DISPOSAL OF SOLID ALUMINUM PROCESS WASTES IN THE OCEAN

by

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CONTENTS

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I. Introduction

Reynolds Aluminum Company, Longview, Washington, has requested permission from the Portland District, U. S. Army Corps of Engineers, to dump solid aluminum process wastes at one of three localities in the Pacific Ocean near 125° W. longitude, 46° N. latitude. These sites are approximately 40 miles off the mouth of the Columbia River and are shown on Fig. 1, which is an overlay from U.S.C.G.S. chart no. 6002.

This report discusses the probable disposition of the material to be dumped.

II. Material and Dumping Schedule

One-hundred seventy-five thousand tons of accumulated material, Kelly residue, is to be dumped at a rate of 1000 tons per day within a one-year period beginning about July 1, 1968. This material is generated at the rate of 18,000 tons per year and the company proposes to dump each annual accumulation within a one-month period.

In addition to the Kelly residue, the company wishes to dump another material, lime mud, generated at the rate of 8,600 tons per year, within an 8-day period each year at the 1000 tons per day rate.

Detailed chemical and physical characteristics of each material as provided by the Corps of Engineers are given in Tables 1, 2, and 3.

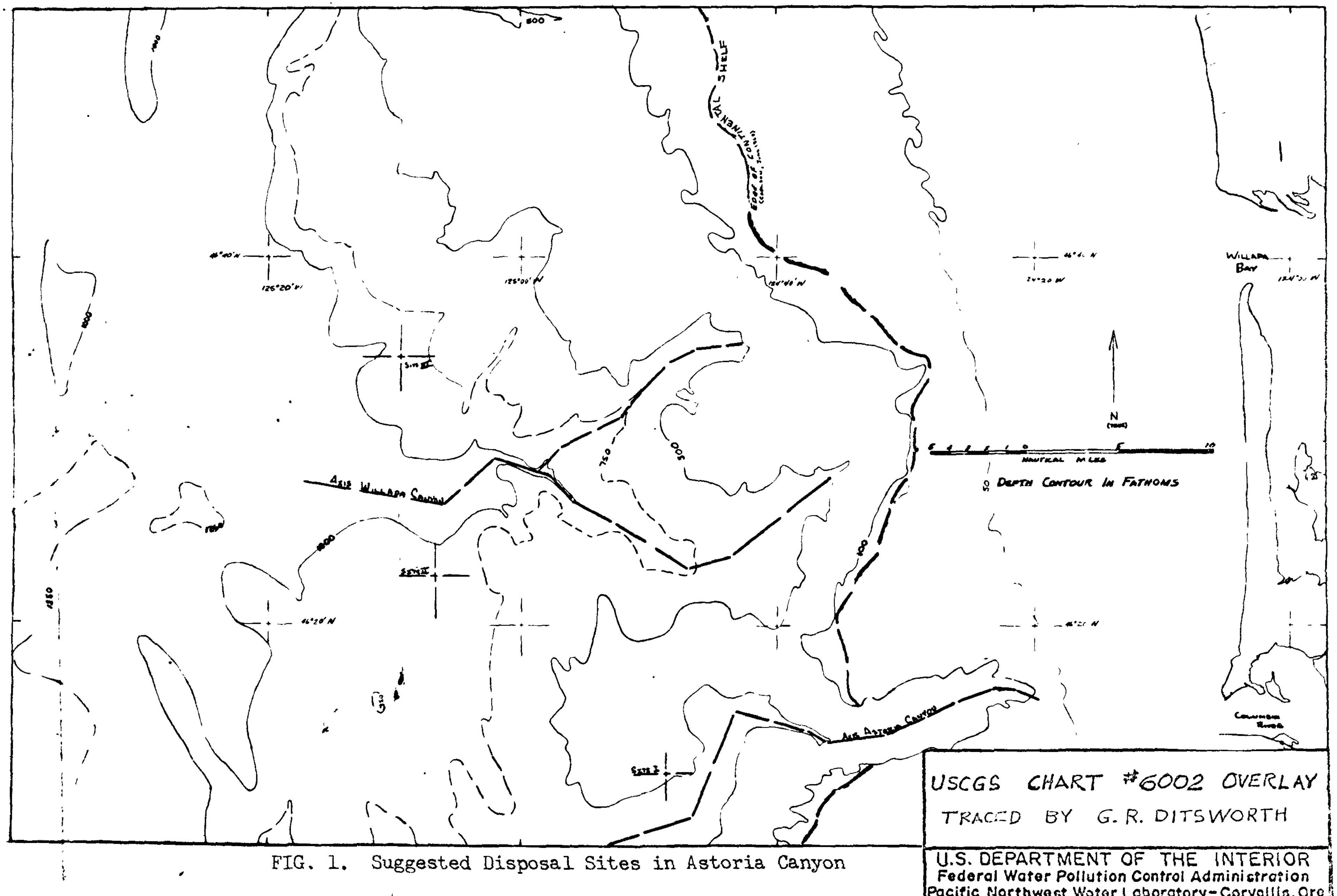


FIG. 1. Suggested Disposal Sites in Astoria Canyon

TABLE 1

DESCRIPTION OF WASTE MATERIALS

Material: Kelly Residue

Chemical Analysis			Sieve Size	
Component	Wt. %		Tyler Mesh	Cum. % Retained
Carbon	35		65	6.0
Water	12		100	13.7
Al_2O_3	35		150	22.6
Na_3AlF_6	3.5		200	29.3
CaF_2	8		Pan	
Fe_2O_3	1.5			
SiO_2	5			
	100			

Particle Density: 168 pounds per cu. ft. (Sp. Gr. - 2.7)

Settling Rate: 3.5 feet per hour in calm sea water at 50°F.

Location of Stockpile: SE end of Reynolds Metals Company property, Longview, Washington, between spurs of Northern Pacific Railway

Size of Stockpile as of 7-1-67: 175,000 tons

Rate of Generation: 18,000 tons per year

Proposed Dumping Schedule: 1,000 tons per day; 20,000 tons per month until stockpile is depleted, beginning about 7-1-68 and ending about 7-1-69. Thereafter, the annual generation of 18,000 tons can be disposed of in less than one month at 1,000 tons per day.

TABLE 2

KELLY RESIDUE

LABORATORY ANALYSIS			WEIGHTED VALUES			
Sample	CN⁻, ppm		Area Represented, Sq. Ft.	Fraction of Total Area	Weighted Values, ppm CN⁻	
	Total	Free			Total	Free
1	1.06	0.89	9,375	0.0675	0.07155	0.06008
2	1.78	1.23	8,200	0.0590	0.10502	0.07257
3	2.20	1.94	7,025	0.0506	0.11132	0.09816
4	1.63	0.62	7,250	0.0522	0.08509	0.03236
5	1.67	0.59	15,025	0.1082	0.18069	0.06384
6	6.38	0.84	10,000	0.0720	0.45936	0.06048
7	3.12	0.90	10,000	0.0720	0.22464	0.06480
8	4.44	3.10	10,010	0.0721	0.32012	0.02235
9	29.48	13.38	10,060	0.0724	2.13435	0.96871
10	3.52	0.66	10,000	0.0720	0.25344	0.04752
11	2.68	1.32	14,625	0.1058	0.28354	0.13966
12	1.65	0.57	10,125	0.0729	0.12028	0.04155
13	1.10	0.53	7,850	0.0565	0.06215	0.02995
(Avg. 14-17 to find A)						
14	103.07	47.89				
15	98.12	44.48				
16	78.50	49.87				
17	2.47	0.57				
Avg.,A	70.54	35.70	9,375	0.0675	4.76850	2.41330
Sum of 1-13+A			138,920	1.0007	9.18	4.12
					Total	Free

TABLE 3

DESCRIPTION OF WASTE MATERIALS

Material: Lime Mud

Chemical Analysis		Sieve Size	
Component	Wt. %	Tyler Mesh	Cum. % Retained
$CaCO_3$	90	65	4.4
CaF_2	10	100	16.4
	100	150	53.8
		200	88.7
		Pan	100.0

Bulk Density: 88 pounds per cu. ft.

Particle Density: 187 pounds per cu. ft. (Sp. Cr. = 3.0)

Settling Rate: 3.7 feet per hour in calm sea water at 50°F.

Location of Stockpile: Immediate east of Kelly Residue stockpile

Size of Stockpile: zero, as of 7-1-67

Rate of Generation: 8,600 tons per year

Proposed Dumping Schedule: 1,000 tons per day for eight consecutive days each year, beginning about 7-1-68, not on the same days that Kelly Residue is dumped.

III. Pollution Aspects

The cyanide portion of the Kelly residue appears to be of major concern from pollutional considerations. Little information concerning tolerable concentrations in sea water has been found. However, McKee and Wolfe (1963) cite opinions of various investigators that wastes should not be discharged to ocean waters when the resulting HCN concentrations will exceed 0.05 mg/l. This concentration is equivalent to .0488 mg/g in sea water at 32°/oo salinity and 10°C. Cyanide ions in water react, depending on the pH of the system, to form undissociated hydrogen cyanide (HCN). Since this is the form in which the ion is the most toxic, it is appropriate to consider toxicity expressed in relation to the HCN concentration. At a pH of 8, approximately 6.7% is in the form of a cyanide ion (CN^-).

We will presume for the purpose of this analysis that this is to be the maximum allowable concentration of HCN in the area of the discharge of the waste materials. Table 2 shows that the weighted average concentration of free cyanide ion in the accumulated stockpile of Kelly residue is 4.12 parts per million. However, because of the rather large variability in the analyses of the various sections of the stockpile, we would prefer to use for this analysis the average of four analyses in one section of the stockpile which amounted to 35.7 ppm of free CN^-. While this is a considerable over-estimate for the pollutional aspects of the stockpile as a whole, it is not unreasonable to use a value this high to represent possible hazardous conditions of any one particular large load of residue. A 1,000 ton barge load would then contain

71.4 pounds of free CN^-. The equivalent in terms of HCN would be 74 pounds.

IV. Possible Pollution Problems

A. Enroute

Chip barges in the Yaquina River, petrochemical tankers in the Ohio River, and chlorine barges in the Mississippi River have suffered accidental spills or been sunk, with subsequent release of the material to the waterway. There is a distinct possibility that the same type of accident could occur with the transport of the Kelly residue material down the Columbia River to its ultimate disposal site in the ocean. The resulting pollution problem would appear to be more serious for this situation than that resulting from the intentional dumping of the barge at the disposal site. Assuming a relatively low flow of the Columbia River of 123,000 cfs, the uniform distribution of a sunken barge load of 1,000 tons over a period of one hour would produce a concentration of suspended solids of 86 mg/l. Similarly, the concentration of HCN would be about three mg/l.

A more appropriate and precise analysis is provided by a mathematical model of the lower Columbia River considering the effects of diffusion as well as advection and considering that the barge contents would probably be dissolved and redistributed over a much longer period of time. The resulting pollution problem would be most serious at Longview, Washington, and would diminish as the accident site approached the ocean. Unfortunately, the limit of our mathematical model at present is mile 20, and the analysis is carried out for an accidental spill at that location.

Assuming that the barge contents are distributed uniformly for a day and confined to the flow through the south channel of the river (see figure 2) the suspended solids concentration would be about four mg/l, and the concentration of HCN would be about .14 mg/l.

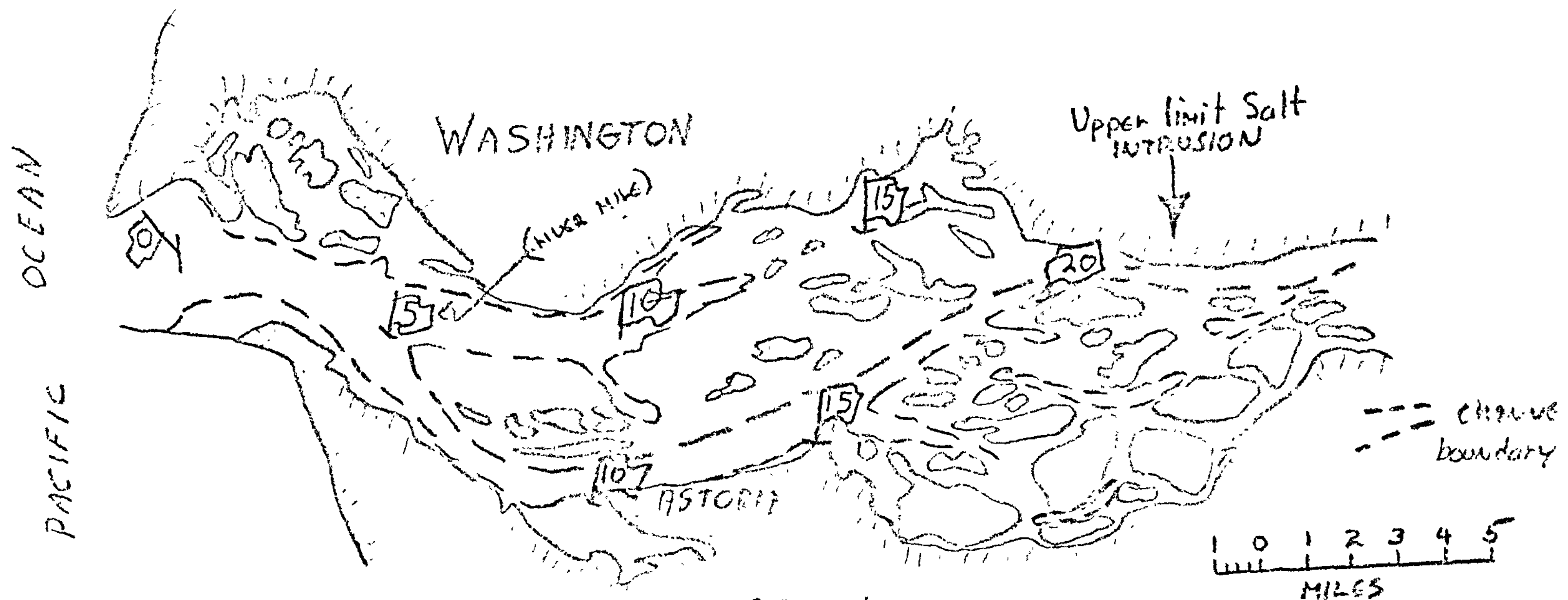
Under similar conditions, but assuming the complete flow of the Columbia River participates in the distribution of the wastes, the concentration would be about .6 mg/l of solids and .02 mg/l of HCN.

Because of the rapid flushing of the Columbia River at this point, these concentrations will be localized to within a few hundred square meters for a period of 1 to 2 hours.

B. At Ocean Disposal Site

Currents in the area are poorly defined and influenced by wind and local bathymetry. Generally, surface currents are northerly in the winter and southerly in the summer. Average velocities of these currents vary from 10 to 20 cm/sec and 5 to 20 cm/sec respectively. (Budinger, Coachman and Barnes, 1964).

Stevenson (1966), using parachute drogues, measured subsurface currents off Newport, Oregon from 1962 to 1965. Mean current velocities in this area were found to be 9.9 cm/sec at 0-10 meters depth, 6.2 cm/sec at 40-60 meters depth, 4.8 cm/sec at 75/150 meters depth and 6.2 cm/sec at 200-250 meters depth. The mean direction of these currents was south-southeasterly.



Columbia River & Main Channels

FIG. 2

No specific information has been found about the nature of the current at the much greater depth found at the suggested disposal site. The current regime on the ocean floor will have an effect on the accumulation of solids if they reach the ocean floor due to sedimentation, while the surface currents will have an effect on the initial distribution of the material as it is dumped from the barge.

1. Transport with Current

When the barge contents are discharged at the disposal site, possible pollution problems may result if the material is finely divided and evenly distributed so that the relatively high surface currents will transport the material, perhaps toward the beaches. If for some reason all of the CN^- were dissolved by the surface waters and retained in the top two meters, distribution over 360,000 square meters would be required to reduce the potential HCN concentration to below 5 mg/l. This represents a circle of radius 340 meters. This is the result which might be expected if sedimentation were governed by the individual particle settling rates as indicated in Tables 1 and 3. However, this behavior is not expected, as the material most probably will be compacted into various size clumps. While there is no exact method of analysis for the resulting sedimentation rate, guidance can be provided by considering two cases which represent the range of likely situations. One is to assume the material is a slurry and settles like a liquid of the same bulk density; the other is to assume all of the barge contents act as a single clump of material which settles in a discrete fashion.

Assuming the material acts as a slurry, it will initially settle with a high velocity due to the large volume of dense material. As it proceeds downward the turbulent boundary between the slurry and the ambient sea water will cause mixing of the two and the creation of a wide, less dense, "cloud" of slurry. As the cloud continues to settle, it will be further diluted by sea water and will decelerate. At a depth ZMAX the cloud will become so dispersed, and the downward velocity will be so degraded, that settling will be determined by the mechanics of the individual discrete particles. ZMAX has been calculated to be 390 meters, and the calculated time of travel to this depth is 99 seconds, according to the method of Morton, Taylor and Turner (1956).

If, on the other hand, the mass acts as a large discrete particle, it will fall with a constant velocity through the water column until reaching the bottom pass ZMAX in 16.5 seconds. Its average settling velocity will be 23.6 cm/sec.

In reality, the material will probably settle in an intermediary fasion between the two discussed.

Surface currents have the most effect in the cloud analysis, causing increased dilution, and will possibly transport some particles away from the main flow of the cloud, which would remain essentially vertical.

2. Bottom Accumulation

If the barges can dump within a one-mile radius of the desired dumping location, the most concentrated possible result on the bottom will be an accumulation of solids with a one-mile radius. Under this assumption the present stockpile of Kelly residue would be represented by an average area distribution of 43 pounds per square meter. The annual production of residue would result in an accumulation of 4 pounds per square meter per year and the lime mud would add another two. If the annual accumulation of 18,000 tons of Kelly residue and 8,600 tons of lime mud were completely dissolved and/or suspended at any one time over this same area, to a depth of one meter, the concentration would be about 3000 mg/l. (Assuming a free cyanide ratio of 20 micrograms per gram, the concentration of HCN would be very near the maximum recommended allowable.) Considering the fact that distribution over another meter would reduce the concentration to one half this value, plus the extreme possibility against its occurrence in the first place, it seems unlikely that a dangerous situation regarding the solids would exist. In considering the HCN danger, it should be pointed out that the concentration would be reduced in time by bacterial decomposition.

According to Fair and Geyer (1954), deposited solids may be lifted from the bottom and transported if theoverlying water has a velocity above a critical value dependent on grain size, frictional resistance, and cohesiveness of the particles. With some assumptions a value of 7.3 cm/sec was computed for an estimated mean grain size of 0.02 mm. The fact that the bottom is much lower than the edge of the continental shelf (80-90 fathoms) in this area (Carlson, 1968) suggests that even if currents of this magnitude occur, scoured bottom material would be subject to considerable additional impediments to transport toward the beach (Sverdrup, Johnson and Fleming, 1942).

Merely as a point of reference, it is noted that New York city disposes of 175,000 tons of sewage sludge annually, by barging to a disposal area 13 miles east of New York Harbor, where the water depth is 30 meters.

IV. Summary and Recommendations

The analysis at hand indicates that acute pollution problems are not likely to occur at the dumping site, but that a short-term problem may arise due to the high HCN concentration associated with an accidental spill of a barge in the Columbia River. Similar disposal situations have not been sufficiently studied to allow precise determination of the fate of the solids or prediction of long-term pollutional effects. In this light the following recommendations are offered:

1) Based upon computed settling rates and apparent effect of horizontal dispersion by currents, it appears that proposed dump site two would be the most favorable. It is in water approximately 900 fathoms (1647 meters) deep and near the mouth of Willapa Canyon, which will cause deep settling material to be funneled further seaward. Also, it is further from the continental shelf than either site one or three. If possible, this recommendation should be reviewed after a hydrographic study to ascertain bottom currents in the area.

2) The CN^- content of each barge load should be determined before departure.

3) Each barge voyage should be forecast and accidental groundings or spills reported to an appropriate monitor.

4) Further study of the sedimentation mechanics of this type of disposal method should be supported with special emphasis on prototype studies.

5) Additional evidence should be sought on the long-term biological effects of low HCN concentrations in sea water.

6) Any permit to dump should be subject to review on the basis of additional evidence provided by the studies recommended.

References

Budinger, T. F., L. K. Coachman, and C. A. Barnes. 1964. Columbia River Effluent in the Northeast Pacific Ocean, 1961, 1962: Selected Aspects of Physical Oceanography. Technical Report No. 99, Department of Oceanography, University of Washington, Seattle, 78 p.

Carlson, P. R. 1968. Marine Geology of Astoria Submarine Canyon. Ph.D. thesis. Oregon State University, Corvallis. 259 p.

Fair, G. M., and J. C. Geyer. 1954. Water Supply and Waste Water Disposal. Wiley, New York. 973 p.

Morton, B. R., Sir Geoffrey Taylor, and J. S. Turner. 1956. Turbulent Gravitational Convection from Maintained and Instantaneous Sources. Proc. Royal Soc. London. Ser. A., 234: pp. 1-23.

McKee, J. E. and H. W. Wolfe. 1963. Water Quality Criteria. State Water Quality Control Board, State of California, Sacramento. 548 p.

Stevenson, M. R. 1966. Subsurface currents off the Oregon Coast. Ph.D. thesis. Oregon State University, Corvallis. 140 p.

Sverdrup, H. U., M. W. Johnson, and R. H. Fleming. 1942. The Oceans. Prentice Hall, Englewood Cliffs, N. J. 1087 p.