

**A FIELD EXPOSURE OF
RAINBOW TROUT
IN THE
AVON RIVER
DOWNSTREAM
OF THE
STRATFORD
SEWAGE TREATMENT PLANT**



Ministry
of the
Environment

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DOWNSTREAM OF THE STRATFORD
SEWAGE TREATMENT PLANT**

BY

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INTRODUCTION

Total residual chlorine (TRC) levels which would likely be lethal to fish have been found in the Avon River downstream of the Stratford sewage treatment plant (STP) discharge (W.R.A.U., 1979). Furthermore, under low-flow conditions, TRC concentrations exceeding the MOE objective of 2 µg/L were observed for at least 150 m downstream (W.R.A.U, 1979.)

One of the recommendations in the report, cited above, was that:

"Chlorine residual in the reach downstream from the Stratford STP should be reduced below the toxic level for aquatic life. This could be achieved by eliminating chlorination, using another type of disinfection or chlorination followed by dechlorination."

Therefore, in conjunction with that recommendation and as a part of the 1980-82 SAREMP project, this study was undertaken to demonstrate the presence of a zone of impact from the STP effluent, and to define and document the extent of such a zone in regard to *in situ* fish lethality.

A similar exposure of fish was carried out in Big Otter Creek downstream of the STP at Tillsonburg (pop. 20,000). The study findings indicated that after 24 h the effluent plume was lethal to all of the test fish located nearshore to the STP, in excess of 50 m downstream of the discharge. On the other hand, in a replicate exposure, no fish mortality was observed in the same stretch of river over 48 h, when sewage disinfection was carried out by UV irradiation (Flood *et al*, 1984). In addition, it should

be noted that the quality of waste disinfection by UV light was equivalent to that of chlorination (Palmateer *et al*, 1983).

DESCRIPTION OF STUDY SITE

Stratford is a summer tourist area and an agricultural community of 27,000 residents. The area of interest is a portion of the Avon River immediately west of the city, although theoretically within its boundary. Adjacent land uses are agricultural and stream habitat is variable, ranging from moderately deep pools to shallow riffle and grassy areas.

The Stratford STP is a tertiary treatment plant with a 27,300 m³/day capacity. The effluent is chlorinated in a 3-pass contact chamber with a 20-minute retention time. It is discharged continuously with the exception of a 1/2-hour interruption/day at approximately 7:30 a.m. to backwash the sand filters.

METHODS

Station Locations

1) Chemical Sampling

Transects A to L were located across the river at fixed points throughout the length of the study area. Four sampling stations (1-4) were placed equidistance apart along each transect, with an exception in the case of transects A and L. At the L location, chemical samples were taken at the mid-stream fish cage location only; while the upstream control site consisted of a single station designated as A.

2) Fish Exposure

The initial cage locations were based on TRC levels throughout the study area immediately prior to the exposure. The cages were placed at a select number of locations corresponding to chemical sampling stations as set out by MOE regional personnel. Fish exposures were undertaken at distances of 17, 78.5 (2 cages), 209, 475, 572 and 637 m downstream of the STP outfall, with the corresponding station designations of 82, E1 and E2; H1, 3, K and L, respectively (Figure 1, page 4). The rationale for the specific cage locations was as follows:

- i) A (23 m) - was located immediately upstream of the STP discharge and as such it represented the control site.
- ii) 82 (17 m) - was the closest station to the STP outfall which consistently received the highest TRC concentrations during the study.
- iii) E1 and E4 (78.5 m) - were situated along opposite banks of the river. They encountered the lowest TRC levels of the four stations across the E transect and were selected to demonstrate whether a non-lethal zone of passage would exist at this point in the river.

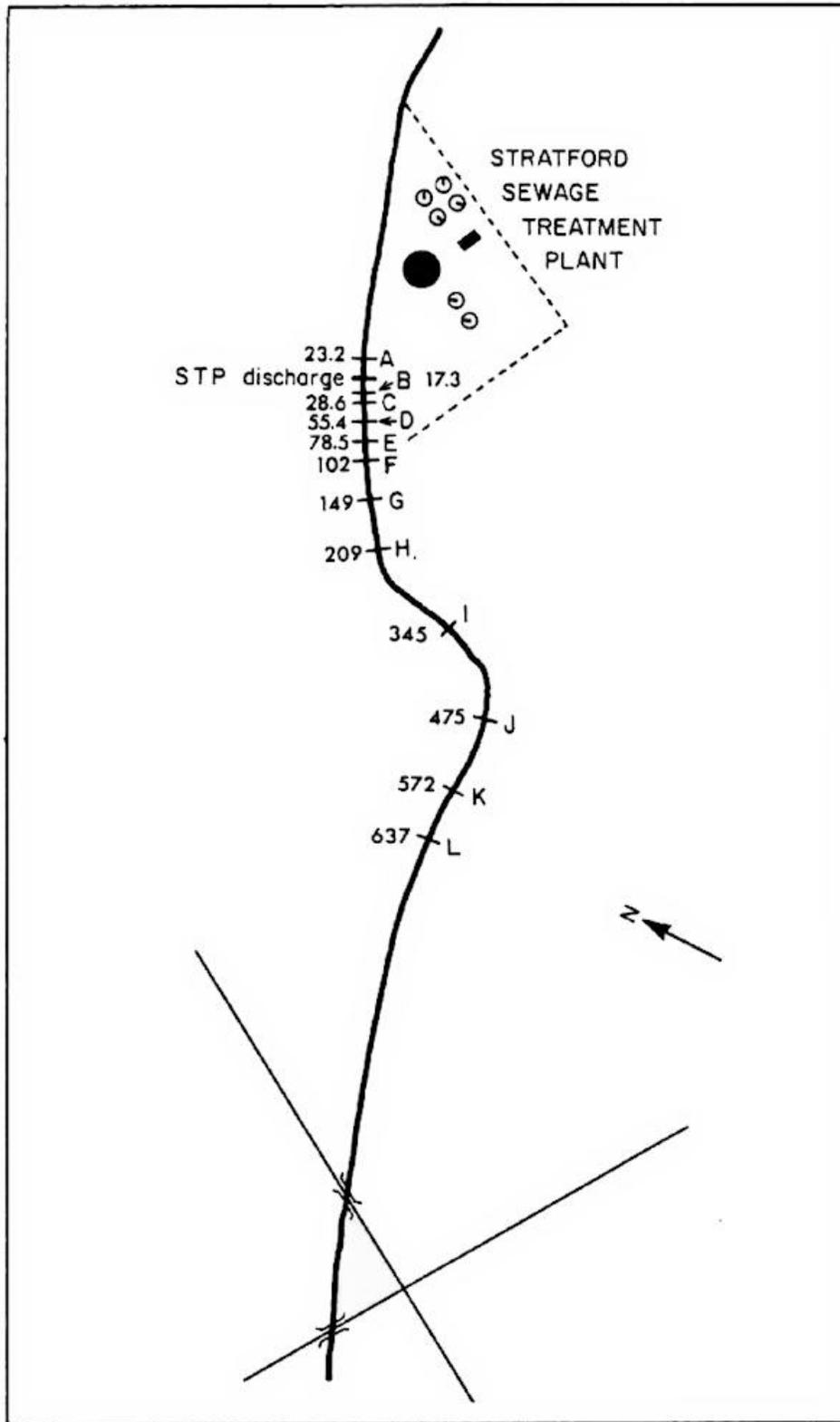


FIGURE 1 : Distances (m) of sampling sites and fish cage locations from STP discharge.

- iv) H1 (209 m) - received the highest TRC concentrations at this transect.
- v) J 475 m) - was a mid-stream stations, bracketed by the two chemical sampling stations which encountered the highest TRC concentrations at this transect, J2 and J3.
- vi) K and L- were placed mid-stream, 572 and 637 m downstream of the STP discharge. They were added one and two days after the start of the study, respectively; due to unexpected fish mortalities at J.

Test Fish

Rainbow trout (*Salmo gairdneri*) fingerlings were supplied by Aqua-farms of Feversham, and maintained in dechlorinated Toronto tap water at the Ministry of the Environment, Rexdale laboratory prior to use in this study. They were initially held in the laboratory at 10°C, whereupon a one-week acclimation was undertaken by raising their water temperatures, 1°/day, to 15°C. The fish were held the final three days at temperatures which coincided with study site levels (14.5 - 16.5°C). The mortality rate during the holding period was less than 1%/week.

The fish were transported to the test site in polyethylene bags containing an oxygen headspace. Upon arrival, they were held a further 24 hours at the control site prior to the exposure. No mortality was observed during this period.

The mean($\bar{x} \pm$ S.D.) weight and length of fish used in the study were 3.8 \pm 1.2 g and 6.8 \pm 0.8 cm, respectively.

Fish Cages

The cages used in this study were developed by Munro and Pawson (Pawson *et al*, 1983). They were constructed of a 1.9 cm (3/4") polyvinylchloride pipe frame with a nylon 0.6 cm (1/41-mesh bag. The cage tops and bottoms were 1 m equilateral triangles separated by a 0.5 m depth. Placement of the cages was on the river bottom with one of the angular corners facing upstream.

Test Procedures

The fish exposures commenced Wednesday, September 8, 1982 and finished on Monday, September 13, 1982. Fifty fish were tested at each site. Mortality was recorded hourly for the first 6 hours of the exposure and every morning, mid-day and late afternoon thereafter, for the remainder of the week. A fish was considered dead when, after mild prodding, there was no visible movement or signs of respiration. All dead fish were removed from the cages immediately upon observation.

Water temperatures and dissolved oxygen were monitored continually at the control site and downstream of the STP outfall, between sampling transects F and G (Figure 1). The temperatures and oxygen levels recorded at both sites fell within the range of 13.2 - 17.2°C and 7.6 - 11.8 mg O₂/L, respectively. Oxygen levels were also measured daily in each cage or when significant mortality (> 10%) was observed in a cage (all oxygen levels were greater than 7.0 mg/L throughout the test).

Water samples were collected from the exposure sites once daily for metals and general water quality parameters. Total residual chlorine, ammonia nitrogen, pH and conductivity were measured on-site as often as possible each day, in order to best characterize chemical fluctuations within the plume.

Exposure sites K and L were added mid-day 24 and 48 hours (respectively) after the start of the study. No observations were made or chemistry samples collected at the study site during the weekend (most mortality results had already occurred by the Friday afternoon). Final observations at the control, J, K and L sites were undertaken mid-day Monday, the following week; along with dissolved oxygen (all > 8.2 mg/L) and temperature readings (20° °C). All control fish were sacrificed, weighed and measured (for total length).

RESULTS AND DISCUSSION

Complete fish mortality occurred within 48 h, as far as 209 m downstream of the Stratford STP discharge; while 66% of the fish at the 475 m site died within a 96 h period (Figure 2). The two closest sites to the outfall that produced no fish mortality were the control and the exposure site located 572 m downstream of the STP.

The maximum values of copper, zinc, nickel, lead and aluminum measured at the exposure sites during the study were 0.02, 0.13, 0.04, < 0.003 and 0.3 mg/L, respectively (Appendix A). In terms of their lethality to rainbow trout, the effects from these metals would be minimal especially since river hardness levels at the exposure sites ranged from 349 - 463 mg/L (as CaCO₃) throughout the study (U.S. E.P.A., 1973 and 1976).

The toxicants of major concern in regard to lethality were TRC and unionized ammonia. Their contribution to fish lethality is outlined in the discussion of results for each exposure station.

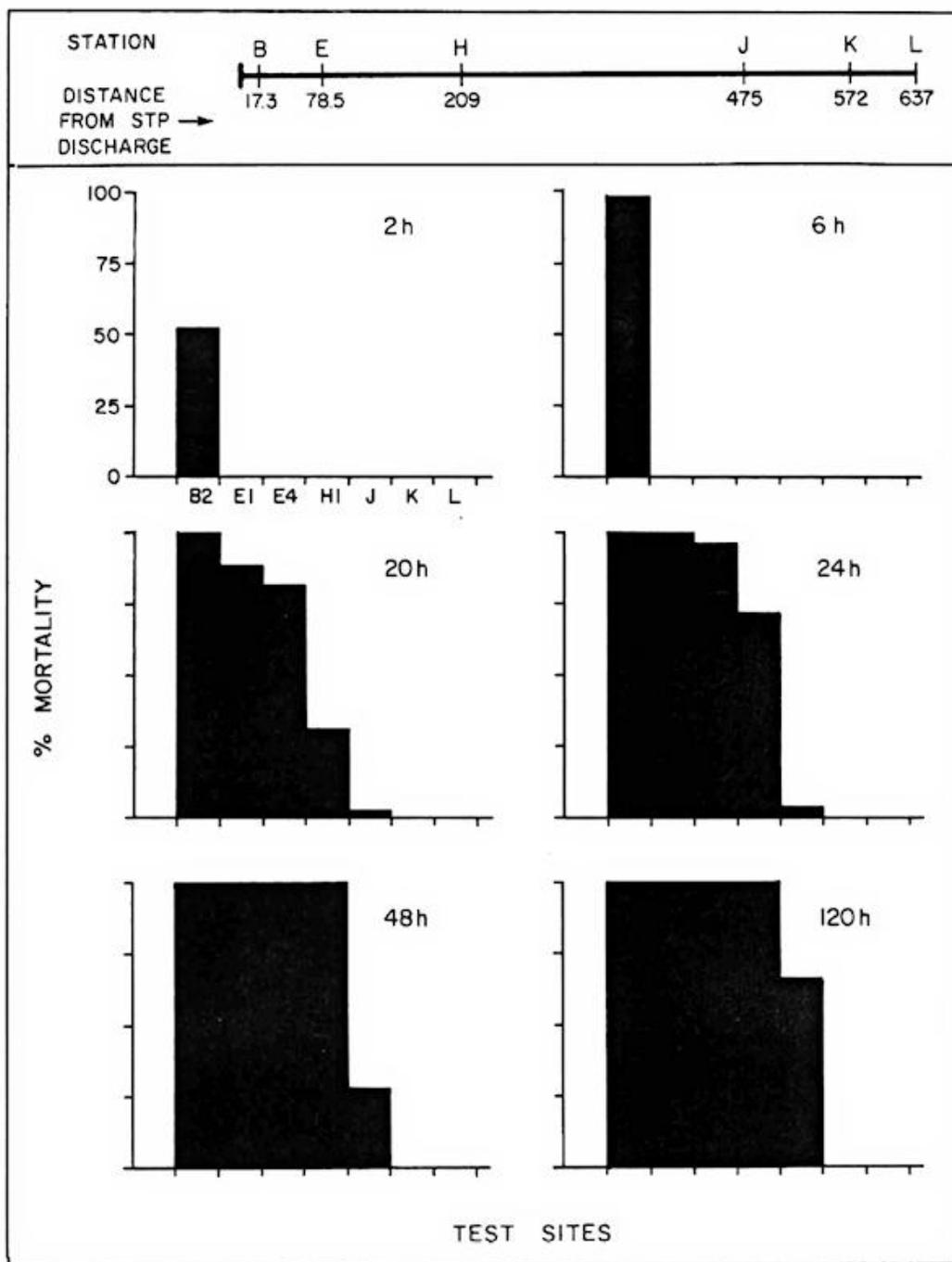


FIGURE 2. Fish mortality for the Avon River exposure sites downstream of the Stratford STP outfall at progressive periods during the *in situ* bioassays.

1) Station B2: 17m downstream

The first evidence of lethality in the study was observed at the 17 m station. Fifty percent of the test fish at that site were dead within two hours while 98% mortality was observed 4 hours later. During that period, TRC levels of 228 and 194 µg/L were measured at the beginning of and 3 h into the exposure, respectively. These values are consistent with levels found to cause fish mortality in the time frame under consideration (Mattice and Zittel, 1976).

No other station produced fish mortality during the initial 6 hours observation time on Day 1 of the exposure. Unionized ammonia levels at all sites and TRC levels at all exposure sites downstream of B2 were less than values reported to be lethal to rainbow trout within 6 hours. The highest level of unionized ammonia during that 6-h period was 0.06 mg/L, while the TRC concentrations ranged from 0 - 28 µg/L downstream of B2.

2) Stations E1 and E4: 78.5 m downstream

Within the initial 20 h of the exposure, fish mortality levels of 88 and 82% had occurred at cages E1 and E4. The corresponding TRC values at those sites were 234 µg/L and 48 µg/L, respectively; while the epicentre of the plume as it passed the 78 m transect appears to have been closest to station E2 (TRC - 308 µg/L). Therefore, since both sites E1 and E4 were situated within 2.5 m opposite shorelines over a 16 m expanse of river, and they represent sites with the lowest TRC values either side of the plume epicentre, it appears that there would be no reasonable zone of passage for migratory fish under normal conditions of chlorinated effluent discharge from the Stratford STP.

The highest levels of unionized ammonia in the study were measured along the 78 m transect at the 20 h observation time. However, the values of 0.13 and 0.12 mg

NH₃/L for E1 and E2 respectively, were still lower than the lowest value (0.2 mg/L) cited in the literature as lethal to rainbow trout (Liebmann, 1960).

3) Station H1: 209 m downstream

A 32% lethality level and a corresponding TRC of 94 µg/L were observed 209 m downstream of the STP discharge 20 h into the exposure. The TRC concentration is similar to a level (108µg/L) which produced 60% mortality within an 11-hour period (Basch and Truchan, 1971).

Although TRC levels at site H1 dropped dramatically from 94 to 3 µg/L, 3 h later; and remained in the 13 - 33 µg/L range during the following 7 h; a latent effect of the exposure was observed with a further 58% mortality response during that 20 - 30 h test period. It appears that the fish were irreversibly damaged during the period of high TRC values (~ 94 µg/L) to the point of eventual death.

4) Station 3: 47.5 m downstream

A threshold mortality level of 2% occurred at station 3 during the initial 24 h exposure period; while a 26% level was observed within 48 h. The mortality eventually increased to 66% over a 120-h period which included a weekend. Day-time TRC values for the 48 h period leading up to the weekend ranged from 0 - 20 µg/L; while TRC levels of as low as 10 µg/L have been shown to kill adult salmonids in a period of several days (U.S. E.P.A., 1976). No chlorine analyses were available beyond the initial 48-h exposure period.

5) Station K: 572 m downstream; and Station L: 637 m downstream

The fish exposures at sites K and L were added 24 and 48 h after the initial sites were set-up due to unexpected fish mortality at station 3. These exposures ran for 96

and 72 h respectively and no fish mortalities were observed during those periods. The highest TRC residuals occurred at chemical sampling stations K2 and K3, with levels of 5 µg/L measured on two successive sampling runs. The other analyses for the K and L transects showed chlorine to be non detectable.

6) Indigenous Fish Observations

During the week of September 6th, three separate observations were made of indigenous fish, under stress, "skiddering" across the water surface in the vicinity of transect B. These fish likely moved downstream into a concentrated portion of the plume which caused immediate irritation and uncontrolled excitement. Whether the fish moved into the plume by accident or were attracted is unknown. There is evidence in the literature that fish are drawn toward certain concentrations of chlorine which are lethal to them (Sprague and Drury, 1969; Servizi and Marten, 1974).

Also on Day 2, two fish (*Catostomus* sp.) were found dead in a sluggish part of the river approximately 240 m downstream of the STP outfall. These fish most likely died in the vicinity of the STP effluent discharge and floated downstream from there, because evidence based on our exposure results suggest that the survival and therefore presence of a fish population at the point of discovery is highly unlikely. Furthermore, the possibility of an upstream migration of fish to the point of discovery appears slim for there is a long fast flowing section of river immediately downstream which would act as a migratory barrier to young fish (7-9 cm suckers).

The only observation of unstressed fish in the river involved a school of minnows (species unidentified) at approximately 2.5 m downstream of station J.

CONCLUSIONS

- 1) Fish lethality was observed as far as 475 m downstream of the Stratford sewage treatment plant discharge, over a 96-h period, while residual chlorine was detected as far as 572 m downstream.
- 2) Ninety-eight percent of the fish exposed 17 m downstream of the STP discharge died within 4 h. Total residual chlorine concentrations, which were in the 194-228 µg/L range during the exposure, are consistent with levels found to cause fish mortality within a 4-hour period.
- 3) There appears to be no zone of passage for fish at a point 78.5 m downstream of the STP discharge, based on fish mortality across that transect.
- 4) Fish indigenous to the Avon River appeared to be adversely affected by the STP plume.

RECOMMENDATIONS

Consideration should be given to employing an alternative type of sewage disinfection at the Stratford STP, such as a UV light system currently being evaluated at the Tillsonburg STP, or dechlorination of the present effluent prior to discharge.

Appendix A: The Maximum and Minimum Levels of Chemical Constituents measured in the Avon River in the vicinity of the Stratford STP, September 8-12/82 (mg/L unless otherwise noted).

Exposure Stations and Distance from Discharge	TRC (µg/L)	NH ₃ -N	TKN	pH (no units)	Cond. (µmhos) cm	Alk. (as CaCO ₃)	Na	Cl	SO ₄
upstream									
A - 23 m	0	0.02-0.70	1.0-1.2	8.2-8.4	500-620	212-215	17-19	31-32	70-76
downstream									
B2 - 17 m	168-348	4.4-7.5	1.7-5.7	7.5-7.7	960-1260	214-233	123-156	137-210	213-240
E1 - 78 m	0-260	1.7-6.5	2.4-5.0	7.6-8.0	940-1260	207-217	73-117	94-138	148-240
E4 - 78 m	0-48	2.0-6.9	2.2-3.8	7.8-8.0	760-940	209-218	55-71	75-80	132-160
H1 - 209 m	3-103	3.3-4.7	3.1-5.4	7.7-7.9	880-1160	203-231	87-108	110-128	158-208
J- 475 m	0-37	1.8-4.4	2.2-4.0	7.7-7.9	940-1160	204-226	70-99	85-118	142-190
K - 572 m	0-5	0.3-0.5	3.6-3.7	7.7	920-1140	221-222	91-93	100-106	172-175
L- 637m	0	-	-	-	-	-	-	-	-

N.B. - single value designates no variation in the level; N ≥ 3 except for stations K and L.

Appendix A: The Maximum and Minimum Levels of Chemical Constituents measured in the Avon River in the vicinity of the Stratford STP, September 8-10/82 (mg/L unless otherwise noted).

Exposure Stations and Distance from Discharge (m)	Cu	Zn	Al	Cr	Pb	Fe	Hardness (as CaCO ₃)
upstream							
A - 23 m	<0.01	0.02-0.03	<0.02-0.02	< 0.02-0.02	< 0.03	0.19-0.22	300-311
downstream							
B2 - 17 m	0.01	0.02-0.03	<0.2-0.2	<0.02	< 0.03	0.11-0.17	418-463
E1 - 78.5 m	< 0.01-0.01	0.02	<0.2-0.2	< 0.02-0.02	< 0.03	0.16-0.18	371-424
E4 - 78.5 m	< 0.01-0.01	0.02-0.03	<0.2-0.2	< 0.02-0.04	< 0.03	0.14-0.21	344-374
H1 - 209 m	< 0.01-0.01	0.02-0.03	<0.2-0.3	<0.02	< 0.03	0.12-0.25	394-406
J- 475 m	< 0.01-0.02	0.02-0.13	<0.2-0.3	<0.02	< 0.03	0.14-0.25	356-402
K - 572 m	-	-	-	-	-	0.17-0.20	380
L - 637 m	-	-	-	-	-	-	

N.B. - single value designates no variation in the level; N ≥3 except for stations K and L.

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