AMCHITKA BIOENVIRONMENTAL PROGRAM
LIMNOLOGY OF AMCHITKA ISLAND, ALASKA

ANNUAL PROGRESS REPORT

July 1, 1971 - June 30, 1972

by

Thomas J. Birch

April 1973

NOTICE

This report was prepared as an account of work sponsored by the United States Government. Neither the United States nor the United States Atomic Energy Commission, nor any of their employees, nor any of their contractors, subcontractors, or their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness or usefulness of any information, apparatus, product or process disclosed, or represents that its use would not infringe privately owned rights.

Prepared for the U. S. Atomic Energy
Commission under Contract No. AT(26-1)-171

BATTELLE
Columbus Laboratories
505 King Avenue
Columbus, Ohio 43201

MASTER

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

JK9

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency Thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

DISCLAIMER

Portions of this document may be illegible in electronic image products. Images are produced from the best available original document.

ABSTRACT

Gross morphological changes to lakes as a result of Cannikin were largely limited to lakes within a 1-mile radius of Surface Zero. Four lakes near SZ were completely drained by tilting of their basins and/or cracking of their bottom seals and two others were partially drained. No new physical disturbances attributable to Cannikin were observed in lakes near Long Shot or Milrow SZ.

A new lake was formed as a result of Cannikin. The lake, in the Cannikin subsidence crater, may become the largest lake on Amchitka. The crater was expected to reach near maximum depth by the fall of 1972. The flooding of drill mud materials by the waters impounded in the crater may create a minor pollution problem in the new lake.

Observation of potential short-term effects to chemical and biological parameters in Amchitka lakes due to Cannikin were masked by the effects of a severe storm which struck Amchitka on D-1. While there were increases in spring of 1972 in values of pH and alkalinity of a sufficient magnitude, nature, and location to suggest a relationship to Cannikin, there was an apparent masking effect on subtle changes in water chemistry in the spring due to very dry weather. Concentrations of particulate organic matter were temporarily increased in a number of lakes as a result of Cannikin. Higher-than-normal values persisted into the spring in a few of these lakes. A number of additional disturbances to lakes and streams as a result of test-support activities are cited.

TABLE OF CONTENTS

	<u>Page</u>
INTRODUCTION	1
PROGRAM APPROACH	1
Objectives	1
Methodology.	2
Criteria for Evaluating Test-Related Effects	2
Cannikin Intensive-Study Lakes	2
Sampling Periods	5
EVALUATION OF TEST-RELATED EFFECTS AND LIMNOLOGICAL INVESTI- GATIONS	5
Physical Parameters	5
Gross Morphological Changes to Lakes.	5
New Lake Formation	7
Chemical Parameters	9
Alkalinity and pH	9
Total Hardness.	19
Specific Conductance, Chlorides, and Solids	19
Organic Matter.	20
Stream Samples	24
Trace Elements	27
Biological Parameters	27
Plankton	27
Primary-Productivity Investigations	33
Additional Disturbances Due to Support Activities	35
EFFECTS OF CANNIKIN ON MILROW INTENSIVE-STUDY LAKES	36
REFERENCES	37

APPENDIX A

WEATHER CONDITIONS ON AMCHITKA DURING THE SAMPLING PERIODS	A-1
--	-----

LIST OF TABLES

Table 1.	Identification of Lakes Studied During Autumn, 1971, and Spring, 1972	3
Table 2.	Summary of Test-Related Morphological Changes Observed on Intensive-Study Lakes	6
Table 3.	Chemical Data From Three Ponds Formed as a Result of Cannikin	9

LIST OF TABLES
(Continued)

	<u>Page</u>
Table 4. Status of Preevent Values of pH and Alkalinities in Intensive-Study Lakes	10
Table 5. Chemical and Physical Data from Amchitka Lakes During Fall, 1971 and Spring, 1972	11
Table 6. First Postevent Samples Compared with Last Preevent Samples . . .	15
Table 7. A Comparison of Pre- and Post-Cannikin pH Data Collected During Autumn on Amchitka Between 1967 and 1971	16
Table 8. A Comparison of Pre- and Post-Cannikin Alkalinity Data Collected During Autumns of 1967 and 1971 on Amchitka	18
Table 9. Residue (Solids) Analyses From Selected Stations During Spring, 1972	20
Table 10. Statistics for Organic-Matter Samples From 26 Lakes on Amchitka During October, 1971	20
Table 11. Organic-Matter Concentrations (mg/l) in Open Lake Water During Autumn, 1971 and Spring, 1972	21
Table 12. Pre- and Post-Cannikin Organic-Matter Concentration in Lakes Near SZ and in a Control Group	23
Table 13. Chemical Data From Amchitka Streams	25
Table 14. Open Lake Water Production and Chemical Parameters in the Inlet Streams, Open Lake Water, and Outlet Streams in Selected Amchitka Lakes Between May 26 and June 3, 1972	26
Table 15. Concentrations (mg/l) of Trace Elements in Three Amchitka Lakes	28
Table 16. Zooplankton Population Concentrations of Cannikin-Effects Intensive-Study Lakes (Organisms/Liter)	29
Table 17. Rotifer Populations of Amchitka Lakes, Spring, 1972	32
Table 18. Rates of Carbon Fixation by Phytoplankton During Autumn 1971 and Spring 1972	34

LIST OF FIGURES
(Continued)

	<u>Page</u>
Figure 1. Milrow and Cannikin Effects Study Lakes	4
Figure 2. Cannikin-Effects Evaluation Lakes Within 3,200 M of SZ	4
Figure 3. The Cannikin Subsidence Crater Showing New Lakes and Displacement Differentials in Feet	8
Figure 4. Absolute Changes in Particulate Organic-Matter Concentrations Post-Cannikin in Lakes at Various Distances From SZ	24
Figure A-1. 24-Hour Maximum and Minimum Air Temperatures and Average Daily Water Temperatures - Amchitka, Alaska	A-2
Figure A-2. 24-Hour Precipitation Water Equivalent at Amchitka, Alaska	A-2
Figure A-3. Precipitation (Water Equivalent) by Month During Three Years at Amchitka, Alaska (Amchitka Airstrip Tower)	A-3

LIMNOLOGY OF AMCHITKA ISLAND, ALASKA

by

Thomas J. Birch

INTRODUCTION

The United States Atomic Energy Commission has been conducting a Bioenvironmental Program on Amchitka Island, Alaska, under the direction of Battelle Memorial Institute-Columbus Laboratories since 1967 to predict and evaluate the effects of AEC operations on the Amchitka environment. AEC activities on Amchitka have included two underground nuclear tests and the support services required for the performance and evaluation of these tests. The first test, designated Milrow, was October 2, 1969, and the second, Cannikin, was November 6, 1971. Previously, Project Long Shot, a small underground nuclear test, was conducted by the U. S. Department of Defense with the assistance of the AEC in October, 1965.

Effects analysis of the impact of AEC activities on the freshwater ecosystem of Amchitka have been part of the Amchitka Bioenvironmental Program. Limnological reconnaissance, representing a portion of the total freshwater ecology program, has been conducted by investigators from Battelle's Columbus Laboratories. Additional freshwater ecology programs have been conducted by Utah State University scientists.

This report describes the work of the limnology program between July 1, 1971, and June 30, 1972. Limnological investigations on Amchitka prior to FY 1972 are described in annual progress reports printed by Battelle Memorial Institute and designated by the following report numbers: BMI-171-103, BMI-171-117, BMI-171-124, BMI-171-129, and BMI-171-145. Freshwater ecology investigations conducted by Utah State University are described in the following Battelle reports: BMI-171-104, BMI-171-127, BMI-171-133, and BMI-171-142. The limnological investigations during FY 1972 concentrated on documentation of short-term effects attributable to Cannikin and longer-term effects on the basis of samples acquired 7 months after the detonation. The short-term effects of Cannikin are summarized for all Bioenvironmental Program elements in the D+2 Months Report (Kirkwood and Fuller, 1972).

PROGRAM APPROACH

Objectives

The objectives for evaluating short-term effects of Cannikin included the detection of changes in phyto- and zooplankton genera and monitoring any gross chemical or physical changes occurring to the lakes as a result of Cannikin. The data collected were evaluated in perspective to seasonal trends in these parameters and the probable long-term significance of observed disturbances to the ecology of Amchitka.

The objectives of the D+7 months investigations were to (1) detect subtle effects of the Cannikin event not evident in the short-term observations, (2) evaluate the status of lakes on which short-term effects were observed, and (3) assess the Milrow intensive-study lakes as compared to their pre-Cannikin status.

Methodology

The methods and materials employed in the conduct of these investigations are consistent with those used during prior sampling programs. These methods have been described and reported by Birch (1972) and Koob (1968, 1969, 1971).

The general approach in short-term investigations was to acquire samples as frequently as possible from a select number of intensive-study lakes so that test effects could be distinguished from seasonal trends. Analyses were not made in situ, they were conducted in the laboratory on water samples from the lakes. A smaller number of samples were acquired from the study lakes during the D+7 months investigations to detect chemical or biological parameters outside the range of natural variation as observed during the previous spring-sampling periods. Weather data were obtained from records at the Amchitka airstrip control tower.

Criteria for Evaluating Test-Related Effects

The criteria established for evaluation of short-term seismic disturbance to the freshwater ecosystems of the Island included (1) partial or complete drainage of a lake due to fracture of the bottom seal or to a breach of the peat retaining dam, (2) increase in alkalinity due to the rupture of the peat mat in the watershed with resulting exposure of surface drainage water to alkaline subsurface rock deposits, (3) decrease in primary productivity as detected by a reduction of pH, (4) reduction in plankton populations due to direct or indirect effects of the ground shockwave, and (5) increase in suspended silt load due to disturbance of sediments. In practice, Criterion 5 was largely excluded because previous observations suggested that the information obtained did not warrant the expenditure of resources required.

Cannikin Intensive-Study Lakes

A total of 39 lakes were sampled during the autumn 1970 and spring 1971 field programs to acquire base-line information in preparation for Cannikin. Some of these lakes were also intensive-study lakes for Milrow. Of these lakes, 27 were sampled for event-related study during October-November, 1971. The lakes were selected on the basis of (1) morphology and relative permanence, (2) location with respect to SZ, (3) accessibility, (4) the existence of prior sampling data, and (5) coordination of limnological sampling with the freshwater fisheries investigations. The lakes involved in the sampling program described in this report are identified in Table 1. The locations of the lakes are indicated in Figure 1.

The 17 lakes sampled within a 2-mile (3.2 km) radius of SZ are shown in more detail in Figure 2.

TABLE 1. IDENTIFICATION OF LAKES STUDIED DURING
AUTUMN, 1971, AND SPRING, 1972

Lake Designation		Lake Name	Map ^(a) Number	Coordinate	Intensive Study Lake ^(b)
BCL	USU				
1	AJ	Pumphouse Lake	2023 I NE	585932	M
1a			2023 I NE	562927	
2	AC	Clevenger Lake	2023 I NE	556945	M
5	DA	Jones Lake	2023 I NE	576965	M
7		Range Pond	2023 I NW	515965	MC
9		Rifle Pond	2023 I NW	516963	MC
10		Duck Pond	2023 I NW	515962	MC
19b	AL	Silver Salmon Lake	2023 I NW	541990	
23	BH	Upper Twin Lake	2023 I NW	518986	
26	BT	Weed Lake	2023 I NW	527994	MC
28	AQ	Quonset Lake	2023 I NW	51900	M
29		Long Shot Lake	2023 I NW	512002	MC
30		Long Shot Pond	2023 I NW	514006	MC
31b	DD	Round Lake	2023 I NW	521016	MC
33		Strange Pond	2024 II SW	493030	MC
35		Mud Pond	2024 II SW	494034	M
36		Clear Pond	2024 II SW	493034	M
41b			2024 II SW	484033	C
42c	DF		2024 II SW	473039	C
42d	BO		2024 II SW	471041	C
42e	DH		2024 II SW	471036	C
42f	BP		2024 II SW	467048	C
42g	DN		2024 II SW	481045	
43b	DO		2023 II SW	466027	C
43c	DJ		2023 I NW	465025	C
43d			2023 I NW	267026	
43e			2023 I NW	4672016	C
43f			2023 I NW	461016	C
43h			2023 I NW	447018	C
44a			2024 II SW	451037	C
44b			2024 II SW	437033	C
45	DK		2024 II SW	457054	C
49			2024 II SW	449049	
50a	DP		2024 II SW	445053	C
50c			2024 III SE	424047	
51	AU	Emerald Lake	2024 III SE	431066	MC
52a			2024 III SE	415086	C
53			2024 III SE	409091	C
58a	AN	Fault Lake	2024 III NE	393110	MC
N-1		Cannikin Sump	2024 II SW	466039	
N-3		Cannikin Lake	2024 II SW	467040	
N-5		White Alice Lake	2024 II SW	462043	
--		14-Mile Lake	2024 II SW	435063	
--		D-Site Sump	2024 III SE	405088	

(a) U S Army Corps of Engineers map of Rat Islands, Amchitka (Series Q-801)

Coordinate refers to the approximate center of lakes

(b) M = Milrow, C = Cannikin

(c) Straight-line distance between SZ and the nearest lake shore

FIGURE 1. MILROW AND CANNIKIN EFFECTS STUDY LAKES

FIGURE 2. CANNIKIN-EFFECTS EVALUATION LAKES WITHIN 3,200 M OF SZ
(Distances are from Surface Zero to the Nearest Lake Shore)

The limnology program and the fisheries program were coordinated so that all lakes investigated for fisheries data were also sampled for limnological data. In this text, limnology sampling locations are designated by cardinal numbers followed on occasion with letter suffixes; the fisheries program identifies their sampling locations by combinations of two capital letters. Both designations are referenced in Table 1.

Sampling Periods

The field program to collect immediate preevent data was initiated September 16, 1971, and was aborted September 21, due to a postponement of Cannikin. The sampling program was resumed October 13, and lasted through November 17, 1971, a total of 36 days. The sampling program was pursued on a schedule coordinated with the device-testing program. The lack of information concerning a specific test date resulted in frequent adjustments being required in the sampling schedule. Cannikin was detonated at approximately 11:00 a.m. (BST) on November 6, 1971.

The aquatic ecosystems under investigation were evaluated for longer-term effects of the Cannikin event between May 23 and June 6, 1972. Analyses were conducted for pH, alkalinity, dissolved chloride, specific conductance, dissolved solids, dissolved and particulate organic matter, hardness, zooplankton and phytoplankton, and primary productivity of phytoplankton. Analyses were performed on 39 lakes and 10 streams during the periods of investigation. All results and interpretations presented in this section are on the basis of data collected during these periods unless stated otherwise.

EVALUATION OF TEST-RELATED EFFECTS AND LIMNOLOGICAL INVESTIGATIONS

Physical Parameters

Gross Morphological Changes to Lakes

Short-Term Observations. Gross morphological changes to lakes as a result of Cannikin were largely limited to lakes within a 1-mile (1.6 km) radius of SZ. These changes were the result of ground motion produced by the detonation and by the formation of the subsidence crater at H+38 hours. Disturbance to lakes observed by the author outside the 1-mile (1.6 km) radius included a pond which drained near Jones Lake in the dock area and Lake 43e in the Ultra Creek basin which was partially drained due to a crack in the peat retaining dam. The ponded water near Jones Lake was drained due to cracking of the retaining dam originally constructed to support a roadway.

Of a cluster of 7 lakes located due east of SZ, 4 were completely drained by tilting of their basins and/or cracking of their bottom seals (Table 2). These lakes, 42c, 42d, 42e, and 42h were all within 0.6 mile (0.96 km) SZ. Two additional lakes (42a and 42b) were nearly drained prior to the test and their basins appeared to be relatively unchanged following Cannikin. The seventh lake in the cluster (42i) remained intact.

TABLE 2. SUMMARY OF TEST-RELATED MORPHOLOGICAL CHANGES
OBSERVED ON INTENSIVE-STUDY LAKES

Lake BCL (USU)	Coordinate	Distance From Cannikin SZ		Direction From SZ	Drainage
		Miles	Kilometers		
<u>Completely Drained</u>					
42d (BO)	471041	0.51	0.82	East	Bering
42e (DH)	471036	0.57	0.92	Southeast	Bering
42h	472039	0.57	0.92	East	Bering
42c (DF)	473039	0.62	0.99	East	Bering
<u>Partially Drained</u>					
44a	451037	0.76	1.22	Southwest	Pacific
43e	472016	1.65	2.64	Southeast	Pacific
<u>Extensive Shoreline Slumping</u>					
42f (BP)	467048	0.46	0.74	Northeast	Bering
45 (DK)	457054	0.79	1.2	North	Bering

Lake 44a, 0.76 mile (1.2 km) southwest from SZ was partially drained by two cracks in the bottom seal. Lake 42f, 0.46 mile (0.74 km) northeast of SZ, has a lower water level following Cannikin, a probable result of water splashing out of the lake at testtime and during the storm on D-1. No cracks in the bottom seal were observed draining water out of Lake 42f.

Extensive shoreline slumping resulted on Lakes 42f and 45 located 0.46 (0.74 km) and 0.79 (1.2 km) mile from SZ, respectively. Slight shoreline slumping was observed on several other lakes.

No physical changes as a result of Cannikin were observed in the lakes near Long Shot SZ (29 and 30) nor in the lakes near Milrow SZ (19, 20, 21, 22, and 23). Observations on D-Day and D+1 suggested that turbidity in lake water was about typical for the existing weather conditions.

Other physical effects included major channel disruption of the two tributaries to White Alice Creek which flank SZ and the escape of drilling mud and wastes from a fractured dike in a holding pond at Site D. These drilling materials flowed down Falls Creek and entered the Pacific Ocean.

D+7 Months Observations. The status of lakes that incurred morphological disturbances as a result of Cannikin, as reported in the D+2 Months Report (Kirkwood and Fuller, 1972) and in Table 2 was essentially unchanged in June, 1972, from that observed in November, 1971. The lakes completely drained by the event had not refilled,

and the severity of the disturbances to their basins suggests that they may never refill. Lake 43e, partially drained at testtime due to a crack in the peat retaining dam, had a water depth in June, 1972, comparable to that prior to Cannikin. The breach in the peat dam had apparently been sealed with new materials. Lake 44a, tilted and partially drained through cracks in the bottom substrate formed at testtime, had returned to near preevent water levels by June, although slight tilting of the basin was apparent. The cracks in the lake bottom were filled with mud and sand sufficiently to make their visual detection very difficult.

The water level in Lake 42g was lower preevent but unchanged from its immediate postevent level. Excessive quantities of mud and debris suspended in the lake water produced a turbidity that persisted through the calmest days of the sampling period. Despite the generally dry appearance of the Island, a subjective evaluation of the discharge into Lake 33 indicated that it was much greater than observed during any previous investigations on the Island. This apparent increase in discharge may be the result of hydrologic changes in the drainage basin of the lake as a result of Cannikin.

The water in Clevenger Creek was very turbid and milky-white on November 16, 1971. It was very clear and without observable color when resampled on June 3, 1972.

New Lake Formation

An anticipated effect of Cannikin on the freshwater ecosystem of Amchitka is the formation of a new lake in the subsidence crater. During the first few weeks after subsidence, small ponds formed in depressions in the subsidence crater. The subsidence crater area and the locations of the ponds are shown in Figure 3. The contours of displacement differentials in the crater were obtained from a figure entitled "Earth Movement Contour and Key Map", drawing number JSP-094-C110, dated December 21, 1971, prepared by Holmes & Narver, Inc. The plus areas in the diagram are on 1-foot contour intervals and minus areas are contoured in feet as indicated. The locations and sizes of the new ponds are approximate; they are designated N-1 through N-5 for discussion. Basins of Lakes 42c, 42d, 42e, and 42h are shown on the map; these four lakes, completely drained as a result of Cannikin, remained empty during the spring 1972 field work.

The ponds designated N-2 and N-3 were located in the lowest areas of the subsidence crater over the White Alice Creek channel (southeast branch). The ponds designated N-1 and N-4 were at slightly higher elevations, and Pond N-5 was considerably higher. Located almost directly north of SZ, this pond was formed at event time when the water of the northwestern branch of White Alice Creek was impounded by an earth slide. Pond N-1 was formed at testtime when water and drilling mud and materials drained from a fractured C-Site holding pond into a depression in the subsidence crater over the southeastern branch of White Alice Creek. The locations of Ponds N-1, N-2, and N-5 are illustrated very clearly, pre- and post-Cannikin, on Plates I and II of the D+2 Months Report (Kirkwood and Fuller, 1972).

During late May and early June, 1972, Ponds N-2 and N-3 were little more than puddles standing in the old stream bed. Observations indicating that these ponds had covered a larger area earlier in the spring were confirmed by island residents. In contrast, the water level in Ponds N-1 and N-5 appeared similar to that observed in November, 1971. The subsidence crater is expected to eventually fill with water to a depth of approximately 20 feet and form one large lake which will include Ponds N-1, N-2, N-3, and N-4.

FIGURE 3. THE CANNIKIN SUBSIDENCE CRATER SHOWING NEW LAKES AND DISPLACEMENT DIFFERENTIALS IN FEET

If the materials damming the water forming Pond N-5 are not rapidly eroded, which appears unlikely, this pond will probably remain separated from the large lake. Pond N-5 will probably not increase much in size beyond its present area. It is anticipated that surface drainage will flow into the subsurface cavities produced by Cannikin until they fill. At this time, which is predicted for early autumn 1972, the surface drainage will form the new lake in the crater which, in this report, is called "Cannikin Lake". An appropriate name for Pond N-5 would be, in this author's opinion, "White Alice Lake".

As these new "lakes" are located over stream beds that existed in those areas, they will have some irregularities in their bottom morphologies. As they increase in size and cover more of the tundra adjacent to the stream beds, lakes with soft bottom compaction and substrates high in organic-matter content will result. In addition to the materials from the original holding pond, materials from the drill-back operation have entered Pond N-1. These materials have, no doubt, produced a bottom sludge in this pond much different from what would have evolved naturally with the mineralization of the tundra substrate. Previous observations of the effects of similar contaminants from drilling operations at other locations on the island indicate that these materials will

severely retard the development of biological communities in the affected area and will alter the water chemistry. The water in Pond N-1 was highly discolored: mud brown or tan. On the basis of observations, all ponds except N-1 had very clear water and would have been expected to have very low turbidity values if analyzed. Pond N-1 was highly turbid and visibility was limited to a few centimeters below the surface.

A limited number of water-chemistry parameters determined for Ponds N-1, N-3, and N-5 are shown in Table 3. Ponds N-3 and N-5 had near-neutral pH's and alkalinities consistent with the flow of water into them at sampling time. The chloride content and

TABLE 3. CHEMICAL DATA FROM THREE PONDS FORMED AS A RESULT OF CANNIKIN

Pond	Date	pH	Alkalinity, mg/l	Chloride, mg/l	Specific Conductivity, micromhos/cm ²
N-1	6/5/72	8.37	130.0	--	410
N-3	6/5/72	7.36	12.0	40.2	185
N-5	6/5/72	7.18	37.5	38.0	230

specific conductivities were also comparable to those for similar-size lakes in undisturbed areas on the island. The higher values of pH, alkalinity, and specific conductivity of the water analyzed from Pond N-1 reflects the impact of the drilling materials on the water chemistry. Referring to prior experience, drill mud leaked into Emerald Lake (51) from another lake (14-Mile Lake) into which it was pumped for storage, during the Cannikin drilling operations. The pH and alkalinity increased in Emerald Lake from 6.67 and 5.0 mg/l to 7.03 and 27.7 mg/l, respectively. The lake containing the drill mud had a pH of 8.10, alkalinity of 450.0 mg/l, and specific conductivity of 1350. The odor and surface film present on Pond N-1 at the time of sampling suggested the presence of hydrocarbons. An oil-like film surfaced when the bottom substrates were disturbed.

No biological samples were collected from any of these new ponds. Luxuriant growths of algae, typically found in some Amchitka streams, were present in Ponds N-2, N-3, and N-5. Aquatic macrophytes were observed in all the ponds except N-1. No fish were sighted in the ponds. An important point to reference with the experience at Emerald Lake was the complete elimination of observable biota for several months following the influx of the drill mud into it.

Chemical Parameters

Alkalinity and pH

Water chemistry of the intensive-study lakes was, in general, similar in the immediate preevent period to that of previous autumn sampling periods. As Table 4 indicates, pH values in 59 percent of the lakes were essentially unchanged from data

collected in previous years. About 27 percent of the lakes had slightly higher pH values during autumn 1971 than was observed in prior years and the remaining 14 percent were lower.

During the preevent sampling period, pH values decreased or remained relatively stable in most intensive study lakes. Increases were observed in 7 percent of the lakes. This trend of decreasing pH was probably a reflection of decreasing rates of primary productivity in lakes with the advance of the autumn season and the dilution of lake water with slightly acidic rain water. In the last samples acquired prior to the event, there were decreases in the pH relative to the next previous sample in 63 percent of the lakes. Values were increased in about 30 percent of the lake samples and remained unchanged in slightly over 7 percent.

TABLE 4. STATUS OF PREEVENT VALUES OF pH AND ALKALINITIES IN INTENSIVE-STUDY LAKES

Expressed as percentages of the total number of lakes included in the sample.

Direction of Change	1971 Values Compared With Prior Autumn Values	Trend of Values During 1971 Sampling Period	Last Preevent Sample
	pH		
Values Increased	27.3	7.4	29.6
Values Decreased	13.6	59.3	63.0
Values Unchanged	59.1	33.3	7.4
Alkalinity			
Values Increased	9.1	48.2	48.2
Values Decreased	22.7	0.0	14.8
Values Unchanged	68.4	51.8	37.0

Alkalinity data from about 68 percent of the lakes were essentially unchanged from previous autumn data while some 22 percent of the lakes were slightly decreased and another 9 percent were slightly increased. The trend of alkalinity values in the lakes during the preevent sampling period was either to remain relatively stable or to increase. Some 48 percent of the lakes indicated increasing alkalinities during October and November, 1971, while none of the intensive-study lakes were decreasing in alkalinity. Some 75 percent of the lakes were essentially unchanged or increased in alkalinity in the last preevent sample when compared with the next previous sample acquired from the lakes. The data from analyses for pH, alkalinity, specific conductance, dissolved chloride, and water temperatures during October and November, 1971, are presented in Table 5.

It was anticipated that test effects, if any, would result in a reduction in pH values due to reduced primary productivity and/or increased alkalinity values resulting from the exposure of subsurface alkaline bedrock by tearing or rupturing of the peat mats in the

TABLE 5. CHEMICAL AND PHYSICAL DATA FROM AMCHITKA LAKES DURING FALL 1971 and SPRING 1972

Lake	Date	pH	Alkalinity, mg/l	Total Hardness (EDTA), mg/l	Specific Conductance, micromhos/cm ²	Chloride, mg/l	Temperature, C
1	9/20/71	7.91	61.5	--	308	--	9.0
	5/24/72	8.11	64.3	--	320	47.2	6.7
	6/1/72	8.47	65.3	--	305	48.0	8.3
1a	6/5/72	10.43	36.7	25.0	355	63.7	7.8
2	9/20/71	8.62	69.5	--	280	--	8.0
	5/24/72	8.36	61.5	25.0	305	47.7	6.1
	6/1/72	8.94	64.9	--	290	46.2	8.3
5	9/20/71	7.76	97.7	--	345	--	9.0
	5/24/72	8.61	88.0	20.0	350	50.5	5.8
	5/31/72	8.95	80.5	--	330	48.7	7.8
7	9/20/71	5.86	0.7	25.0	200	--	8.0
	5/27/72	5.82	1.2	--	310	80.2	6.3
9	10/17/71	6.47	1.0	--	220	51.3	6.0
	10/22/71	6.47	1.7	--	--	--	3.0
	10/30/71	6.45	3.0	--	235	--	3.8
	10/30/71	6.52	2.3	--	230	--	7.0
	11/9/71	6.17	1.5	--	270	--	6.1
	11/15/71	6.61	1.7	--	270	--	--
	5/27/72	6.60	3.5	32.5	310	82.2	--
	6/2/72	6.95	4.7	--	310	--	6.7
10	10/17/72	6.73	4.0	--	320	80.0	6.0
	10/22/72	6.58	4.5	--	--	--	4.0
	10/30/71	6.56	6.0	--	330	--	7.3
	11/9/71	6.52	3.8	--	400	--	6.1
	11/15/71	6.73	4.3	--	405	--	--
	5/27/72	6.86	9.0	55.0	500	133.7	--
	6/2/72	7.22	9.8	--	495	--	7.7
19b	5/29/72	7.63	34.8	--	240	47.5	7.0
	5/30/72	7.64	36.6	32.5	250	47.5	--
	6/4/72	8.00	50.0	--	255	--	6.1
23	9/20/71	7.00	11.5	--	150	--	7.0
26	10/20/71	7.50	21.5	--	195	34.3	4.8
	10/30/71	7.16	23.5	--	170	--	4.9
	11/11/71	7.04	17.9	--	205	--	2.0
	11/14/71	7.11	20.3	--	204	--	<1.0
	11/16/71	7.38	19.8	--	200	--	<1.0
	5/26/72	7.64	24.0	20.0	208	45.0	6.2
	5/27/72	7.37	23.3	27.5	210	45.0	--
	5/31/72	7.65	26.4	--	205	43.7	7.7
28	9/20/71	7.62	36.0	--	180	--	8.0
	5/27/72	7.53	23.6	17.5	205	43.2	--
	6/4/72	7.66	26.1	--	205	--	7.7
29	10/15/71	7.38	13.5	--	145	29.5	4.0
	10/24/71	7.24	15.5	--	--	--	2.5
	10/31/71	7.12	15.2	--	150	--	5.0
	11/10/71	7.40	13.5	--	165	--	4.0
	11/15/71	7.05	13.6	--	160	--	--
	5/26/72	6.93	12.2	22.5	--	44.5	5.1
	5/27/72	6.99	12.5	15.0	190	43.7	--
	6/2/72	7.45	13.0	--	185	--	7.7

TABLE 5. (Continued)

Lake	Date	pH	Alkalinity, mg/l	Total Hardness (EDTA), mg/l	Specific Conductance, micromhos/cm ²	Chloride, mg/l	Temperature, C
30	10/15/72	5.83	0.5	--	120	27.8	3.9
	10/24/71	6.07	0.7	--	--	--	2.0
	10/31/71	5.82	1.0	--	135	--	4.5
	11/10/71	6.12	1.0	--	145	--	3.0
	11/15/71	6.46	1.0	--	150	--	--
	5/26/72	5.97	1.1	17.5	155	42.8	6.2
	5/27/72	5.87	1.0	--	165	41.2	--
	5/31/72	5.92	0.7	--	165	--	6.7
31	10/18/71	7.35	17.5	--	180	35.8	7.0
	10/23/71	7.35	20.0	--	--	--	1.8
	10/30/71	6.91	19.0	--	185	--	4.0
	11/10/71	7.45	16.0	--	195	--	3.5
	11/14/71	7.21	18.7	--	200	--	<1.0
	5/27/72	7.37	18.7	30.0	220	51.0	--
	6/1/72	7.58	20.5	--	223	--	7.8
33	10/20/71	7.20	15.0	--	155	29.0	4.9
	10/30/71	7.05	15.0	--	140	--	6.0
	11/11/71	7.16	11.2	--	165	--	2.0
	11/16/71	7.45	11.0	--	170	--	<1.0
	5/27/72	7.21	14.1	30.0	195	44.5	7.2
	6/3/72	7.54	14.5	--	190	42.5	5.8
35	11/12/71	5.94	0.7	--	125	--	1.0
	5/29/72	5.57	0.5	10.0	170	44.5	7.0
36	11/12/71	5.58	0.8	--	160	--	1.0
	5/29/72	5.53	0.5	12.5	175	45.0	7.0
41b	10/20/71	5.96	0.7	--	135	29.5	3.8
	10/31/71	5.86	1.0	--	138	--	4.0
	11/8/71	5.86	1.0	--	140	--	5.2
	11/15/71	6.05	1.0	--	170	--	--
	5/27/72	6.09	1.0	12.5	160	41.2	--
42c	10/15/71	6.36	1.2	--	120	28.0	6.8
	10/22/71	5.94	1.0	--	--	--	3.0
	11/1/71	6.16	1.5	--	125	--	4.8
	11/4/71	6.24	1.0	--	125	--	2.9
42d	10/18/71	7.65	30.0	--	210	36.3	7.0
	10/22/71	7.57	37.0	--	--	--	3.0
	11/1/71	7.18	32.5	--	220	--	5.0
	11/4/71	7.13	32.5	--	200	--	2.5
42e	10/17/71	5.94	1.0	--	127	27.0	4.5
	10/24/71	6.33	2.5	--	--	--	1.5
	11/1/71	6.08	2.5	--	140	--	5.0
	11/4/71	6.37	3.0	--	135	--	3.0
	11/9/71	6.04	6.0	--	160	--	--
42f	10/17/71	5.46	0.3	--	130	27.8	4.5
	10/23/71	5.40	0.3	--	--	--	1.0
	11/1/71	5.36	<0.5	--	135	--	5.0
	11/4/71	5.48	<0.5	--	138	--	2.5
	11/9/71	5.41	<0.5	--	150	--	6.8
	5/29/71	5.43	0.2	12.5	155	37.2	7.0
	6/2/72	5.30	0.2	--	130	--	4.4

TABLE 5. (Continued)

Lake	Date	pH	Alkalinity, mg/l	Total Hardness (EDTA), mg/l	Specific Conductance, micromhos/cm ²	Chloride, mg/l	Temperature, C
42g	10/15/71	7.31	16.7	--	200	42.5	6.0
	10/31/71	7.17	19.0	--	200	--	4.3
	11/9/71	7.03	10.5	--	230	--	6.3
	5/29/72	7.49	27.7	--	215	43.7	7.0
	5/30/72	7.54	28.5	25.0	220	44.2	--
	6/4/72	7.75	32.3	--	212	--	6.1
43b	10/18/71	5.79	0.5	--	122	27.8	6.5
	10/23/71	5.66	0.5	--	--	--	1.0
	11/1/71	5.51	<0.5	--	125	--	4.9
	11/4/71	5.77	0.5	--	125	--	2.8
	11/8/71	5.70	0.8	--	140	--	4.5
	11/14/71	6.21	1.1	--	160	--	<1.0
	5/27/72	5.87	1.0	15.0	145	37.2	--
	5/31/72	5.93	1.2	--	145	--	--
43c	10/18/71	6.96	8.5	--	150	30.8	6.5
	10/23/71	6.90	9.8	--	--	--	1.0
	11/1/71	7.16	10.5	--	150	--	4.8
	11/4/71	6.73	9.5	--	150	--	2.8
	11/8/71	6.66	7.0	--	155	--	4.5
	11/14/71	6.61	7.5	--	188	--	<1.0
	5/27/72	7.25	1.5	30.0	180	42.0	--
	6/4/72	7.47	17.3	--	190	--	6.1
43d	6/5/72	5.73	0.5	15.0	150	37.7	--
43e	10/19/71	6.78	4.0	--	142	32.0	5.0
	11/3/71	6.79	5.5	--	150	--	5.0
	11/10/71	7.04	3.7	--	275	--	3.0
	5/28/72	7.20	13.0	25.0	180	41.7	5.0
43f	10/19/71	7.05	10.0	--	175	37.5	5.0
	11/3/71	7.06	11.5	--	180	--	5.0
	11/10/71	7.01	10.0	--	205	--	3.0
	5/28/72	7.52	23.0	37.5	230	51.5	5.6
43h	10/19/71	7.06	12.5	--	220	52.8	5.0
	11/3/71	7.28	14.0	--	245	--	5.0
	11/10/71	7.17	11.6	--	285	--	3.0
	5/28/72	7.38	22.5	30.0	295	69.2	5.0
44a	10/20/71	7.02	9.8	--	160	35.3	3.0
	11/1/71	6.97	11.0	--	178	--	5.3
	11/4/71	6.78	11.0	--	180	--	2.2
	11/8/71	6.94	10.0	--	200	--	5.0
	11/13/71	6.72	11.4	--	215	--	1.0
	5/27/72	7.18	15.3	20.0	170	40.7	--
44b	10/19/71	7.50	23.5	--	240	46.3	5.5
	11/3/71	7.25	24.5	--	240	--	5.0
	11/10/71	7.39	17.5	--	280	--	3.4
	5/28/72	7.45	35.3	42.5	250	50.0	5.8
45	10/20/71	7.20	13.5	--	185	37.5	3.5
	11/1/71	7.17	16.0	--	180	--	4.9
	11/4/71	7.03	17.0	--	195	--	2.8
	11/8/71	6.76	11.0	--	195	--	--
	11/13/71	6.97	11.5	--	200	--	1.0

TABLE 5. (Continued)

Lake	Date	pH	Alkalinity, mg/ l	Total Hardness (EDTA), mg/ l	Specific Conductance, micromhos/ cm ²	Chloride, mg/ l	Temperature, C
45	5/ 27/ 72	7.26	15.0	--	175	39.5	--
	6/ 3/ 72	7.66	17.0	15.0	165	39.5	0
49	10/ 20/ 71	6.27	1.5	--	125	28.3	4.0
	11/ 1/ 71	6.27	2.0	--	125	--	4.9
	11/ 4/ 71	6.49	2.0	--	130	--	3.0
	11/ 8/ 71	5.91	1.2	--	140	--	4.0
	5/ 27/ 72	6.46	2.0	10.0	160	41.2	--
50a	10/ 20/ 71	7.22	14.0	--	160	32.3	4.5
	10/ 31/ 71	7.07	15.5	--	160	--	4.1
	11/ 8/ 71	7.02	12.0	--	170	--	4.0
	11/ 13/ 71	6.83	11.9	--	170	--	1.0
	5/ 27/ 72	7.14	15.5	25.0	160	33.7	3.9
50c	10-19/ 71	7.50	30.5	--	250	46.3	5.5
	10/ 3/ 71	7.45	31.0	--	255	--	5.0
	11/ 10/ 71	7.58	22.3	--	285	--	3.0
	5/ 28/ 72	7.54	39.4	35.0	255	49.7	3.0
51	11/ 12/ 71	7.24	16.7	--	195	--	1.0
	5/ 27/ 72	6.84	6.5	17.5	175	39.4	--
52a	10/ 15/ 71	7.10	6.5	--	140	29.5	2.0
	10/ 31/ 71	6.96	8.5	--	150	--	4.3
	11/ 11/ 71	7.07	7.5	--	155	--	2.0
	11/ 15/ 71	6.85	7.9	--	175	--	--
	5/ 27/ 72	6.37	2.0	15.0	140	35.0	3.9
53	10/ 18/ 71	6.70	4.0	--	130	28.5	6.2
	11/ 1/ 71	6.67	4.8	--	138	--	5.0
	11/ 11/ 71	6.77	3.5	--	145	--	2.0
	11/ 15/ 71	7.02	4.0	--	155	--	--
	5/ 27/ 72	6.60	3.0	12.5	155	38.7	4.4
58a	10/ 17/ 71	6.41	3.5	--	120	26.8	6.0
	10/ 24/ 71	6.54	3.0	--	--	--	3.3
	10/ 30/ 71	6.26	3.5	--	120	--	4.3
	11/ 11/ 71	6.70	3.0	--	135	--	2.0
	11/ 15/ 71	6.87	3.0	--	125	--	--
	5/ 27/ 72	6.83	3.0	12.5	155	37.7	--
	6/ 1/ 72	6.73	2.9	--	145	--	6.7
Cannikin Sump	6/ 5/ 72	8.37	130.0	20.0	410	--	--
Cannikin Lake	6/ 5/ 72	7.36	12.0	--	185	40.2	--
White Alice Lake	6/ 5/ 72	7.18	37.5	37.5	230	38.0	--

drainage basins of lakes. These types of changes were anticipated to be very subtle, if even expressed, in short-term evaluations. Unfortunately, subtle effects were generally masked by the severe storm which struck Amchitka on D-1.

Table 6 presents a summary of pH and alkalinity changes in intensive study lakes observed in the first postevent sample as compared with the last preevent sample. Post-Cannikin, about as many intensive-study lakes had increased in pH as had decreased in pH. Only 4 percent of the lakes remained unchanged. The changes in alkalinity were considerably better defined than those in pH. Of the lakes, 80 percent decreased in alkalinity, 12 percent remained unchanged, and 8 percent increased.

The observed changes in pH in the intensive-study lakes ranged from -0.55 to +0.54 pH units. The largest positive change occurred in Lakes 30, 31b, 58a. The greatest negative changes were observed in Lakes 9, 42e, and 49. The only positive changes in alkalinity in the intensive-study lakes were in Lakes 42e and 43b. Lake 42e was nearly completely drained as a result of Cannikin and the sample was obtained from the water remaining in the fractured lake basin. Lake 43b incurred shoreline slumping at testtime. Negative changes ranged from -0.5 mg/l in Lake 58a to -8.7 mg/l in Lake 50c. Others that incurred particularly high reduction in alkalinity were Lakes 26, 31b, 33, 42g, 44b, 45, and 50a. Most of these lakes have a naturally high variance about their mean alkalinity values. These decreases in alkalinity are not considered to be test related but rather reflect the effects of the storm of D-1. There was no relationship apparent between the direction and/or the magnitude of the changes in pH and the distance of the lakes from SZ.

TABLE 6. FIRST POSTEVENT SAMPLES COMPARED WITH
LAST PREEVENT SAMPLES

Direction of Change	Percent	
	pH	Alkalinity
Values Increased	44	8
Values Decreased	52	80
Values Unchanged	4	12

Table 7 presents a comparison of pre- and postevent pH data collected from intensive-study lakes during autumn sampling periods from 1967 to 1971. The means and variances are calculated for the preevent data on intensive-study lakes. Of the 22 intensive-study lakes listed in the table, about 14 percent had mean pH values less than 6.0, 31 percent were between 6.0 and 6.6, 41 percent were between 6.7 and 7.2 and 14 percent were in excess of a pH of 7.3. The lowest mean pH value (5.51) was calculated for Lake 42f and the highest mean pH (7.50) occurred in Lake 26.

Variances (S^2) about the mean pH ranged from a low of 0.94 in Lake 45 to a high of 18.74 in Lake 26 (Table 7). Of the lakes, 32 percent had variances below 4.2, 46 percent were between 5.0 and 9.9, 18 percent were between 10.0 and 14.9, and only one (Lake 26) has a variance above 15.0. Lakes 26, 31b, 33, and 43c had the greatest variation about the mean pH.

TABLE 7. A COMPARISON OF PRE- AND POST-CANNIKIN pH DATA COLLECTED DURING AUTUMN ON AMCHITKA BETWEEN 1967 AND 1971

Lake	Analyses	Preevent Data				Postevent Data	
		Time Period	Range	Mean (X)	Variance (S ²)	Date	pH
42F (BP)	8	1967-1971	5.36 - 5.80	5.51	1.82	-	-
42D (BO)	7	1970-1971	7.13 - 7.72	7.37	6.86	-	-
42E (DH)	6	1970-1971	5.92 - 6.69	6.22	8.87	XI-9-71	6.04
42C (DF)	6	1970-1971	5.59 - 6.36	6.04	7.71	-	-
44A	8	1967-1971	6.45 - 7.20	6.86	7.36	XI-8-71 XI-13-71	6.94 6.72
45 (DK)	5	1967-1971	7.00 - 7.20	7.08	0.94	XI-8-71 XI-13-71	6.76 6.97
43B (DO)	8	1970-1971	5.51 - 6.49	5.82	8.47	XI-8-71 XI-14-71	5.70 6.21
49	9	1967-1971	6.11 - 6.70	6.37	3.57	XI-8-71	5.91
43C (DJ)	7	1970-1971	6.15 - 7.16	6.71	12.44	XI-8-71 XI-14-71	6.66 6.61
42G (DN)	4	1970-1971	6.71 - 7.35	7.13	8.62	XI-9-71	7.03
50A (DP)	7	1967-1971	6.65 - 7.30	7.03	6.88	XI-8-71 XI-13-71	7.02 6.83
41B	5	1970-1971	5.86 - 6.70	6.18	10.77	XI-8-71 XI-15-71	5.86 6.05
33A	13	1967-1971	6.40 - 7.46	6.94	13.45	XI-11-71 XI-16-71	7.16 7.45
29	12	1967-1971	6.50 - 7.52	7.21	7.95	XI-10-71 XI-15-71	7.40 7.05
30	12	1967-1971	5.40 - 6.36	5.86	5.63	XI-10-71 XI-15-71	6.12 6.46
31B	12	1968-1971	6.70 - 7.90	7.37	12.43	XI-10-71 XI-14-71	7.45 7.21
52A	4	1967-1971	6.77 - 7.20	7.01	3.48	XI-11-71 XI-15-71	7.07 6.85
53	4	1967-1971	6.52 - 7.10	6.75	6.14	XI-11-71 XI-15-71	6.77 7.02
26	15	1967-1971	6.76 - 8.20	7.50	18.74	XI-11-71 XI-14-71 XI-16-71	7.04 7.11 7.38
9	15	1967-1971	5.80 - 6.52	6.19	4.43	XI-9-71 XI-15-71	6.17 6.61
10	13	1967-1971	6.38 - 6.85	6.62	3.88	XI-9-71 XI-15-71	6.52 6.73
58B	12	1968-1971	6.26 - 6.90	6.64	4.45	XI-11-71 XI-15-71	6.70 6.87

Table 8 presents a comparison of pre- and postevent alkalinity data collected during autumn sampling missions between 1967 and 1971. Mean alkalinities ranged from a low of 0.6 mg/l in Lakes 42f and 43b to a high of 32.9 mg/l in Lake 42d. The percentage of lakes in ranges of mean alkalinity were 46 percent between 0.6 and 4.9 mg/l, 18 percent between 5.0 and 9.9 mg/l, 4 percent between 10.0 and 14.9 mg/l, 14 percent between 15.0 and 19.9 mg/l, and 18 percent over 20.0 mg/l.

Variance (S^2) about the mean alkalinity ranged from a low of 0.3 in Lake 43b to a high of 440.9 in Lake 26 (Table 8). Of the lakes, 40 percent had variances under 4.9, 9 percent between 5.0 and 9.9, 18 percent between 10.0 and 19.9, 14 percent between 20.0 and 39.9, and 18 percent ranged from 40.0 to 450.0. The greatest variance about the mean alkalinity values were calculated for Lakes 26, 31b, 33, and 42g.

Postevent pH and alkalinity data were compared with all available preevent data from autumn sampling periods. Of 19 intensive-study lakes sampled after the event, alkalinity values for 13 lakes were within ranges of alkalinity observed during autumn sampling periods prior to the event. Alkalinity values higher than those previously observed were obtained in postevent samples on Lakes 42e and 43b. Values lower than previous records were obtained from Lakes 45, 42g, 50a, and 53.

Only four lakes had postevent pH values outside previously recorded autumn ranges. Lakes 9 and 30 had postevent pH values higher than their previously recorded pH.

Data on pH, alkalinity, specific conductance, dissolved chloride, hardness, and water temperatures collected from intensive-study lakes during May and June, 1972, are presented in Table 5. The water-quality parameters during this period were rather severely influenced by a weather factor. The lack of normal amounts of precipitation during the winter and spring resulted in generally increased concentrations of dissolved solids in the lakes. This tended to mask or to make subtle Cannikin's effects on water chemistry.

The seasonal pattern observed during prior sampling periods has been that values for pH, alkalinity, specific conductivity, and chloride have generally been higher in most lake waters during the autumn than during spring sampling periods (Birch, 1972). Of the lakes examined for water-quality parameters in May and June, 1972, data collected prior to autumn 1971 existed for 25 lakes used to evaluate Cannikin effects and data from previous spring sampling periods existed for 18 lakes. Comparing the spring 1972 data of the 18 lakes, with data from previous spring analyses, 8 (Lakes 8, 26, 28, 33, 43c, 44a, 49, and 50a) had higher values for both pH and alkalinity than recorded from prior years. Two others (Lakes 30 and 53) had higher pH values and 3 (Lakes 10, 29, and 31b) had higher alkalinities. Lakes 41b, 42f, and 58a showed essentially no change in these parameters from prior years. No changes in pH were observed in Lakes 10, 29, and 31b and alkalinities were unchanged in Lakes 30, 43b, and 53. The highest pH values on record were exceeded during spring 1972 in Lakes 9, 33, 42g, 43c, 43e, 43f, 43h, and 45. Similar high records for alkalinities were recorded for Lakes 9, 42g, 43c, 43e, 43f, 44a, 44b, and 50c. Lake 52a had values for both pH and alkalinity which were lower than recorded during previous springs.

Comparing the spring 1972 data on the 25 lakes with data collected during prior autumn sampling periods, the pH in 8 lakes and the alkalinity in 10 lakes were higher than previously observed fall values. pH values of 16 lakes were similar to fall values and only Lake 52a had lower pH. Alkalinity was more typical of fall values in 12 lakes but lower than typical fall values in Lakes 29, 52a, and 52d.

TABLE 8. A COMPARISON OF PRE- AND POST-CANNIKIN ALKALINITY DATA COLLECTED DURING AUTUMNS OF 1967 AND 1971 ON AMCHITKA

Lake	Analyses	Preevent Data				Postevent Data	
		Time Period	Range	Mean (X)	Variance (S ²)	Date	Alkalinity, mg/l
42F	8	1967-1971	0.3- 1.0	0.6	1.0	-	-
42D	7	1970-1971	30.0-37.0	32.9	4.62	-	-
42E	6	1970-1971	1.0- 4.8	2.9	16.4	XI-9-71	6.0
42C	6	1970-1971	1.0- 1.5	1.1	0.4	-	-
44A	7	1967-1971	9.0-12.0	10.7	10.4	XI-8-71 XI-13-71	10.0 11.4
45	4	1970-1971	13.5-17.0	15.6	21.8	XI-8-71 XI-13-71	11.0 11.5
43B	8	1970-1971	0.5- 1.0	0.6	0.3	XI-8-71 XI-14-71	0.8 1.1
49	8	1967-1971	1.5- 2.5	2.1	1.4	XI-8-71	1.2
43C	7	1970-1971	7.0-10.5	9.5	17.2	XI-8-71 XI-14-71	7.0 7.5
42G	4	1970-1971	16.7-26.0	21.9	222.3	XI-9-71	10.5
50A	6	1967-1971	14.0-16.5	15.8	9.7	XI-8-71 XI-13-71	12.0 11.9
41B	5	1970-1971	0.7- 1.5	1.2	1.6	XI-8-71 XI-15-71	1.0 1.0
33A	13	1967-1971	2.0 - 15.0	9.7	296.1	XI-11-71 XI-16-71	11.2 11.0
29	12	1967-1971	13.0 - 17.0	15.1	16.7	XI-10-71 XI-15-71	13.5 13.6
30	11	1967-1971	0.5 - 1.0	0.9	0.4	XI-10-71 XI-15-71	1.0 1.0
31B	12	1968-1971	16.5 - 32.0	23.5	258.4	XI-10-71 XI-14-71	16.0 18.7
52A	4	1967-1971	6.5 - 10.0	8.4	20.6	XI-11-71 XI-15-71	7.5 7.9
53	4	1967-1971	4.0 - 4.8	4.3	1.6	XI-11-71 XI-15-71	3.5 4.0
26	14	1967-1971	12.5 - 38.0	26.1	440.9	XI-11-71 XI-14-71 XI-16-71	17.9 20.3 19.8
9	15	1967-1971	1.0 - 3.0	1.6	3.1	XI-9-71 XI-15-71	1.5 1.7
10	13	1967-1971	2.0 - 10.0	6.0	39.7	XI-9-71 XI-15-71	3.8 4.3
58B	12	1968-1971	2.0 - 8.0	4.7	5.26	XI-11-71 XI-15-71	3.0 3.0

Increases of a sufficient magnitude, nature, and location to suggest a relationship to Cannikin were observed in the pH of Lakes 9, 33, 42g, 43d, 43f, 43h, 44a, 45 and in the alkalinity of Lakes 9, 33, 42g, 43c, 43e, 43f, 43h, 44a, 44b. This suggestion remains unsubstantiated for the present, however, due to the lack of sufficient data from previous spring periods and the apparent masking effect of the dry weather on subtle changes in water chemistry which may be attributable to Cannikin. All of these lakes with the exception of Lake 9 are within 3.2 km of SZ.

Total Hardness

Total hardness determinations to provide additional data on the water chemistry of Amchitka lakes and streams were conducted for the first time during the spring 1972 period (Table 5). The total hardness of water can be attributed to cations of calcium, magnesium, aluminum, iron, manganese, strontium, and zinc. Except for calcium and magnesium, the concentrations of these cations are usually insignificant in natural water. Therefore, hardness has been defined as a characteristic of water which represents the total concentration of these two ions only (A.P.H.A., 1971). The amount of hardness that is equivalent to the total alkalinity is termed "carbonate hardness" and the amount of hardness in excess of this is termed "noncarbonate hardness". Of the 34 lakes for which hardness data are presented in Table 5, 25 had noncarbonate hardness and Lake 26 had noncarbonate hardness in one of the two samples.

The total-hardness values ranged from a high of 55.0 mg/l in Lake 10 to a low of 10.0 mg/l in Lake 49. Spark-source mass spectrometry data on water from Lake 10 indicates that very little of the hardness was contributed by ions other than calcium and magnesium. Noncarbonate hardness ranged from a low of zero in Lakes 45, 42g, 50c, 28, 26, 196, and 1a to highs of 29.0 and 46.0 mg/l in Lakes 9 and 10, respectively. Noncarbonate hardness values for most lakes were between 5.0 and 15.0 mg/l while most total-hardness values were between 15.0 and 35.0 mg/l.

Specific Conductance, Chlorides, and Solids

In the absence of the typically abundant freshwater inputs from precipitation and snow melt, most of the lakes investigated on Amchitka had increased concentrations of dissolved solids; this fact was reflected in increased values for specific conductance. Of the 18 lakes for which prior spring data existed, 17 had higher specific conductivities than recorded during previous springs. There was no change in Lake 52a. From the 25 lakes where prior spring and/or fall data existed, 13 record high values for specific conductance were observed. In addition, 15 of these lakes had conductivity values higher than those typical of the autumn period. All of the lakes with prior spring data had higher chloride concentrations than during previous springs. The highest chloride concentrations observed during all sampling periods were recorded for 19 of the 25 lakes. Only 5 of the 25 lakes had chloride concentrations comparable to fall values. The remaining 20 lakes were higher.

Samples from 6 lakes were analyzed for total, nonfiltrable, and filtrable residues to provide some data with which to evaluate the relationship between dissolved solids and specific conductance in Amchitka lakes. Since data for specific conductance exists from prior sampling periods, it will be most useful to attempt to establish a factor, if possible, relating these two parameters from the data presented in Table 9 and from future data. The six lakes selected for this analysis are representative of the various lake types found

on Amchitka. Lakes 7 and 30 are acid-brown water lakes with very low alkalinity while Lakes 26, 29, and 31b are near neutral in pH and have alkalinities between 10 and 30 mg/l. Lake 5 is slightly alkaline with pH usually between 8.0 and 9.5 and alkalinities between 50 and 90 mg/l.

TABLE 9. RESIDUE (SOLIDS) ANALYSES FROM SELECTED STATIONS DURING SPRING, 1972(a)

Lake	Total Residue (Total Solids), mg/l	Nonfiltrable Residue (Suspended Solids), mg/l	Filtrable Residue (Dissolved Solids), mg/l	Specific Conductance, micromhos/cm ²	Dissolved Solids Specific Conductivity
5	222.2	19.5	202.8	338	0.60
7	200.2	8.3	192.0	270	0.71
26	62.4	16.3	46.1	65	0.71
29	118.9	3.8	115.1	200	0.57
30	121.1	20.2	100.9	175	0.58
31b	141.0	11.4	129.4	260	0.50

(a) Samples dried at 103-105 C, Millipore filter pore size = 0.45 micron.

There was no apparent relationship in these samples between either pH or alkalinity and total, suspended, or dissolved solids. There is, of course, an inherent relationship between the dissolved-ion content of water and its capacity for conducting an electric current which is measured by specific conductance. An empirical factor may be used to estimate dissolved-ion content from specific conductance by multiplication. Standard Methods (A.P.H.A., 1971) indicates that the factor may vary between 0.55 and 0.90. In Table 9, these factors vary from 0.50 to 0.71 and average 0.61. Additional solids analyses are required to assess these relationships in Amchitka lakes.

Organic Matter

During the autumn of 1971, 26 lakes were sampled for total, particulate, and dissolved organic-matter content prior to the Cannikin event. Total organic-matter concentrations ranged between 1.2 and 59.2 mg/l but total organic-matter concentration exceeded 20 mg/l in only 6 lakes. Particulate organic matter ranged between 0.4 and 56.1 mg/l while the range of dissolved organic-matter concentrations was considerably more narrow ranging from a high of 12.4 mg/l to a low of 0.4 mg/l. Data from previous sampling periods indicate that the concentrations of organic matter may vary considerably between Amchitka lakes and between different sampling periods on the same lake. A statistical summary of the various fractions of organic matter in these samples is presented in Table 10 while the raw data are shown in Table 11.

TABLE 10. STATISTICS FOR ORGANIC-MATTER SAMPLES FROM 26 LAKES ON AMCHITKA DURING OCTOBER, 1971

	Total	Particulate	Dissolved
X	15.6	11.5	4.1
s ²	272.0	256.4	7.7
s	16.5	16.0	2.8

TABLE 11. ORGANIC-MATTER CONCENTRATIONS (mg/l) IN OPEN LAKE WATER DURING AUTUMN 1971 AND SPRING 1972

Lake	Date	Total	Dissolved	Particulate	Lake	Date	Total	Dissolved	Particulate
1	9-20-71	8.1	5.1	3.0	43b	10-18-71	12.3	4.7	7.6
1a	6- 5-72	91.7	25.3	66.4		11-14-71	16.0	3.8	12.2
2	9-20-71	6.7	6.7	0.0		5-25-72	9.5	1.7	7.8
	5-25-72	5.7	2.2	3.5	43c	10-18-71	13.4	5.3	8.1
5	9-20-71	7.4	6.5	0.9		11-14-71	8.9	3.5	5.4
	5-25-72	7.2	1.7	5.5		5-25-72	5.8	1.8	4.0
7	9-20-71	16.9	9.4	7.5	43d	6-5-72	3.2	2.0	1.2
	5-25-72	6.0	2.0	4.0	43e	10-19-72	53.3	5.8	47.5
9	10-17-71	43.6	3.5	40.1		5-28-72	18.5	2.5	16.0
	11-15-71	30.3	4.6	25.7	43f	10-19-71	34.1	7.3	26.8
	5-25-72	13.0	3.3	9.7		5-28-72	6.5	1.2	5.3
10	10-17-71	39.9	5.3	34.6	43h	10-19-71	59.2	3.1	56.1
	11-15-71	15.8	6.5	9.3		5-28-72	28.3	2.4	25.9
	5-25-72	11.0	7.0	4.0	44a	10-20-71	4.6	3.1	1.5
19b	5-29-72	8.2	5.0	3.2			31.1	6.8	24.3
	5-30-72	7.8	4.9	2.9		5-25-72	7.0	2.4	4.6
26	10-20-71	6.0	4.5	1.5	44b	10-19-71	6.9	1.2	5.7
	11-14-71	9.0	8.0	1.0		5-28-72	7.6	5.1	2.5
	5-25-72	4.5	1.0	3.5	45	10-20-71	2.3	1.9	0.4
	5-26-72	6.7	5.1	1.6		11-13-71	9.4	2.1	7.3
28	9-20-71	4.4	4.1	0.3		5-25-72	5.0	0.1	4.9
	5-25-72	5.1	2.0	3.1		6- 3-72	14.0	3.5	10.5
29	10-15-71	8.0	4.7	3.3	46	10-19-71	7.9	1.3	2.6
	11-15-71	8.7	7.0	1.7			6.7	2.6	4.1
	5-25-72	3.0	2.2	0.8		5-25-72	8.3	3.2	5.1
	5-26-72	3.3	1.8	1.5	49	10-20-71	3.9	1.3	2.6
30	10-15-71	22.6	4.3	18.3			6.7	2.6	4.1
	11-15-71	14.0	8.1	5.9		5-25-72	8.3	3.2	5.1
	5-25-72	7.6	2.6	5.0	50a	10-20-71	1.0	0.4	3.6
	5-26-72	6.7	1.5	5.2			7.9	1.7	6.2
31b	10-18-71	-	7.6	-		5-25-72	4.9	2.0	2.9
	11-14-71	5.1	4.5	0.6	50c	10-19-71	5.6	2.1	3.5
	5-25-72	5.0	2.0	3.0		5-28-72	11.0	5.5	5.5
33	10-20-71	5.9	4.1	1.8	51	5-25-72	15.3	12.4	2.9
	5-25-72	6.7	4.0	2.7	52a	10-15-71	4.2	3.0	1.2
	6- 3-72	6.3	-	-		11-15-71	2.8	2.2	0.6
35	5-29-72	1.8	0.5	1.3		5-25-72	10.7	2.8	7.9
36	5-29-72	2.5	0.8	1.7	53	10-18-71	2.9	1.2	1.7
41b	10-20-71	6.3	4.9	1.4		11-15-71	5.1	3.1	2.0
	11-15-71	13.7	4.2	9.5		5-25-72	2.0	0.3	1.7
	5-25-72	13.7	2.5	11.2	58a	10-17-71	1.2	0.8	0.4
42c	10-15-71	19.7	1.8	17.9		11-15-71	2.4	1.5	0.9
42d	10-18-71	8.3	5.6	2.7		5-25-72	2.4	2.2	0.2
42e	10-17-71	15.1	12.4	2.7	Cannikin Sump	6- 5-72	17.4	14.7	2.7
42f	10-17-71	13.3	10.1	3.2	White Alice Lake	6- 5-72	6.9	5.0	1.9
	5-29-72	80.8	0.3	80.5					
42g	10-15-71	8.7	4.2	4.5					
	5-29-72	7.0	5.8	1.2					
	5-30-72	6.7	6.7	0.0					

During October, the mean particulate organic matter in these 26 lakes accounted for about 74 percent of the mean total organic matter in the lake water. Generally, only about one-fourth of the organic matter present in the lakes dissolved. However, as indicated by the variance about the means, the amount of particulate organic matter present in lakes varied considerably. Concentrations of dissolved organic matter were considerably less variable in the lakes sampled.

Organic matter in Amchitka lakes is naturally derived from several sources. Principal allocthonous inputs include organic matter flowing into the lakes in incoming streams where these exist, the addition of materials from the shoreline where wave action is eroding banks, and organics excreted into lake water by waterfowl. Slight contributions, no doubt, result from wind-blown matter entering the lakes. Autocthonous organic matter is produced by primary production of plants and bacteria, decomposition processes, resuspension of organics from surface sediments, and excretion of organic matter by aquatic biota. Increased human activities and man-made disturbances to the Island were generally expected to increase the concentration of particulate organic matter in lakes in localized areas for a short time.

In the October samples, total organic-matter concentrations in excess of 20 mg/l were recorded only from lakes in which plankton was abundant or blooming. Lakes 43f, 43e, and 43h on the Pacific Coast south of SZ were particularly high in concentrations of particulate organic matter as were Lakes 9 and 10 in the Rifle Range area. All of these lakes had rather extensive phytoplankton blooms in progress at the time of sampling. Particulate organic matter in these lakes accounted for between 67 and 95 percent of the total organic matter present.

In contrast, phytoplankton concentrations were extremely low in Lakes 42e, 41b, 45, 49, 50a, 33, 29, 53, and 58a. Concentrations of particulate organic matter recorded from these lakes were below 4.0 mg/l and as low as 0.4 mg/l in Lakes 50a and 58a. Particulate organic matter in these lakes was generally less than 40 percent of the total organic matter present unless the total concentrations were extremely low or nonplanktonic organic matter was suspended in the water. In general, lakes with quantities of plankton between these extremes also had intermediate values for organic-matter concentrations.

Lakes 42e and 42f had the highest dissolved-organic-matter concentrations recorded, 12.4 and 10.1 mg/l, respectively. Both of these lakes are acid, brown-water lakes, with peat substrates and no clearly defined inlet or outlet. Lakes 43b and 30, similar lake types, did not have particularly high concentrations of dissolved organics.

Of the 26 lakes sampled for organic matter during mid-October, 15 were resampled during mid-November following Cannikin. Of these lakes 7 were within a 2.2-km radius of SZ while the other 8 were located 6.3 to 10.0 km from the test site. The first group served as a "close in" group which was expected to demonstrate test-related effects considerably more than the latter group which was considered a control group. The results of the organic matter analyses on these two groups of lakes, pre- and post-Cannikin, are summarized in Table 12.

Prior to Cannikin, there was a considerable difference in the mean particulate organic-matter concentration between the two groups. The mean dissolved organics and their variances were much more similar in the two groups. The particulate mean in the control group was considerably higher than that of the "close in" lake group due to phytoplankton blooms in Lakes 9, 10, and 30. With the adverse change in weather, these

TABLE 12. PRE- AND POST-CANNIKIN ORGANIC-MATTER CONCENTRATION IN LAKES NEAR SZ AND IN A CONTROL GROUP

	Total		Particulate		Dissolved	
	Pre-	Post-	Pre-	Post-	Pre-	Post-
<u>CLOSE-IN LAKES (N-7)</u>						
$\bar{X}$	6.3	13.4	3.6	9.9	3.1	3.5
s^2	23.19	71.92	9.46	47.98	4.20	2.91
s	4.81	8.48	3.07	6.92	2.05	1.70
<u>CONTROL LAKES (N-8)</u>						
$\bar{X}$	16.0	11.0	12.6	5.9	3.4	5.1
s^2	295.77	85.08	268.58	73.36	2.73	6.94
s	17.20	9.22	16.39	8.56	1.65	2.63

plankton blooms crashed by the time the post-Cannikin samples were acquired and this is indicated by a corresponding decrease in the particulate mean. The post-Cannikin increase in the dissolved organics in both lake groups reflects the decomposition processes releasing dissolved organics from decaying plankton populations.

In contrast to the situation in the control lakes, there were no plankton blooms in the "close in" lake group prior to the test. These lakes would also be expected to decrease plankton production with adverse weather, as did the control lakes, and therefore to have had decreased post-Cannikin concentrations of particulate organic matter. That this primary productivity decreased is verified by pre- and postevent primary productivity studies on Lakes 43b and 43c. The postevent mean particulate organics increased, and this increase is interpreted as an event-related change. In the short term, the greatest influx of particulate organic matter was probably from resuspension materials in those lakes with a bottom accumulation of organic material. This is demonstrated by the acidic lakes with peaty bottoms such as 43b and 41b. Lake 43c of the "close in" group, which has a sand silt bottom decreased in particulate organics between sampling dates. These three are standing lakes that do not have incoming streams. The bottom seal of Lake 44a was fractured as a result of the test. Considerable organic particulates were entering this lake in the influent stream. Lakes 43b and 41b in the "close in" group and Lakes 30 and 9 in the control group are similar lake types and illustrate the effect of the test increasing particulate organic-matter concentrations in "close in" lakes as compared with decreasing particulate concentrations in the control group. A plot of the magnitude and direction of the postevent change in particulate organic-matter concentrations in the two lake groups is presented in Figure 4.

Organic-matter concentrations were analyzed in samples acquired from study lakes during late May and early June of 1972. During prior sampling periods, particulate organics have tended to be lower in spring samples than in autumn samples (Birch, 1972).

Data on dissolved and particulate organic matter acquired during the spring of 1972, indicated essentially no change in this parameter in most study lakes from pre-Cannikin data. Normal values were obtained on samples from Lake 44a which had

considerably increased postevent particulate organics. However, Lakes 43b, 45, and 49 did have particulate concentrations greater than pre-Cannikin values. Their proximity to SZ suggests that these increases are event related. Lake 52a also had increased particulate organics but this lake had been used as a water source during the winter and was considerably drawn down. Lake 41b particulates were considerably increased over preevent values and remained about equal to immediate postevent levels. Lake 42f showed the most impact of increased organic particulates of any of the study lakes. Values in this lake were some 10 times higher than preevent levels. This lake is the closest study lake to SZ. Both Lakes 42f and 41b are shallow, peat-bottom, acidic lakes.

FIGURE 4. ABSOLUTE CHANGES IN PARTICULATE ORGANIC-MATTER CONCENTRATIONS POST-CANNIKIN IN LAKES AT VARIOUS DISTANCES FROM SZ

Stream Samples

Water samples were collected from 13 sampling sites on 12 Amchitka streams during the autumn of 1971 and the spring of 1972 (Table 13). The most apparent difference between the data for streams and those for the lakes is the uniformity of the data between streams and between sampling dates. On most streams where data are available from both spring and autumn, the spring values for pH, alkalinity, and specific conductance were slightly higher than recorded in autumn during this FY 1972 sampling program. Excluding Clevenger Creek and Falls Creek where disturbances are known

TABLE 13. CHEMICAL DATA FROM AMCHITKA ISLAND STREAMS

Stream and Sampling Site Coordinate	Date	pH	Alkalinity, mg/ l	Total Hardness (EDTA), mg/ l	Specific Conductance, micromhos/cm ²	Chloride mg/ l	Organic Matter, mg/ l		
							Total	Dissolved	Particulate
Clevenger Lake Inlet 559947	6/ 2	8.00	--	17.5	275	40.4	2.4	1.7	0.7
Jones Lake Inlet 573966	5/ 31/ 72	7.86	35.5	22.5	235	47.0	5.3	4.3	1.0
Silver Salmon Lake Inlet 539988	5/ 30/ 72	7.71	44.5	30.0	255	46.2	5.5	3.2	2.3
Clevenger Creek 511968	11/ 16/ 71 6/ 3/ 72	7.40 8.00	99.0 129.5	-- 35.0	460 505	66.2	3.3	3.0	0.3
Duck Cove Creek 505980	11/ 16/ 71 6/ 3/ 72	7.25 7.81	30.5 37.5	-- 30.0	240 270	51.5	3.0	2.5	0.5
Weed Lake Inlet 526995	11/ 16/ 71 5/ 31/ 72	7.15 7.75	20.7 23.0	-- 20.0	225 200	43.6	7.4	5.3	2.1
Bridge Creek 516017	11/ 15/ 71 6/ 3/ 72	7.39 7.68	38.5 55.5	-- 40.0	235 260	39.7	2.8	1.7	1.1
Strange Lake Inlet 493028	11/ 16/ 71 6/ 3/ 72	7.30 7.43	11.5 16.3	-- 20.0	175 218	42.5	5.5	2.0	3.5
Lake 42G Inlet 481045	5/ 30/ 72	7.75	35.9	25.0	225	44.2	7.4	5.5	1.9
C-Site Area Ck., South Branch 477034	11/ 15/ 71 6/ 3/ 72	6.89 7.79	28.5 38.0	-- 27.5	213 --	38.7	2.0	1.5	0.5
C-Site Area Ck., West Branch 476035	11/ 15/ 71 6/ 3/ 72	7.04 --	40.0 57.5	-- 40.0	240 245	38.0	4.0	2.5	1.5
Lake 45 Inlet 456053	11/ 31/ 71 6/ 3/ 72	6.85 7.84	19.5 28.0	-- 25.0	208 200	41.7	5.8	2.6	3.2
Falls Creek 407085	5/ 30/ 72 6/ 5/ 72	7.73 7.97	-- 71.5	-- 35.0	210 330	39.4	3.2	1.7	1.5

to have occurred, the pH varied between 6.85 and 8.00, alkalinity between 11.5 and 57.5 mg/l, and specific conductance between 175 and 275 micromhos/cm². Spring total hardness varied between 17.5 and 40.0 mg/l. Total organic matter varied between 2.0 and 7.4 mg/l and a higher percentage of this matter was in dissolved form than is usually observed in lakes. Clevenger Creek was disturbed by Milrow and Cannikin, and Falls Creek was perturbed by materials escaping from the D-Site holding pond at Cannikin detonation. Elevated alkalinities and specific conductances in these streams reflect these disturbances.

Six lakes were sampled to gain preliminary information on the variability in chemical parameters between the inlet and outlet streams and open lake water. Lakes 2 and 5 were moderately productive for Amchitka lakes, current productivity data on Lake 33 were not available, and the other three lakes were relatively unproductive. Differences between lake systems, illustrated in Table 14, are, no doubt, largely due to differences in rates of primary production and the influence of unusually low flow in inlet streams during these sampling periods (except on Lake 33). The high rate of flow through Lake 33 during the sampling period rendered it little more than a wide place in the stream.

TABLE 14. OPEN LAKE WATER PRODUCTION AND CHEMICAL PARAMETERS IN THE INLET STREAMS, OPEN LAKE WATER, AND OUTLET STREAMS IN SELECTED AMCHITKA LAKES BETWEEN MAY 26 AND JUNE 3, 1972

Lake	pH	Alkalinity, mg/l	Total Hardness (EDTA) mg/l	Specific Conductance micromhos/cm ²	Chloride mg/l	Organic Matter mg/l			Total Primary Production mg C/m ³ /hr
						Total	Dissolved	Particulate	
2									
Inlet	8.00		17.5	275	40.5	2.4	1.7	0.7	
Open Water	8.94	64.9	25.0	290	44.8	5.7	2.2	3.5	12.7
Outlet	9.14		30.0	280	45.2	8.8	2.2	6.6	
5									
Inlet	7.86	35.5	22.5	235	47.0	5.3	4.3	1.0	
Open Water	8.95	80.5	20.0	330	48.8	7.2	1.7	5.5	14.5
Outlet	9.00	87.0	15.0	335	49.8	10.7	4.7	6.0	
19b									
Inlet	7.71	44.5	30.0	255	46.3	5.5	3.2	2.3	
Open Water	7.64	36.6	32.5	250	47.5	7.8	4.9	2.9	0.8
Outlet	7.66	35.1	30.0	245	47.5	6.3	5.7	0.6	
26									
Inlet	7.75	23.0	20.0	200	47.7	7.4	5.3	2.1	
Open Water	7.65	26.4	27.5	205	43.7	6.7	5.1	1.6	0.7
Outlet	7.74	25.3	32.5	210	43.7	7.8	5.5	4.3	
33									
Inlet	7.43	16.3	20.0	218	42.5	5.5	2.0	3.5	
Open Water	7.54	14.5	30.0	190	42.5	6.3			
Outlet	7.40	15.0	15.0	190	45.0	3.0			
42g									
Inlet	7.75	35.9	25.0	225	44.3	7.4	5.5	1.9	-
Open Water	7.54	28.5	25.0	220	44.3	6.7	6.7	0.0	1.2
Outlet	7.50	28.2	25.0	225	44.3	6.5	4.7	1.8	

The uptake of carbon dioxide by photosynthesizing organisms in Lakes 2 and 5 resulted in an increase in pH in the open lake water and the outlet streams of these lakes. The productivity is also reflected in the increasing particulate organics as the water flows through these lakes. With additional sampling, a relationship between rates of productivity and differences in particulate organic matter between inlet and outlet streams could no doubt be defined (Koob, 1971).

Increasing concentrations of dissolved organics in Lake 19b between the inlet and outlet, and decreasing pH suggest that processes resulting in organic matter being broken down by bacterial action were dominating this system at the time the samples were acquired. Additional analyses on these systems will be conducted during the autumn, 1972, to better define these relationships.

Trace Elements

Mass spectrographic analyses were performed on water samples collected from three lakes on November 10, 1971, to provide data on the trace elements present in Amchitka lake water. The results of these analyses are presented in Table 15. The elemental composition of the lake water is presented in micrograms per liter, about equivalent to parts per billion (ppb). The notation "high" in the table for the elements sodium, magnesium, aluminum, silicon, chloride, potassium, and calcium indicates that the concentration of these elements was in excess of the upper limits of quantitative detection for these elements in this type of analysis.

Lake 10, with a mean pH of 6.62 and mean alkalinity of 6.0, is a very productive lake located near the Pacific coast at the Rifle Range area. Lake 45, located 1.27 km north of Cannikin SZ, with a mean pH of 7.08 and a mean alkalinity of 15.6, is a moderately productive lake. Lake 58b, a very unproductive lake, is located in the middle of the Island at the foothills of the mountainous region. It has a mean pH of 6.64 and a mean alkalinity of 4.7.

Additional work on trace elements is planned for FY 1973. Comment and evaluation of the data in this report will be elaborated on in the FY 1973 annual progress report.

Biological Parameters

Plankton

Preevent plankton population densities were generally low in most intensive-study lakes, which is typical for the late-autumn sampling period. Phytoplankton densities were very low in most lakes throughout the investigation. However, phytoplankton was blooming in Lakes 9, 10, 43c, 43e, 43f, 43h, 44a, and 44b. Blue-green algal species were blooming in Lakes 9 and 10; blooms in other lakes were composed of mixed green and diatom species.

Zooplankton counts during the study period are presented in Tables 16 and 17. Rotifers dominated the zooplankton population densities in most intensive-study lakes throughout the sampling program. However, a relatively high number of cladocerans were present in Lakes 10, 42e, 42f, and 43b which are all acidic lakes. The zooplankton populations were generally decreasing throughout the sampling program and were considerably reduced in the postevent samples compared with preevent concentrations. These changes appear to be related to weather conditions and the advancing season. There was no apparent relationship between changes in density of zooplankton populations in the intensive-study lakes and the proximity of the lakes to SZ.

Copepod adults and/or nauplii were collected from every lake sampled during FY 72. Copepod densities were low in samples from most lakes but Lakes 1, 7, 43b, and

TABLE 15. CONCENTRATIONS (mg/l) OF TRACE ELEMENTS
IN THREE AMCHITKA LAKES

Element	Lake			Element	Lake		
	58a	45	10		58a	45	10
Li	1.	1.	0.6	Cd	<0.3	≤0.4	≤0.6
Be	<0.005	<0.002	<0.003	In	<0.3	<0.1	<0.6
B	10.	4.	10.	Sn	<1.	<0.4	<0.6
F	50.	20.	30.	Sb	<0.5	<0.2	<1.
Na	High	High	High	Te	<0.2	<0.06	<0.2
Mg	High	High	High	I	10.	1.	10.
Al	500.	High	50.	Cs	<0.5	<0.2	<1.
Si	High	High	High	Ba	7.	7.	3.
P	5.	30.	6.	La	<0.5	<0.2	<0.3
S	1000.	2000.	1500.	Ce	<0.5	<0.2	<0.3
Cl	High	High	High	Pr	<0.1	<0.06	<0.1
K	High	High	High	Nd	<0.5	<0.2	<0.3
Ca	High	High	High	Sm	<0.1	<0.06	<0.1
Sc	<0.2	<0.6	<3.	Eu	<0.03	<0.2	<0.3
Ti	3.	30.	<20.	Gd	<0.1	<0.04	<0.06
V	0.5	6.	3.	Tb	<0.1	<0.2	<0.3
Cr	1.	1.	1.	Dy	<0.1	<0.1	<0.1
Mn	15.	6.	20.	Ho	<0.1	<2.	<0.3
Fe	25.	1000.	50.	Er	<0.1	<0.1	<0.2
Co	<3.	<1.	<2.	Tm	<0.5	<0.06	<0.06
Ni	<2.	≤3.	<1.	Yb	<0.4	<0.4	<0.6
Cu	3.	2.	<10.	Lu	<0.5	<0.2	<0.3
Zn	≤2.	6.	≤5.	Hf	<0.2	<0.06	<0.3
Ga	<0.4	<0.4	<6.	Ta(a)	<50.	<2.	<6.
Ge	<2.	<1.	<3.	W	<0.1	<0.1	<0.1
As	≤0.5	≤2.	≤3.	Re	<0.1	<0.2	<0.3
Se	<1.	<1.	<3.	Os	<0.4	<0.4	<0.4
Br	400.	400.	600.	Ir	<0.4	<1.	<2.
Rb	2.	10.	10.	Pt	<0.2	<0.2	<0.2
Sr	20.	100.	100.	Au	<0.5	<0.2	<0.3
Y	<1.	<0.4	<0.6	Hg	<0.2	<0.2	<0.2
Zr	<0.6	<0.6	<0.6	Tl	<0.1	<0.1	<0.1
Nb	<0.3	<0.1	<0.2	Pb	2.	0.4	0.2
Mo	<2.	<2.	<3.	Bi	<0.04	<0.04	<0.04
Ru	<0.3	<1.	<2.	Th	<0.05	0.5	0.5
Rh	<0.2	<0.1	<0.2	U	<0.1	0.5	0.5
Pd	<0.3	<0.1	<0.2				
Ag	<0.2	<0.1	<0.1				

(a) Contamination from tantalum electrode holders.

TABLE 16. ZOOPLANKTON POPULATION CONCENTRATIONS
OF CANNIKIN-EFFECTS INTENSIVE-STUDY LAKES
(ORGANISMS/LITER)

Lake	Date	Adult Rotifers	Rotifer Eggs	Cladocerans	Adult Copepods	Copepod Nauplii	Total Zooplankton
1	5-24-72	269	70	1	3	178	521
	5-25-72	52	15	1	1	25	94
	6- 1-72	215	63	3	5	185	471
1a	6- 5-72	1149	1238	1	1	8	2397
2	5-24-72	36	20	3	18	38	115
	5-25-72	17	3	1	3	53	77
	6- 1-72	178	108	1	25	28	340
5	5-24-72	1389	48	1	8	3	1449
	5-25-72	2497	338	18	5	100	2958
	5-31-72	1262	140	13	20	70	1505
7	5-25-72	153	43	0	78	153	427
9	10-17-71	48	15	5	0	0	68
	10-22-71	280	30	0	0	0	310
	10-30-71	1200	575	0	0	0	1775
	11- 9-71	25	8	4	0	0	37
	5-25-72	440	125	10	3	75	653
	6- 2-72	295	38	20	10	48	411
10	10-17-71	15	10	3	0	0	28
	10-22-71	117	34	0	0	0	151
	10-30-71	575	225	250	0	0	1050
	11- 9-71	333	279	237	0	0	849
	5-25-72	4784	68	30	5	48	4935
	6- 2-72	3092	113	38	18	83	3344
19b	5-29-72	8	3	1	1	1	14
	6- 3-72	8	1	1	1	1	12
26	10-20-71	140	30	5	0	0	175
	10-30-71	155	18	0	0	0	173
	11-11-71	25	5	0	0	0	30
	11-14-71	5	0	0	0	0	5
	5-25-72	69	18	0	0	5	92
	5-31-72	101	40	3	5	1	150
28	5-25-72	65	15	3	3	10	96
	6- 3-72	11	3	1	3	3	21
29	10-15-71	8	0	0	0	0	8
	10-24-71	20	0	0	5	3	28
	10-31-71	10	3	0	0	0	13
	11-10-71	0	0	0	5	0	5
	5-25-72	24	3	0	0	5	32
	6- 2-72	81	20	1	1	1	104
30	10-15-71	38	5	3	3	23	72
	10-24-71	43	3	0	3	23	72
	10-31-71	20	0	0	15	28	63
	11-10-71	13	13	0	13	13	52
	5-25-72	81	13	0	5	100	199
	5-31-72	96	3	1	15	70	185
31b	10-18-71	28	10	0	0	0	38
	10-23-71	3	8	0	0	0	11
	10-30-71	18	5	0	0	0	23
	11-10-71	0	0	0	0	0	0
	11-14-71	0	0	0	3	0	3
	5-25-72	27	3	1	5	3	39
	6- 1-72	14	10	1	8	10	43
33	10-20-71	8	0	0	0	0	8
	10-30-71	3	0	0	0	0	3
	11- 9-71	18	8	0	3	0	29
	5-25-72	47	8	1	5	8	69
35	5-29-72	61	15	3	1	3	83
36	5-29-72	34	1	3	3	15	56
41b	10-20-71	15	10	0	0	5	30
	10-31-71	18	18	0	0	0	36
	11- 9-71	20	3	0	0	0	23
	5-25-72	129	58	1	3	15	206

TABLE 16. (Continued)

Lake	Date	Adult Rotifers	Rotifer Eggs	Cladocerans	Adult Copepods	Copepod Nauplii	Total Zooplankton
42c	10-15-71	103	20	0	8	13	144
	10-22-71	65	15	3	5	13	101
	11- 1-71	3	0	0	3	10	16
42d	10-18-71	73	18	0	15	5	111
	10-22-71	60	28	0	0	0	88
	11- 1-71	63	45	0	0	0	108
	11- 4-71	0	0	0	13	0	13
42e	10-17-71	3	3	108	3	0	117
	10-24-71	35	8	15	0	5	63
	11- 1-71	18	13	28	0	0	59
	11- 9-71	200	200	100	0	0	500
42f	10-17-71	10	8	30	5	0	53
	10-23-71	88	10	85	13	0	196
	11- 1-71	18	3	100	48	0	169
	11- 9-71	48	3	75	8	5	139
	5-29-72	55	15	60	58	73	261
42g	10-15-71	8	0	3	3	8	22
	10-31-71	3	0	0	0	0	3
	11- 9-71	0	0	0	0	0	0
	5-29-72	117	13	18	5	8	161
	6- 3-72	116	58	1	1	13	189
43b	10-18-71	13	15	53	8	10	99
	10-23-71	3	0	30	15	3	51
	11- 1-71	5	0	30	35	5	75
	11- 4-71	60	0	150	40	0	250
	11- 9-71	0	0	13	15	3	31
	11-14-71	0	0	0	8	5	13
	5-25-72	18	15	3	20	65	121
43c	10-18-71	50	0	10	0	0	60
	10-23-71	38	3	0	0	0	41
	11- 1-71	25	3	0	0	0	28
	11- 9-71	10	13	0	0	0	23
	11-14-71	0	0	0	0	0	0
	5-25-72	178	23	0	8	3	224
43d	6- 3-72	129	28	3	1	15	176
	6- 5-72	23	15	25	85	20	168
43e	10-19-71	350	50	25	0	0	425
	11- 3-71	175	63	0	0	25	263
	11-10-71	25	25	0	0	0	50
	5-28-72	65	18	3	5	10	101
43f	10-19-71	40	20	10	5	0	75
	11- 3-71	23	63	0	0	0	86
	11-10-71	29	8	0	8	13	58
	5-28-72	61	23	3	3	8	98
43h	10-19-71	275	100	75	0	25	475
	11- 3-71	200	110	0	20	0	335
	11-10-71	56	50	0	25	31	162
	5-28-72	63	35	1	1	10	110
44a	10-20-71	18	0	0	0	0	18
	11- 1-71	20	3	5	3	0	31
	11- 9-71	0	6	6	0	0	12
	5-25-72	79	8	1	5	3	96
44b	10-19-71	83	67	0	0	0	150
	11- 3-71	33	17	0	0	0	50
	11-10-71	38	25	0	13	13	89
	5-28-72	63	13	1	1	3	81
45	10-20-71	20	3	0	0	0	23
	11- 1-71	78	35	0	0	0	113
	11- 4-71	50	0	0	0	0	50
	11- 9-71	8	0	0	0	0	8
	5-25-72	151	23	1	5	30	210

TABLE 16. (Continued)

Lake	Date	Adults Rotifers	Rotifer Eggs	Cladocerans	Adult Copepods	Copepod Nauplii	Total Zooplankton
49	10-20-71	60	20	0	0	0	80
	11- 3-71	10	0	0	0	0	10
	11- 4-71	76	46	0	0	0	122
	11- 9-71	45	13	0	0	0	58
	5-25-72	89	20	1	3	13	126
50a	10-20-71	70	8	3	0	0	81
	10-31-71	55	25	0	0	3	83
	11- 9-71	57	13	0	0	2	72
	5-15-72	5	1	1	1	1	9
50c	10-19-71	125	0	0	0	50	75
	11- 3-71	113	30	0	3	0	146
	11-10-71	25	0	0	50	50	125
	5-28-72	155	45	8	1	5	214
51	5-25-72	6	1	5	1	3	16
52a	10-15-71	18	0	0	0	0	18
	10-31-71	28	10	0	0	0	38
	11- 9-71	20	4	0	0	0	24
	5-25-72	17	3	1	3	53	77
53	10-18-71	8	0	0	0	3	11
	11- 3-71	23	3	0	0	0	26
	11- 9-71	4	0	0	0	0	4
	5-25-72	38	8	0	0	15	61
58a	10-17-71	3	0	0	0	3	6
	10-24-71	3	0	0	0	8	11
	10-30-71	15	8	3	0	3	29
	11- 9-71	0	0	0	4	12	16
	5-25-72	6	3	3	0	5	17
	6- 1-72	13	3	1	5	1	23

TABLE 17. ROTIFER POPULATIONS OF AMCHITKA LAKES, SPRING, 1972

Lake	Date	Keratella Cochlearis	Keratella Quadrata	Polyarthra	Asplanchna	Synchaeta	Filinia	Other Species	Total Rotifers	Percent of Total Zooplankton
1	5-24-72	10	150	38	23	23	20	5	269	51.6
	5-25-72	3	18	20	--	3	--	8	52	55.3
	6- 1-72	30	110	35	15	--	10	15	215	45.6
1a	6- 5-72	--	18	--	908	--	5	218	1149	47.9
2	5-24-72	--	20	--	3	--	8	5	36	31.3
	5-25-72	--	3	5	3	3	--	3	17	22.1
	6- 1-72	3	78	3	13	3	73	5	178	52.3
5	5-24-72	40	1343	--	3	--	--	3	1389	95.9
	5-25-72	88	2125	8	15	8	80	173	2497	84.4
	5-31-72	73	1095	--	13	3	75	3	1262	83.8
7	5-25-72	78	5	45	20	0	0	5	153	35.8
9	5-25-72	18	113	195	40	23	13	38	440	67.4
	6- 2-72	25	55	200	13	--	8	10	295	71.8
10	5-25-72	73	4525	98	15	--	75	3	4784	96.9
	6- 2-72	65	2573	290	13	--	133	18	3092	92.5
19b	5-29-72	--	--	5	--	--	3	--	8	57.1
	6- 3-72	--	3	--	--	--	--	5	8	66.7
26	5-25-72	18	0	25	0	3	18	5	69	75.0
	5-31-72	15	0	23	25	5	20	13	101	67.3
28	5-25-72	5	45	5	10	--	--	--	65	67.7
	6- 3-72	3	5	3	--	--	--	--	11	52.4
29	5-25-72	0	3	13	3	5	0	0	24	75.0
	6- 2-72	0	25	28	5	3	0	20	81	77.8
30	5-25-72	0	0	0	70	0	0	11	81	40.7
	5-31-72	10	0	0	83	0	0	3	96	51.9
31b	5-25-72	0	3	13	3	5	3	0	27	69.2
	6- 1-72	0	5	0	0	3	3	3	14	32.6
33	5-25-72	15	3	23	0	0	3	5	47	68.1
35	5-29-72	23	0	18	5	10	0	5	61	73.5
36	5-29-72	18	0	3	0	5	0	8	34	60.7
41b	5-25-72	70	3	35	13	0	0	8	129	62.6
42f	5-29-72	15	8	3	0	3	3	33	55	21.1
42g	5-29-72	3	40	5	13	35	13	8	117	72.7
	6- 3-72	3	55	20	3	0	20	15	116	61.4
43b	5-25-72	15	0	0	3	0	0	0	18	14.9
43c	5-25-72	95	10	20	30	10	0	13	178	79.5
	6- 3-72	58	0	23	10	10	0	28	129	73.3
43d	6- 5-72	0	0	0	13	0	0	10	23	13.7
43e	5-28-72	20	0	10	15	5	0	15	65	64.4
43f	5-28-72	18	0	20	20	0	3	3	61	62.2
43h	5-28-72	15	0	5	3	15	10	15	63	57.3
44a	5-25-72	0	33	3	15	8	5	15	79	82.3
44b	5-28-72	5	0	25	5	0	18	10	63	77.8
45	5-25-72	15	10	83	25	5	0	13	151	71.9
49	5-25-72	28	3	40	10	3	0	5	89	70.6
50a	5-15-72	0	0	0	5	--	0	0	5	55.6
50c	5-28-72	5	8	63	18	13	35	13	155	72.4
51	5-25-72	0	3	3	0	0	0	0	6	37.5
52a	5-25-72	0	3	5	3	3	0	3	17	22.1
53	5-25-72	3	15	15	0	0	0	5	38	62.3
58a	5-25-72	3	0	0	0	0	0	3	6	35.3
	6- 1-72	0	8	5	0	0	0	0	13	56.5

50c had relatively high concentrations of these organisms. At least three or more species of copepods are present in Amchitka, but resources have not permitted enumeration of these organisms by species. A species of red copepod has been collected from some of the lakes and has been particularly abundant in samples from Lakes 42f and 43b. Copepods were absent in the autumn samples from Lakes, 9, 10, 26, 41b, 43c, 43e, 45, 49, 50a, 52a, and 53 and were very rare in Lakes 31b, 42e, and 58a.

An intensive effort to study cladoceran distribution on Amchitka could likely produce interesting ecological data. As shown in Table 16, FY 1972 cladoceran density was very low in most study lakes at the time of sampling. None of these organisms were taken from Lakes 7, 42d, and 53. Cladocerans were abundant in samples from Lakes 10, 42e, 42f, and 43b; moderate numbers were taken from Lakes 5 and 43h. The four lakes in which particularly high numbers of these organisms were observed were all acidic, brown-water lakes. Other similar lake types did not have high cladoceran densities, however. While enumeration of these organisms has not been partitioned into species, there are at least three different species of cladocerans in the Amchitka lakes that have been studied.

Primary-Productivity Investigations

Primary-productivity investigations were conducted on 13 lakes during the autumn of 1971 and 18 lakes during the spring of 1972 (Table 18). During the autumn, water from all 13 lakes was analyzed prior to Cannikin and primary-productivity analyses were repeated on 3 of these lakes following the test. Three of the lakes (42c, 42d, 42e) were drained by the detonation and subsidence. Additional data on primary productivity in Amchitka lakes has been reported in Birch (1972), Gordon (1969), and Koob (1968, 1969, 1971).

Total carbon-fixation values from the 16 autumn analyses varied from a high of 21.3 mg C/m³/hr in Lake 10 to a low of 0.3 mg C/m³/hr in Lake 30. Dark fixation in the analyses varied between 0.38 and 0.03 mg C/m³/hr. The acidic, brown-water lakes had the lowest rates of carbon uptake in the absence of light. Excluding Lake 1a, total carbon fixation in the spring investigation ranged from a high of 14.5 mg C/m³/hr in Lake 5 to a low of 0.3 mg C/m³/hr in Lakes 29, 43d, and 58a. For the 10 lakes sampled during both autumn 1971 and spring 1972, autumn productivity values were higher than spring values in 6, lower in 3, and about equal in 1 (Lake 26).

Total rates of carbon fixation decreased between 77 and 50 percent in Lakes 31b, 43b, and 43c in the postevent analyses. It is impossible to state whether this was an effect of Cannikin or of the severe change in weather between analysis dates. Experience and the relatively unchanged values for carbon fixation of the spring 1972 data compared with all preevent data suggest that this decrease is attributable to the change in weather.

Both the autumn 1971 and spring 1972 rates of carbon fixation in Lakes 1, 5, 29, 42f, 43b, 43c, and 58a were very comparable to those documented in previous years. Primary productivity data on Lakes 5, 29, and 58a are particularly consistent for all analyses between 1968 and 1972. Lake 9, in the Rifle Range area, had increased total productivity during the spring analyses of 1970 and 1971 following Milrow. The value of 4.0 mg C/m³/hr recorded during spring 1972 is consistent with pre-Milrow spring values from this lake.

TABLE 18. RATES OF CARBON FIXATION BY PHYTOPLANKTON DURING AUTUMN 1971 AND SPRING 1972

Lake	Date	pH	Alkalinity, mg/l	Carbon Fixation, mg C/m ³ /hr		
				Total	Dark	Net
1	6-1-72	8.47	65.3	9.54	0.70	8.24
1a	6-5-72	10.43	36.7	119.81	0.14	119.67
2	6-1-72	8.94	64.9	12.68	0.77	11.91
5	5-31-72	8.95	80.5	14.50	0.45	14.05
9	10-22-71	6.47	1.7	5.50	0.09	5.41
	6-2-72	6.95	4.7	3.97	0.12	3.85
10	10-22-71	6.58	4.5	21.27	0.38	20.89
	6-2-72	7.22	9.8	1.93	0.13	1.80
19b	6-4-72	8.00	50.0	0.85	0.52	0.33
26	11-14-71	7.11	20.3	0.62	0.24	0.38
	5-31-72	7.65	26.4	0.69	0.14	0.55
28	6-4-72	7.66	26.1	1.86	0.26	1.60
29	10-24-71	7.24	15.5	0.60	0.28	0.32
	6-2-72	7.45	13.0	0.29	0.14	0.15
30	10-24-71	6.07	0.7	0.30	0.03	0.27
	5-31-72	5.92	0.7	0.76	0.04	0.72
31b	10-23-71	7.35	20.0	2.63	0.33	2.30
	11-14-71	7.21	18.7	0.61	0.29	0.32
	6-1-72	7.58	20.5	1.26	0.25	1.01
42c	10-22-71	5.94	1.0	1.98	0.18	1.80
42d	10-22-71	7.57	37.0	0.87	0.21	0.66
42e	10-24-71	6.33	2.5	1.60	0.13	1.47
42f	10-23-71	5.40	0.3	0.74	0.04	0.70
	6-2-72	5.30	0.2	2.12	0.05	2.07
42g	6-4-72	7.75	32.3	1.18	0.27	0.91
43b	10-23-71	5.66	0.5	0.82	0.05	0.77
	11-14-71	6.21	1.1	0.39	0.03	0.36
	5-31-72	5.93	1.2	1.26	0.05	1.21
43c	10-23-71	6.90	9.8	2.22	0.24	1.98
	11-14-71	6.61	7.5	0.93	0.15	0.78
	6-4-72	7.47	17.3	1.09	0.13	0.96
43d	6-5-72	5.73	0.5	0.35	0.04	0.31
58a	10-24-71	6.54	3.0	0.42	0.14	0.28
	6-1-72	6.73	2.9	0.29	0.06	0.23

Lake 10, also in the Rifle Range area, had increased productivity values during the spring and autumn of 1971, but a relatively low value for this lake ($1.9 \text{ mg C/m}^3/\text{hr}$) was observed during spring 1972. Values observed in Lakes 26 and 30 during autumn 1971 and spring 1972, and the spring 1972 value from Lake 28 were all lower than previously recorded values from these lakes. The spring 1972 rate of production in Lake 31b was consistent with values from spring sampling during 1968, 1969, and 1970. The spring 1971 value in this lake was slightly increased to $7.2 \text{ mg C/m}^3/\text{hr}$. In summary, no effects attributable to Cannikin were detected in the rates of primary production in selected intensive-study lakes. Lakes 9 and 10 (which were apparently affected by Milrow) had rates of production consistent with pre-Milrow analyses and lower than all post-Milrow analyses, respectively.

Primary-productivity analyses were conducted on Lake 1a during the spring of 1972. This lake is located a short distance behind the main camp area and receives the effluent from the sewage-treatment holding ponds which serve the camp. Input of nutritious materials to this lake is undoubtedly high, and its high rate of primary production ($119.67 \text{ mg C/m}^3/\text{hr}$) suggests that primary productivity rates many times higher than those observed in most Amchitka lakes might be obtainable in the Amchitka environment were it not for a deficiency of nutrients.

Additional Disturbances Due to Support Activities

Most of the disturbances to freshwater lakes that could be attributed to the detonation of Cannikin and the formation of the subsidence crater resulted in subsurface sediment material being recirculated in the water column, changes in the chemical or solids content of water entering the lakes due to disturbances of tundra mats and exposure of new subsurface materials in drainage basins, and partial or complete drainage of lakes. These changes were suggested in most cases through changes in water-chemistry parameters but can be expected to cause changes in the biological communities consistent with the degree of the specific disturbance.

A number of lakes were disturbed by activities associated with drilling test holes and support requirements. Lake 1a (coordinates 562927) and the stream draining this lake have received tremendous nutrient burdens by virtue of the effluent from the sewage aeration pond flowing into the lake. The effects of this input to the lake are strikingly evidenced by changes in chemical and biological parameters. The rate at which this system will move toward its preoccupation status will largely depend on how quickly nutrients are naturally flushed out of the lake.

Perturbations to two lakes resulted from their use as water sources for use in transport and storage of drilling mud and materials. A large water pump was positioned on the north shore of Lake 50a (coordinates 445053) prior to Cannikin to supply water to C-Site. While severe drawdown was never observed, oil and fuel spilled into the lake during the pumping operation. Disturbing the near-shore sediments readily resulted in the formation of a oily surface film in the area of the disturbance. During the winter of 1971-1972, water was pumped from Lake 52a (coordinates 415086). While no oil was observed in the lake, it was very severely drawn down during May, 1972. Several lakes which flowed into Lake 52a were completely drained as a result of this water removal. No doubt, the abnormally low volume of water entering the lake naturally during the spring complicated this situation. Changes in the water chemistry of the water remaining in this lake were noted during the spring sampling period.

The entry of drilling mud and associated materials into three lakes has seriously altered their chemical, physical, and biological characteristics. During the winter of 1970-1971, drilling mud was pumped into Fourteen Mile Lake (coordinates 435063) for storage. This lake was, for all practical purposes, eliminated as a freshwater habitat for Amchitka freshwater biota for the foreseeable future due to the effects of these materials. The materials in this lake ultimately flowed through two smaller ponds (coordinates 432064 and 432065) and entered an intensive-study lake, Emerald Lake (Lake 51). From Lake 51, the materials flowed downstream to enter the Pacific at coordinates 413050. The entry of these materials into Lake 51 had increased the alkalinity to 27.7 mg/l by spring 1971 from 5.0 mg/l during the same week of the preceding spring. pH had increased from 6.67 to 7.03 during the same period. The most serious detriment, no doubt, resulted from increases in suspended solids and the influx of oily materials which covered the bottom substrate. No living plankton or benthic organisms could be found in the southern end of the lake during the spring of 1971. By November, 1971, the pH was 7.24 and alkalinity 16.7 mg/l. This was further altered to a pH of 6.84 and alkalinity of 6.5 mg/l a year later in May, 1972. No living benthos was collected from the sampling station but phytoplankton was present. Because it received only a somewhat diluted slug of drilling materials, this lake should recover within a few years. A third lake (coordinates 405088) at D-Site, having received drilling mud and materials numerous times, has been rendered temporarily useless as an aquatic habitat. These materials have entered the lake from the holding ponds on the site and have also drained into Falls Creek.

EFFECTS OF CANNIKIN ON MILROW INTENSIVE-STUDY LAKES

For Milrow conducted on October 2, 1969, 16 lakes were intensively studied in the limnology program to determine the effects of testing activities on freshwater lakes. The shorter term results of these studies were described by Koob (1971). These lakes have been revisited and sampled at approximately 12, 18, 24, and 30 months after Milrow to determine if there is evidence of long-term effects on these systems and/or evidence of disturbance to these lakes as a result of Cannikin. Longer term effects and recovery were described by Birch (1972). The Milrow intensive-study lakes included Lakes 1, 2, 5, 7, 9, 10, 26, 28, 29, 30, 31b, 33, 35, 36, 51, and 58a. Lakes 7, 9, 10, 26, 29, 30, 31b, 33, 51, and 58a were also Cannikin intensive-study lakes.

As a result of the Milrow detonation, two lakes were partially drained (24 and 25) and a third (31b) incurred multiple short-term effects (Koob, 1971). Subsequent recovery of Lake 31b and the possibility of longer term subtle shifts in chemical and biological parameters in the lakes in the Rifle Range Point area were reported by Birch (1972).

No new disturbances to any of the Milrow intensive-study lakes resulting from Cannikin were observed during the period of study covered by this report. The increases in pH and alkalinity in Lakes 9 and 10 reported previously were very apparent in the spring 1972 samples. These increases were, no doubt, enhanced by the lack of precipitation prior to the time these samples were acquired. These parameters would be expected to slowly return to their original status in the absence of further disturbances in their drainage basin.

REFERENCES

- American Public Health Association. 1971. Standard Methods for the Examination of Water and Wastewater. 13th ed. American Public Health Association, New York. 874 pp.
- Birch, T. J. 1972. Amchitka Bioenvironmental Program. Limnology of Amchitka Island, Alaska. Annual progress report for FY 1971. Battelle Memorial Institute, Columbus Laboratories, U.S. AEC report BMI-171-145. 38 pp.
- Gordon, K. R. 1969. Amchitka Bioenvironmental Program. Primary productivity and limiting factors in four freshwater ponds on Amchitka Island, Alaska. Battelle Memorial Institute, Columbus Laboratories, U.S. AEC report BMI-171-117. 40 pp.
- Kirkwood, J. B. and R. G. Fuller. 1972. Amchitka Bioenvironmental Program. Bioenvironmental safety studies, Amchitka Island, Alaska; Cannikin D+2 months report. Battelle Memorial Institute, Columbus Laboratories, U.S. AEC report BMI-171-147.
- Koob, D. D. 1968. Amchitka Bioenvironmental Program. The freshwater ecology of Amchitka Island. Battelle Memorial Institute, Columbus Laboratories, U.S. AEC report BMI-171-103. 67 pp.
- Koob, D. D. 1969. Amchitka Bioenvironmental Program. Limnology studies, Amchitka Island, Alaska; annual progress report for FY 1969. Battelle Memorial Institute, Columbus Laboratories, U.S. AEC report BMI-171-124. 33 pp.
- Koob, D. D. 1971. Amchitka Bioenvironmental Program. Limnology studies, Amchitka Island, Alaska; annual progress report for FY 1970. Battelle Memorial Institute, Columbus Laboratories, U.S. AEC report BMI-171-129. 39 pp.
- Neuhold, J. M. and W. T. Helm. 1968. Amchitka Bioenvironmental Program. Freshwater vertebrate and invertebrate ecology of Amchitka Island. Battelle Memorial Institute, Columbus Laboratories, U.S. AEC report BMI-171-104. 60 pp.
- Neuhold, J. M. and W. T. Helm. 1970. Amchitka Bioenvironmental Program. Freshwater vertebrate and invertebrate ecology of Amchitka Island; annual progress report for FY 1969. Battelle Memorial Institute, Columbus Laboratories, U.S. AEC report BMI-171-127. 48 pp.
- Neuhold, J. M. 1971. The lowland stream ecosystem of Amchitka Island, Alaska. Bioscience 21 (12): 683-686.
- Neuhold, J. M. and W. T. Helm. 1971. Freshwater vertebrate and invertebrate ecology of Amchitka Island; annual progress report for FY 1970. Battelle Memorial Institute, Columbus Laboratories, U.S. AEC report BMI-171-133. 16 pp.
- Neuhold, J. M., W. T. Helm, and R. A. Valdez. 1971. Amchitka Bioenvironmental Program. Freshwater vertebrate and invertebrate ecology of Amchitka Island; annual progress report, July 1, 1970 - June 30, 1971. Battelle Memorial Institute, Columbus Laboratories, U. S. AEC report BMI-171-142. 25 pp.

APPENDIX A

WEATHER CONDITIONS ON AMCHITKA DURING
THE SAMPLING PERIODS

APPENDIX A

WEATHER CONDITIONS ON AMCHITKA DURING
THE SAMPLING PERIODS

Weather conditions can have considerable influence on chemical, physical, and biological parameters of freshwater resources. Since Amchitka is considered to have some of the least-desirable weather conditions in the world and since the weather conditions prevailing before, during, and after Cannikin influenced the limnological data collected during this period (as well as data from some of the other effects programs), a brief discussion of selected weather data is presented here.

During the autumn of 1971, the maximum daily air temperatures were generally in the forties and ranged from a high of 48 F to a low of 37 F (Figure A-1). Daily minimum temperatures were between 41 F and 26 F and were typically in the thirties during the period of investigation. The daily temperature range was usually narrow (averaging around 7 degrees F). The highest daily fluctuation observed was 11 degrees and the lowest was 3 degrees. The water temperatures in most Amchitka lakes were influenced considerably by air temperatures. The shallow basins of the lakes and the near-continuous stirring by the wind resulted in rapid changes in water temperature with changing air temperatures. During the study period, there was generally about a 24-hour delay in the maximum effect of changing air temperatures on the water temperatures. Figure A-1 presents maximum and minimum daily air temperatures and average daily water temperatures during the study period. There was a general trend of increasing air and water temperatures during late October. Minimum daily air temperatures dropped sharply during the first 3 days of November (D-5 to D-3) and were followed by corresponding decreases in water temperatures. Air temperatures increased rapidly between D-3 and D-1 (November 5). When a severe storm hit the Island on D-1, air and water temperatures decreased rapidly. There was a warming trend between D+1 and D+2 (November 7 and 8) followed by a rapid drop in air temperatures to the lowest point observed during the autumn study period. Ice formed on the surface of the smaller ponds on D+7 (November 13) and there was ice covering most lakes by D+9 (November 15). Ice cover on some lakes was 2 inches thick by D+9.

Most other weather parameters were also variable. It was typically windy, with gusts of variable speed, during the period of investigation. The stirring action of the wind kept the lakes well mixed during the study period. Visibility was very poor on an average of about 1 out of 4 days, and the quantity and frequency of precipitation was increased during the last few days of October and the first few days of November compared with the earlier records (Figure A-2). A detailed account of meteorological conditions on Amchitka from D-2 through D+7 is presented in Appendix B of the D+2 Months Report.

The violent storm which swept Amchitka on D-1 (November 5, 1971) was very detrimental to the limnology program in that it masked possible effects of Cannikin. Hurricane-force winds, gusting over 90 mph, produced extensive damage to Island facilities and severely agitated the lakes stirring liberal quantities of bottom sediments into the water. Considerable amounts of water were blown out of some lake basins. Air temperatures decreased rapidly during the storm, and precipitation totaled 0.47 inch. Some effects of a much-less-severe storm on Amchitka lakes included decreased water temperatures, increased suspended and dissolved solids, decreased pH and alkalinity, and decreased plankton concentration (Birch, 1972).

FIGURE A-1. 24-HOUR MAXIMUM AND MINIMUM AIR TEMPERATURES AND AVERAGE DAILY WATER TEMPERATURES - AMCHITKA, ALASKA

FIGURE A-2. 24-HOUR PRECIPITATION (WATER EQUIVALENT) AT AMCHITKA

During the spring sampling period, there were two clear days with sunshine (May 29th and June 2nd). The sky condition on other days varied between scattered cloud cover and dense fog. Fog reduced the visibility to 1/2 mile or less on 7 of the 15 days of the sampling period. The visibility recorded at the Amchitka tower ranged between 50 miles and 1/4 mile during the 15 days. Wind speed was between 12 and 20 knots on most days and the maximum daily wind speed ranged from 17 to 42 knots during the period. The wind was from the southwest except for a portion (May 26th).

The maximum daily temperatures ranged between 39 and 59 F while the daily minimum ranged between 31 F and 39 F. The maximum daily temperature range was 20 degrees and the minimum, 5 degrees. The average daily temperature range during the sampling period was 10 degrees.

The only significant precipitation during the study period was rain on May 3 and 5, 1972. While most of the lake water levels in intensive-study lakes were just slightly lower than normal, numerous ponds in scattered locations over the entire Island surface were either partially or completely dry. Figure A-3 presents precipitation data from Amchitka during 1970, 1971, and a portion of 1972. Considerably less precipitation fell on the Island between January and May of 1972 than during the same

FIGURE A-3. PRECIPITATION (WATER EQUIVALENT) BY MONTH DURING THREE YEARS AT AMCHITKA AIRSTRIP TOWER

period of 1971. While total precipitation through May, 1972, was 10.12 inches, 15.68 inches fell on Amchitka through May, 1971. February and May, 1972, were particularly dry months for Amchitka. Heavy precipitation during July, 1972, brought the year total (22.91 inches) to a quantity equal to the January through August period (22.62 inches) during 1971. Total precipitation during calendar year 1971 was 39.48 inches and during 1970, 45.07 inches.