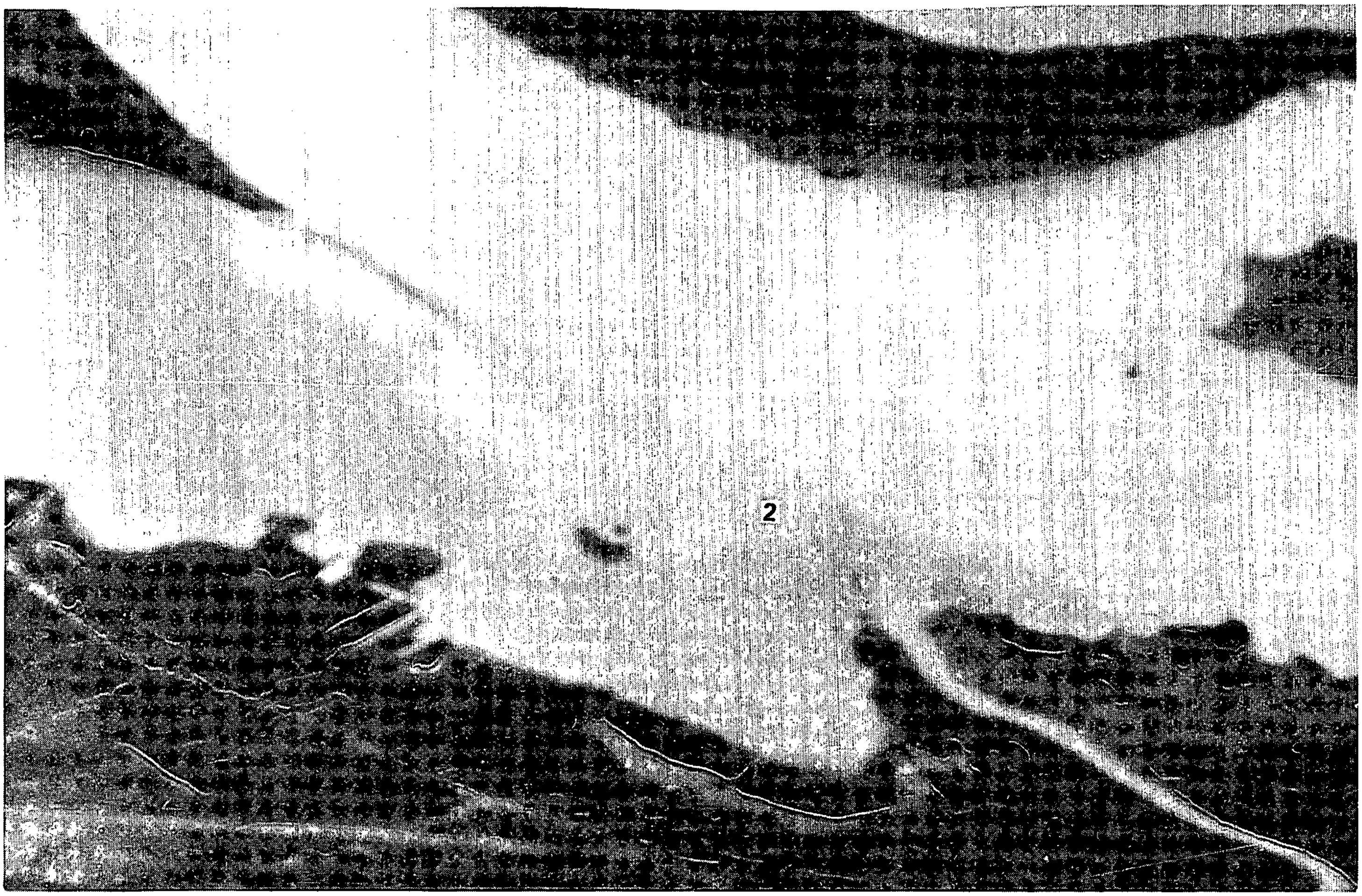


Figure 2B. Shallow water feature, Pointe-au-Sable. Flight C, August 12, 1968, at 5,100 feet.

detector, so this scanner was designed with an A.C. coupling and an automatic gain control. The combined effect of these two features is to discard the average, or background signal, and record only the signal variations. A greater range of tone and better detail are obtained in addition to a great reduction in the effect of overshoot. However, except over a small range and in adjacent areas, no quantitative relationship can be established between the temperature and density on the negative. Thus for large areas of water in different locations, similar tones do not necessarily indicate the same temperature.

General Considerations

The above limitations of the Reconofax IV and V scanners render a quantitative estimate of the temperature impossible. Poor imagery is obtained in areas of crooked or meandering shore lines, where strong temperature contrasts exist between land and water. The presence of land and water in the same scan line can depress the gain enough to obscure certain anomalies.

One other serious limitation that is common to the imagery produced by both types of scanners is geometric distortion. There are three main causes of geometric distortion: the non-linear scan across the image; aircraft crab arising from the cross-wind; and the V/H (velocity/-height) ratio as the aircraft changes altitude or ground speed. The scale of the image can vary from one location to another, and the scale across the image is a function of the look angle (compression of distance towards each edge). Thus no scale is shown on the imagery and it is difficult to determine the precise location of anomalies and to make mosaics from the imagery. Distortion is well-illustrated in Figure 2G on the land portion of the imagery.

ANOMALIES DETECTED

Several anomalies were detected; their locations are shown in Figure 1, and the actual imagery of these anomalies is illustrated in Figures 2A to 2G. The flights on which they were detected are indicated in Table 2.

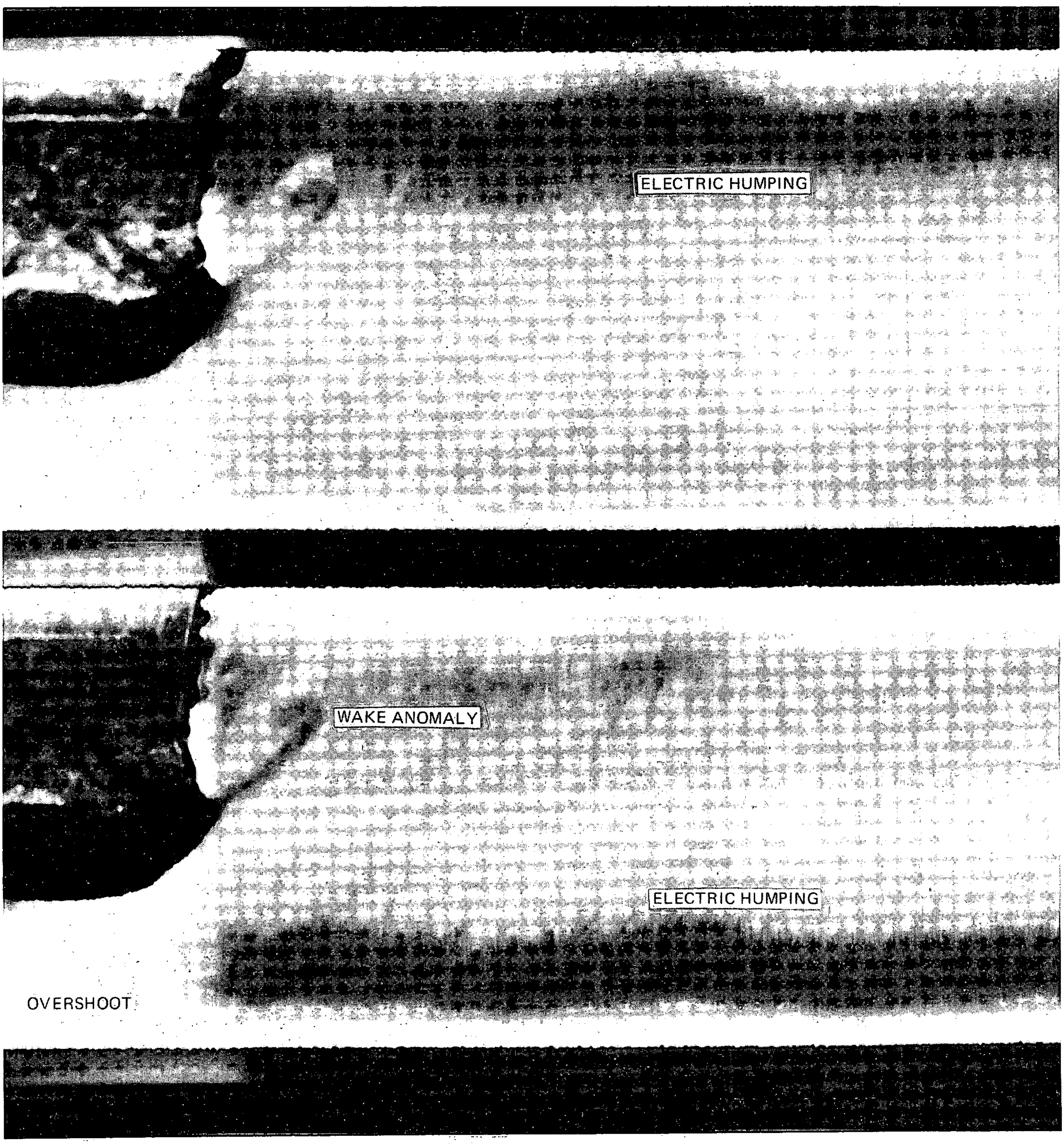


Figure 2C. Wake anomaly at Pointe-aux-Bleuets. Flight A, October 27, 1965, at 5,000 feet.

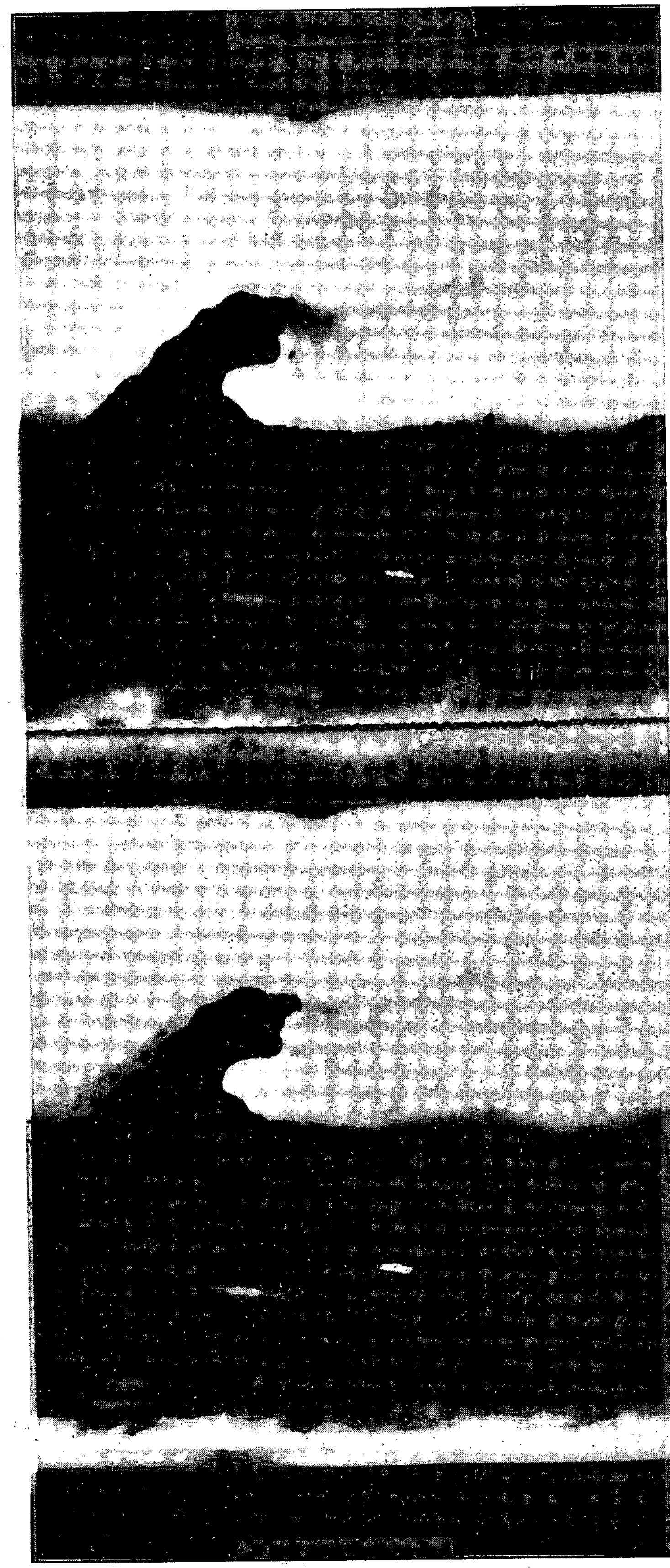


Figure 2D. Wake anomaly at Pointe-Parsons. Flight A, October 27, 1965, at 5,000 feet.

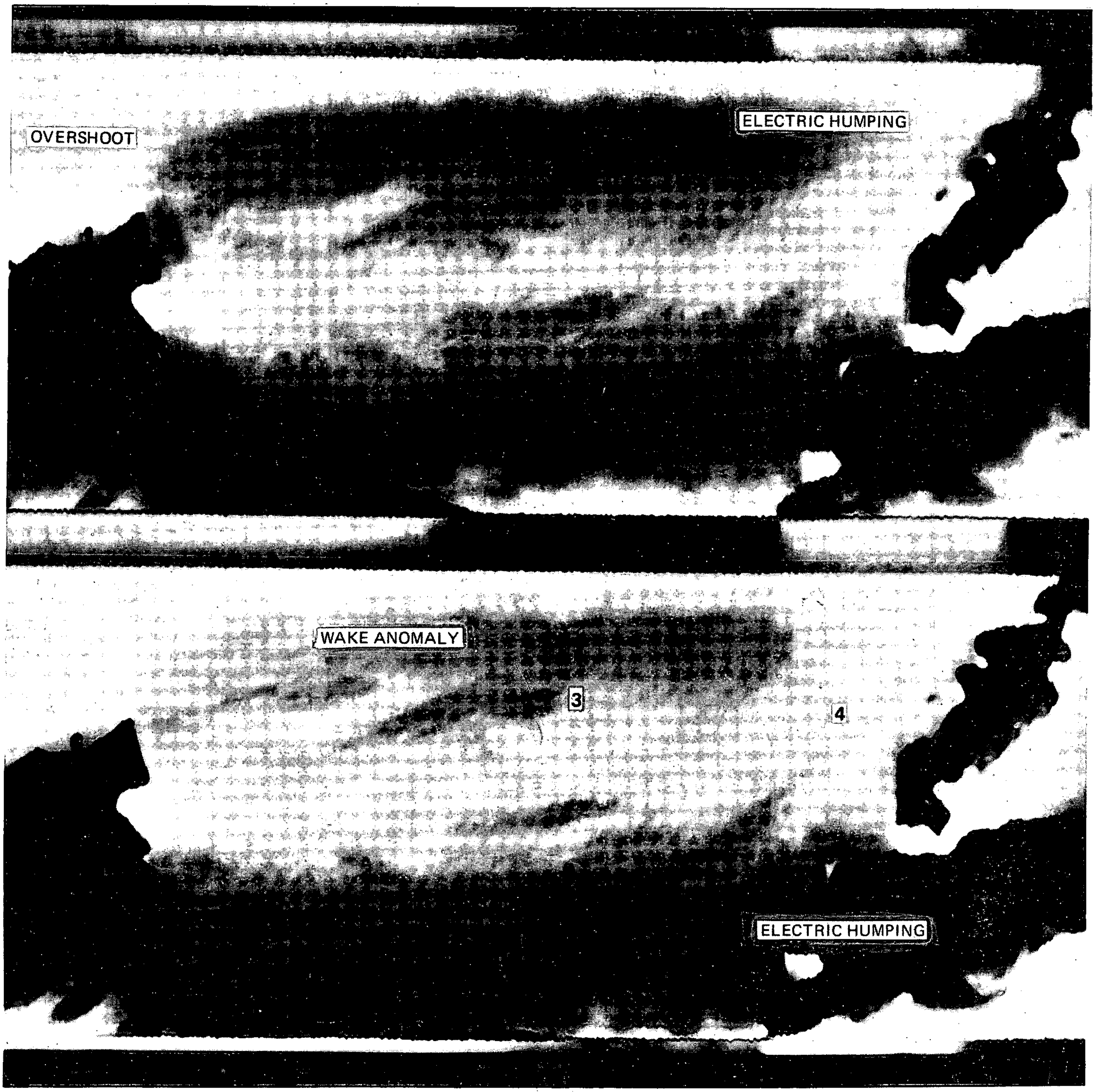


Figure 2E. Belle Plage Bay. Flight A, October 27, 1965, at 5,000 feet.

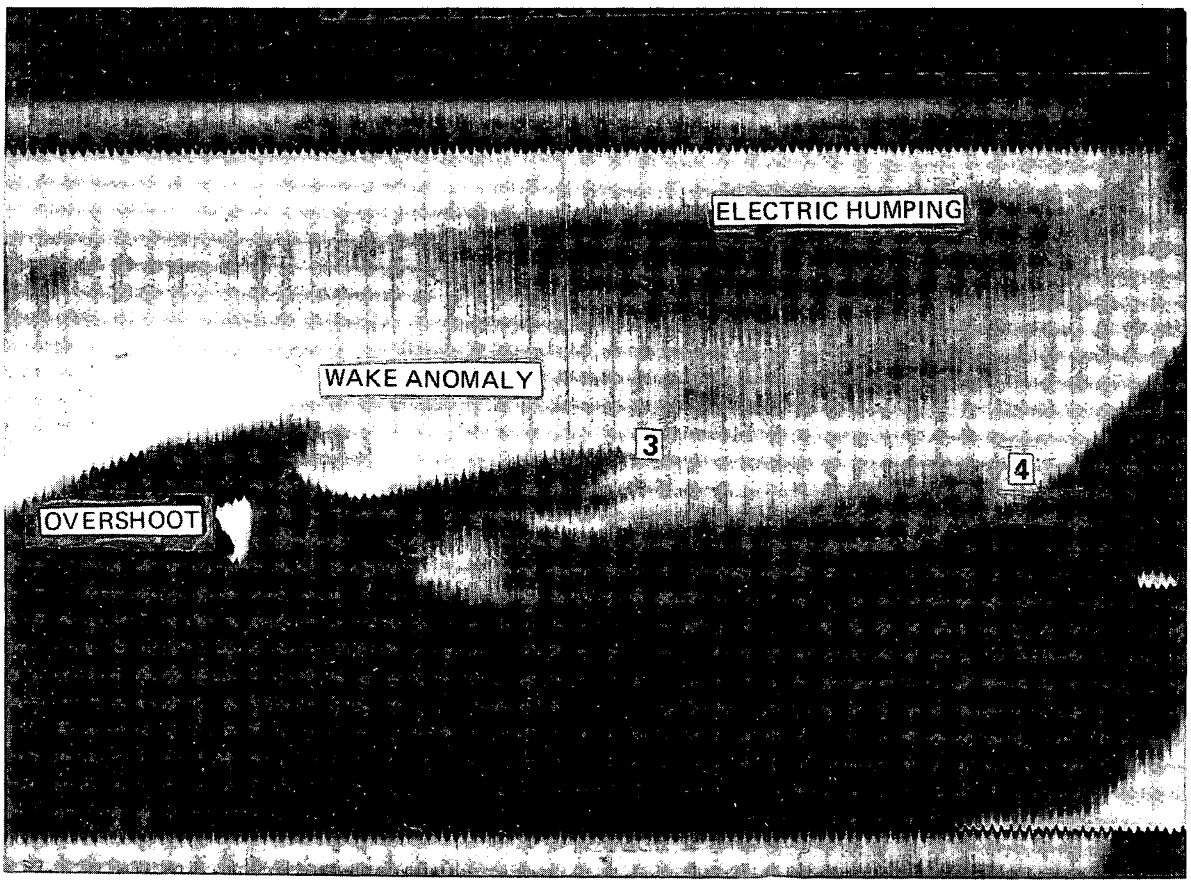


Figure 2F. Belle Plage Bay. Flight B, October 29, 1965, at 9,000 feet.

Some features of the river, such as currents and wakes, produce thermal anomalies, which can easily be detected, for these features are present on conventional aerial photographs as physical disturbances. One example of this type of anomaly is a strong linear current feature originating from Carillon Island (anomaly #1, Figure 2A). Similarly, wakes formed by the water flowing past a point jutting out into the river, also show thermal anomalies (Figure 2C and 2D).

Some infrared anomalies occurred adjacent to the shoreline of shallow bays, but without any corresponding manifestation on aerial photographs. These are attributed to the shallow water of the bay cooling in the evening faster than the deeper water nearer the centre of the river (anomaly #2, Figure 2B).

Belle Plage Anomalies

From previous work by Tremblay and Hobson (1962), groundwater is known to discharge into Belle Plage Bay. This area was studied to see if any thermal pattern existed which might be related to the groundwater discharge.

In the 1965 imagery, large cool inshore and offshore anomalies are present as dark patches (Figures 2E and 2F). Groundwater discharge was suspected to be the cause. However, the anomalies were not detected in the imagery obtained in 1963 and 1969. It is now apparent that they were produced by electronic humping in the Reconofax V scanner that was used in 1965 only. This indicates that considerable caution must be exercised in interpreting this imagery.

Repeated flights in 1968 and 1969 only determined two anomalies (Nos. 3 and 4, Table 2) consistent with those found in 1965. Anomaly No. 3 occurs just southeast of Pointe-Cavagnal (Figures 2E, 2F and 2G) and was detected in 1965, 1968 and 1969. A mosaic was produced from the imagery obtained in 1969 from an altitude of 1,000 feet. This revealed considerably more detail than the previous imagery of 1965 and 1968. Anomaly No. 3 is about a mile in diameter and consists of alternating light and dark patches which indicate a mixing of warm and cold water respectively. This mixing is not visible in the imagery flown at 9,000 feet (Figure 2F), but it can be seen in the imagery flown at 5,000 feet (Figure 2E).

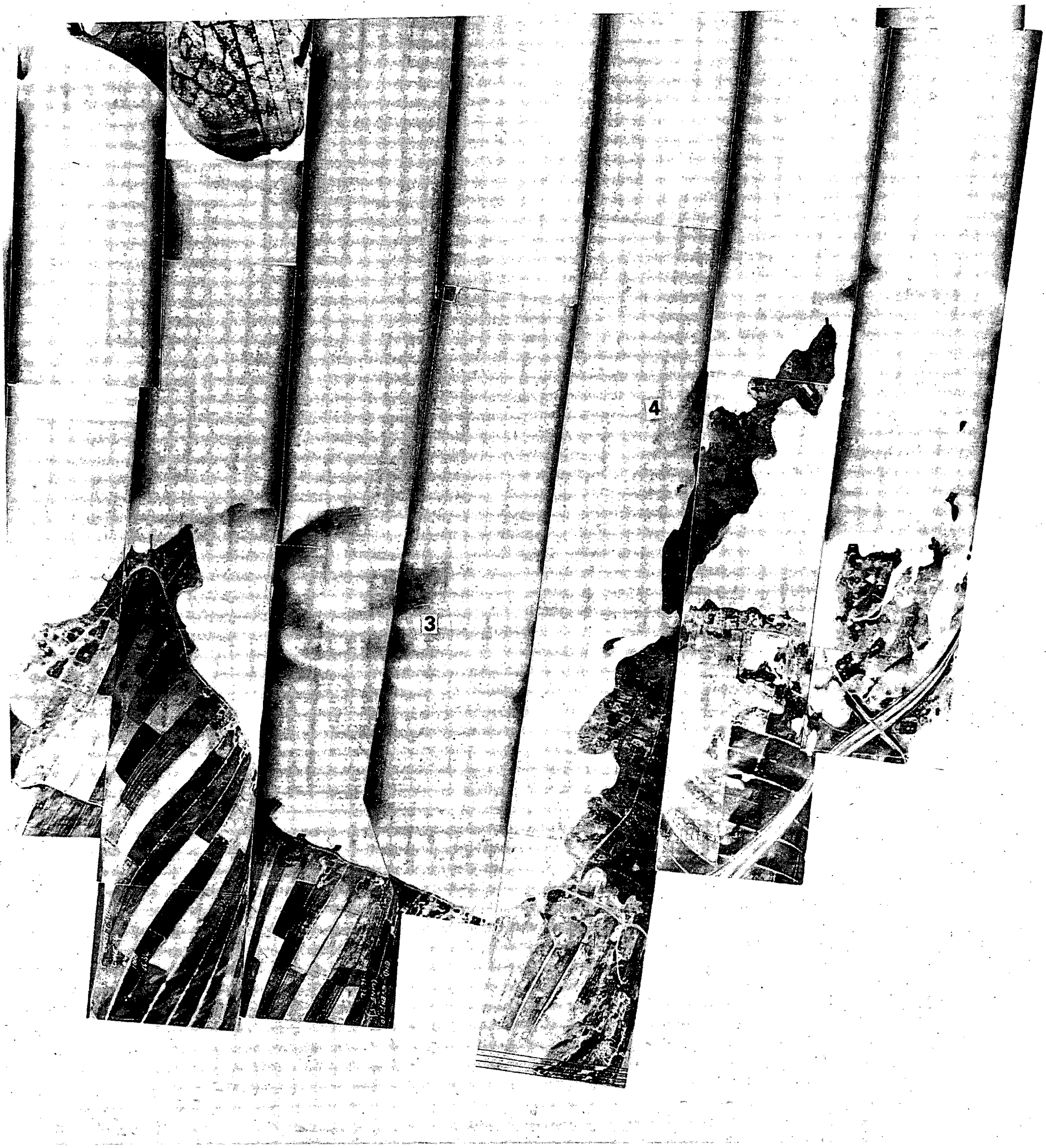


Figure 2G. Mosaic at Belle Plage Bay. Flight E, November 24, 1969, at 1,000 feet.

Table 2 - Flights in which Anomalies were Detected

Anomaly No.	Location	Flight A	Flight B	Flight C	Flight D	Flight E	Comments
1	Near Carillon Island	X	X	X	X	N.F.	Linear streamflow feature
2	Confluence of the Rigaud and Ottawa Rivers	N.F.	N.F.	X	N.F.	N.F.	Shallow water anomaly
3	Near Pointe-Cavagnal	X	X	N.F.	X	X	Suspected groundwater
4	Near Ile Cadieux	X	X	N.F.	X	X	Suspected groundwater

X – present; N.F. – not flown

One part of this anomaly (Figure 2G) is caused by the wake created from Pointe-Cavagnal; however, the aerial photographs show only a small wake. Also other points similar in size and shape to Pointe-Cavagnal (i.e. Pointe-aux-Bleuets, Figure 2C, and Pointe-Parsons, Figure 2D) have a small infrared anomaly due to the wake effect. The larger part of this anomaly appears to be distinct from this wake effect and could be due to some cause other than the point, possibly groundwater.

Anomaly No. 4 occurs on the south side of Belle Plage Bay parallel to Ile Cadieux. Its position varied slightly between the flights of 1965, 1968 and 1969. This ambiguity in position is mainly due to the inherent distortion of the scanner, the different flight altitudes, and to the electronic humping of the 1965 imagery partly obscuring the anomaly. However, the shape is fairly consistent over these years; it is composed of several linear dark streaks occurring parallel to Ile Cadieux. Most likely it is revealing the current pattern along the shoreline, for a faint linear current pattern can also be detected on the aerial photographs in the same position. However, the source of the thermal difference may be groundwater discharge.

Both anomalies Nos. 3 and 4 are undoubtedly modified by the current pattern, but both occur immediately downstream from groundwater discharge areas situated on the bottom of the bay. They appear to have about the same size and location in these flights. Complete coincidence did not occur, nor was it expected, since the shape of the anomaly at any one time depends upon many factors, such as the current in the river, the wind present, and the lines flown.

HYDROGEOLOGY

To show that groundwater is being discharged into Belle Plage Bay and the locations of these discharge areas, it is necessary to describe the pertinent aspects of the hydrogeology of the sand and gravel aquifer. Then the discharge areas can be compared with the locations of the infrared anomalies.

Hydrogeologic and seismic studies were first conducted in this area by Tremblay and Hobson (1962). Supplementary well information has been collected by Courtemanche (1968), and offshore seismic work (Faesslen, 1968) was carried out to extend the geologic control under Belle Plage Bay. All this information has been compiled in Figures 3 and 4, and the accompanying cross-sections.

A bedrock valley was discovered in the Precambrian and Paleozoic rocks (map-unit 1, Figure 3) by Tremblay and Hobson in 1962. The position of this bedrock valley and its boundary walls has controlled the deposition of the sand and gravel aquifer and hence controls the groundwater flow.

St. Lazare Station to Belle Plage Bay

The stratigraphic succession of unconsolidated deposits that fill this valley in the area is shown in Figure 3 and cross-section A - B. Drilling results from wells A and B (Courtemanche, 1968) indicate that the bedrock is the nearly flat-lying Nepean sandstone of Cambrian age.

A lower glacial till (map-unit 2) is known to have a maximum thickness here of 18 feet, and was deposited in the bottom of this valley. This is overlain by a glacial-fluvial sand and gravel (map-unit 3) which has a maximum known thickness here of 20 feet. This sand and gravel deposit forms an aquifer which is confined by the clay deposits of map-unit 6. At the southwestern corner of this area, it is overlain by a thin till (map-unit 4) having a maximum known thickness of 6 feet. This till is overlain by a glacial-fluvial sand deposit ranging up to 110 feet in thickness (map-unit 5). From well B to Belle Plage Bay, thick deposits of lacustrine and Champlain sea clays (map-unit 6) are in facies relation with the glacial-fluvial sand deposit. These clay deposits contain the occasional boulder zones and are overlain by thin alluvial sand (map-unit 7) and some discontinuous deposits of peat and muck (map-unit 8).

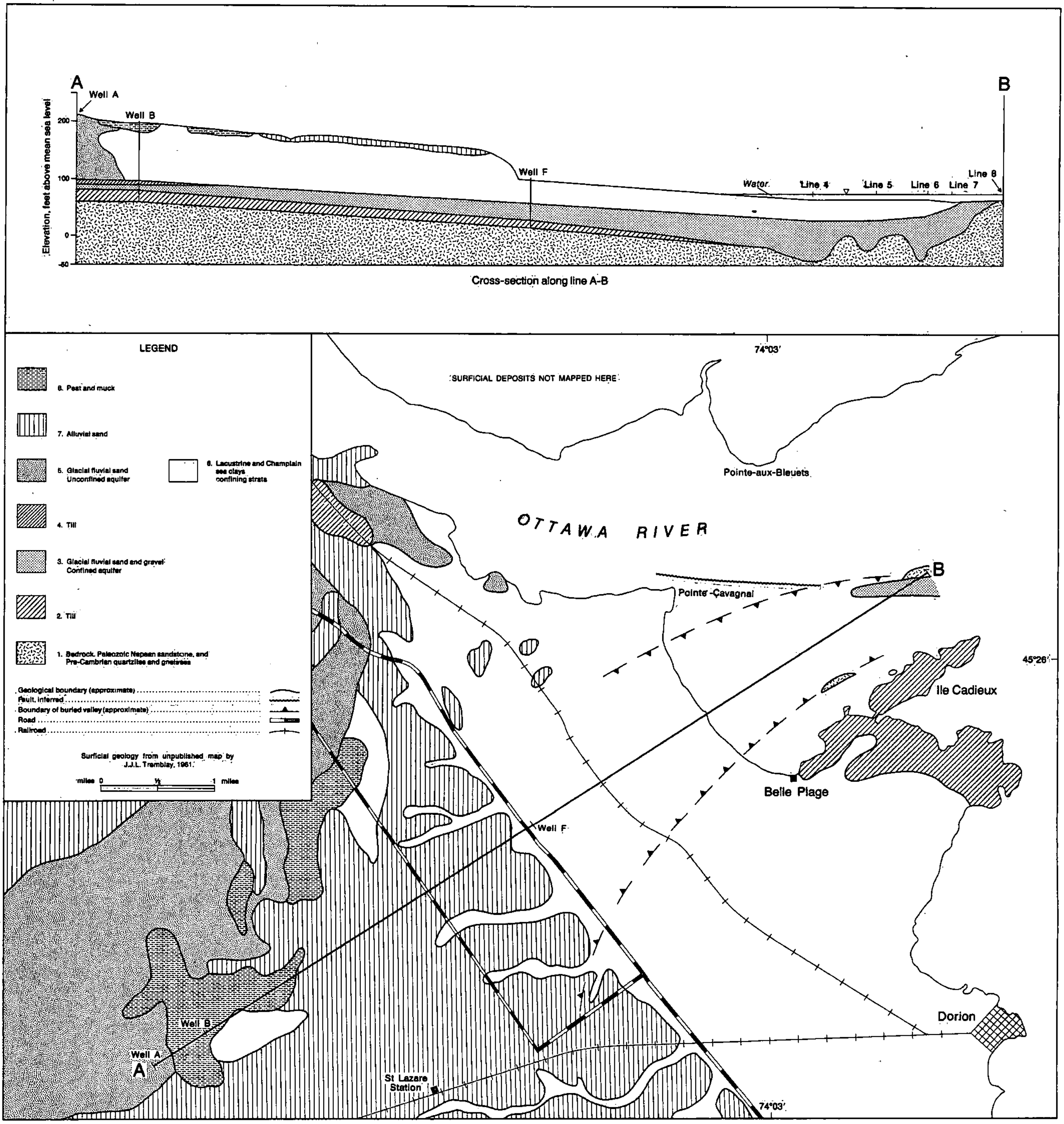


Figure 3. Geological map of Belle Plage Region.

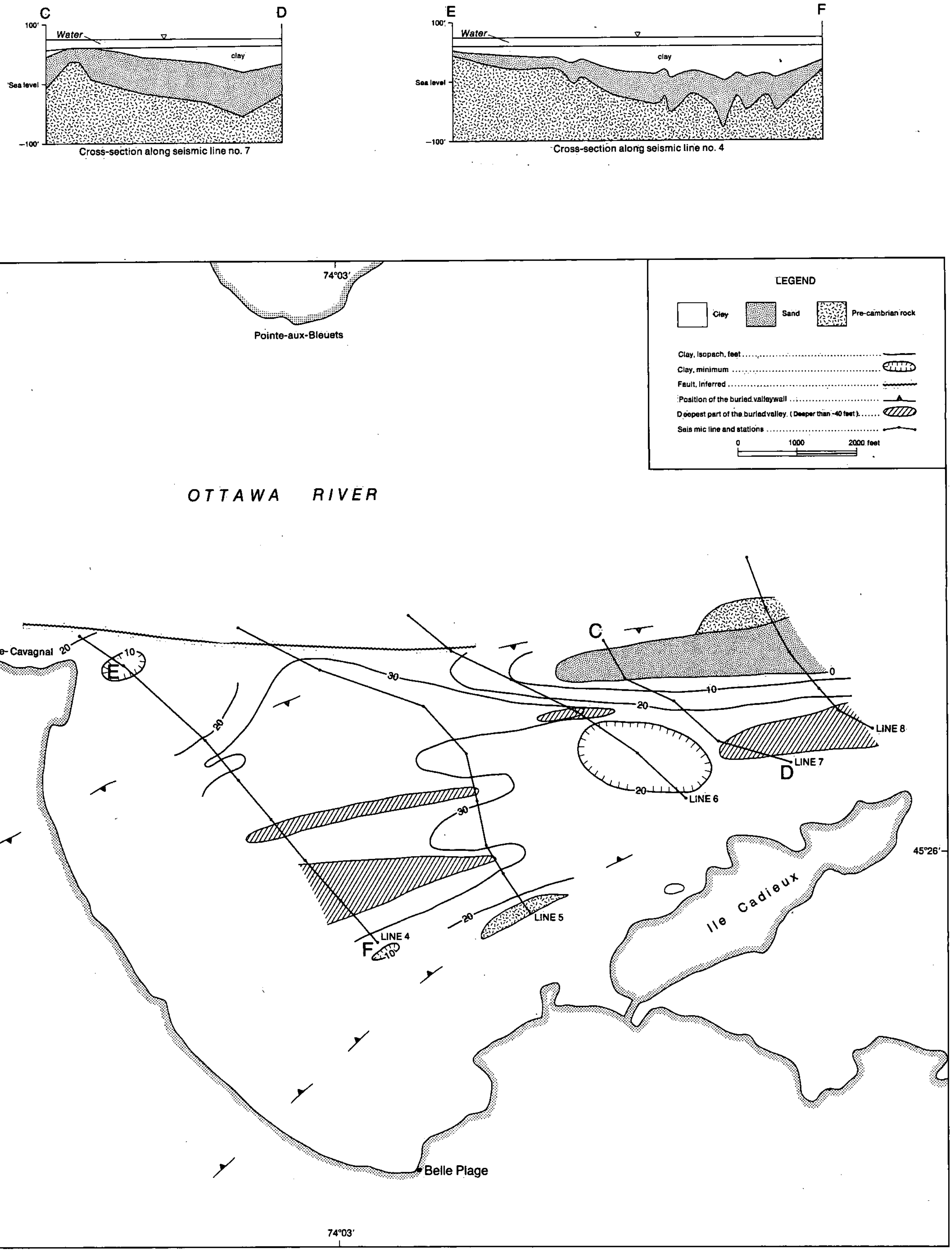


Figure 4. Geology of Belle Plage Bay.

The glacial-fluvial sand (map-unit 5) has a large areal extent in the southwestern corner of this area and beyond the limits of Figure 3. In these places, it forms an extensive recharge area and is hydraulically connected through the thin intervening till to the sand and gravel aquifer (map-unit 3). This aquifer extends to Belle Plage Bay and has a hydraulic gradient of about 22 feet per mile towards the Bay (Tremblay and Hobson, 1962). It is confined by the thick clay deposits of (map-unit 6).

Belle Plage Bay

The geology of this area was determined by a seismic survey along the five lines shown in Figure 4. The lack of stratification within the bedrock and its very uneven nature indicate that here it is composed of Precambrian igneous or metamorphic rock rather than Nepean sandstone. The presence of the bedrock valley is indicated by four trenches having depths deeper than 40 feet below sea level, which extend across the bay in a southwest to northeast direction. The walls of the valley from two partially buried ridges on either side of these trenches. One wall extends from Pointe-Cavagnal to the large Precambrian outcrop near the centre of the bay (Figure 4), and follows a fault on the far side of the ridge. The position of the other valley wall is situated parallel to Ile Cadieux through the Precambrian outcrop at the end of line 5.

The seismic reflection profiles (cross-sections C - D and E - F) detected two layers of overburden that are situated on top of this bedrock. The lower layer is distinguished by marked stratification which is sub-parallel to the bedrock surface. This is interpreted to be the glacial – fluvial sand and gravel (map-unit 3), having a maximum thickness of 84 feet (cross-section E - F). The greatest thickness on any seismic line nearly always occurs in the deep bedrock trench. The upper layer of overburden is generally more homogeneous, with some stratification in its lower portions. Reflections from point seismic sources have been observed within this upper layer, indicating the presence of boulders. This is interpreted to be the lacustrine and Champlain sea clays (map-unit 6), having a maximum thickness of 55 feet. The areas of large thickness (greater than 30 feet on Figure 4) overlie the deep trenches of the bedrock. This clay acts as a confining layer to the sand aquifer and forms the bottom surface of the bay (Figure 4).

Examination of the clay isopachs (Figure 4) reveals that there is a large area north of Ile Cadieux where this sand appears at the surface of the bottom of the bay (cross-section C - D, Figure 4). This appears to be the main discharge area within Belle Plage Bay for the confined aquifer and thus is a place where an infrared anomaly might be expected. An even larger discharge area could occur outside the bay, close to the centre of the river, where the sand of the buried valley would be exposed by the deep channel of the river.

Two other areas of clay minima, which may be possible discharge areas, exist near Pointe-Cavagnal and Ile Cadieux. They are mentioned here because infrared anomalies Nos. 3 and 4 were found in these areas. The cross-section E - F (Figure 4) indicates the geology across the bay along line 4. The confining clay strata tend to wedge out against the flanks of bedrock highs of the valley walls near these two areas.

Near Pointe-Cavagnal the sand and gravel aquifer is overlain by about five feet of clay. With these seismic results, strata thickness can not be resolved to better than five feet, so it is possible that the clay is completely absent here. In this case groundwater could be discharging upwards to the bottom of the bay.

At the southeast end of this cross-section (Point F), the clay thins out rapidly and the sand is within 5 feet of the surface. Unfortunately the seismic line ended here so information beyond this point is not available. Groundwater could be discharged to the surface here. Also at the end of line 5, near Ile Cadieux the sand and gravel aquifer pinches out against the Precambrian outcrop, which will form an impermeable barrier to groundwater flow and could deflect it upwards possibly through the overlying 8 feet of clay.

Thus, there is definitely one large discharge area in the bay and possibly two smaller discharge areas near Pointe-Cavagnal and Ile Cadieux respectively (Figure 4).

COMPARISON OF DISCHARGE AREAS AND INFRARED ANOMALIES

A comparison of the positions of the sand discharge areas and the infrared anomalies can be made to see if a correlation exists. The 1969 mosaic was considered to be the most reliable imagery to show the position of the anomalies and is used in Figure 5 to compare with the discharge areas.

No anomaly occurs over or near the main sand discharge area. This could be due to the fact that it is situated near the edge of the bay where the current is much stronger and the river is much deeper, so the groundwater would be dispersed quickly and may not reach the surface of the river.

The outer limit of Anomaly No. 3 situated off Pointe-Cavagnal is affected by the current sweeping past the point. However, the larger part of this anomaly occurs within Belle Plage Bay and could be caused by groundwater discharge through the clay minima.

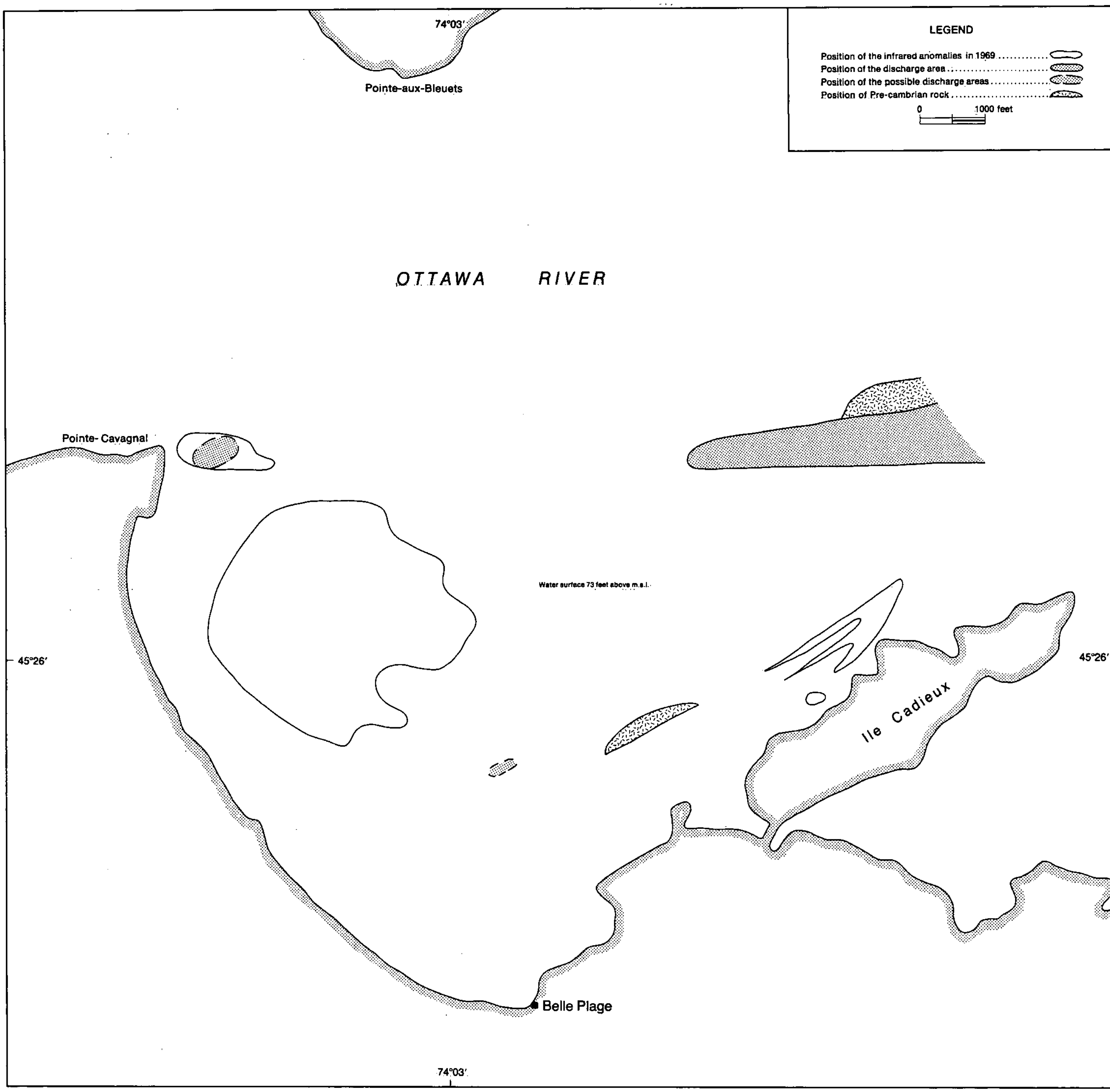


Figure 5. Position of the infrared anomalies and the possible groundwater discharge areas.

Anomaly No. 4 could be caused by a possible sand discharge area that seismic evidence suggests might occur between lines 4 and 5 or by the Precambrian outcrop deflecting groundwater upwards. The exact position of the infrared anomaly was impossible to determine due to distortion of the imagery.

CONCLUSIONS

(1) In no case in this study was a positive identification of groundwater made. However, it is likely that anomaly No. 3 is caused by groundwater.

(2) The scanner did reveal the wakes and currents in the river far better than the aerial photographs. Unfortunately, these effects tend to obscure the imagery of any groundwater anomaly. Thus there is more likelihood of detecting groundwater anomalies of this kind in lakes than in fast flowing rivers.

(3) The best imagery was obtained at a low altitude and by flying overlapping flight lines so that a mosaic could be made from the image strips. A mosaic is much more useful than strips for locating the anomalies and interpreting them.

(4) Details shown on the land are far more complex than those revealed over water. The best imagery is obtained by flying over a large expanse of water where there is a relatively uniform emissivity, rather than constantly flying back and forth over land and water which frequently results in electronic overshoot.

(5) Caution is warranted when interpreting infrared anomalies for they may be due to peculiarities of the scanner itself, such as electronic humping or to the weather conditions.

REFERENCES

Courtemanche, Jean-Louis, 1968. Alimentation en eau potable. Rapport au Conseil Municipal de la ville de Dorion.

Faesslen, C.W., 1968. Report on hydrosonde survey, Lake of the Two Mountains, Quebec. Huntec Ltd., Montreal, Quebec (open-file report available at Inland Waters Branch, Department of the Environment, Ottawa, Ontario).

Fischer, W.A., R.M. Moxham, F. Polcyn, and G.H. Landis, 1964. Infrared surveys of Hawaiian volcanoes. Aerial Surveys with infrared imaging radiometer depict volcanic thermal patterns and structural features. Science, 146, pp. 733-742.

Holter, M.R., S. Nudelman, G.H. Suits, W.L. Wolfe, and G.J. Zissis, 1962. Fundamentals of infrared technology. The Macmillan Co., New York, N.Y., p. 442.

Lee, K., 1969. Infrared exploration for shoreline springs at Mono Lake, California, Test Site. Proc. of the Sixth International Symposium on Remote Sensing of Environment, University of Michigan, Ann Arbor, Michigan, U.S.A., 13-16 October, vol. 2, pp. 1075-1100.

Ory, T.R. and R.W. Stingelin, 1966. Airborne infrared survey experiments in Canada. Unpublished report, H.R.B. Singer Inc., Science Park, State College, Penn., U.S.A. (open-file available at Geological Survey of Canada Library, Ottawa, Ontario).

Slaney, V.R., H. Gross, and L.W. Morley, 1967. Airborne infrared scanning survey along the shorelines of the Lower Great Lakes. Proc. of the Second Seminar on Air Photo Interpretation in the Development of Canada, Ottawa, Ontario, 13-15, March, pp. 76-86.

Tremblay, J.J.L., and G.D. Hobson, 1962. Vaudreuil map-area, Quebec. Geological Survey of Canada, Canada Department of Mines and Technical Surveys, Ottawa, Ontario, Paper 61-20, Part I and Part II. Available in the Dept. of the Environment, Inland Waters Directorate, Groundwater files).

Tremblay, J.J.L., 1963. Surficial geology, Vaudreuil map-area. Unpublished map, available at Inland Waters Branch, Canada Department of the Environment, Ottawa, Ontario.

Wilson, A.E., 1941. Valleyfield, Quebec and Ontario. Geological Survey of Canada, Department of Energy, Mines and Resources, Ottawa, Ontario, Map 660A.

University of Michigan, Mich. (Wolfe, W.L., Ed.), 1965. Handbook of military infrared technology. Office of Naval Research, Department of the Navy, Washington, D.C., U.S.A., p. 906.