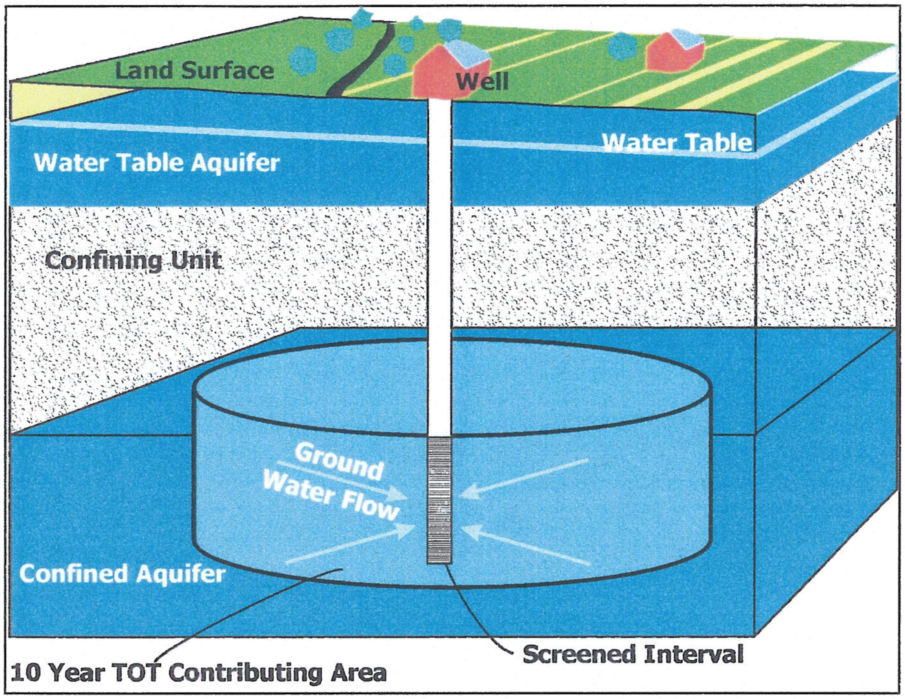
SOURCE WATER ASSESSMENT

FOR TOWN OF OCEAN CITY
WORCESTER COUNTY, MD



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SUMMARY

The Maryland Department of the Environment's (MDE) Water Supply Program has conducted a Source Water Assessment for the Town of Ocean City. The major components of this report as described in Maryland's Source Water Assessment Plan (SWAP) are: 1) delineation of an area that contributes water to the source, 2) identification of potential sources of contamination, and 3) determination of the susceptibility of the water supply to contamination. Recommendations for management of the assessment area conclude this report.

The sources of the Ocean City's water supply are two Coastal Plan confined aquifers known as the Ocean City and Manokin aquifers. Twenty four wells are currently being used to pump the water out of these aquifers. The source water assessment area was delineated by the Water Supply Program using methods approved by the U. S. EPA.

Potential sources of contamination within the assessment area were identified based on MDE site visits, a review of MDE's databases. Well information and water quality data were also reviewed. A map showing the source water assessment areas and potential contaminant sources is enclosed.

The susceptibility analysis for Ocean City's water supply is based on a review of the water quality data, potential sources of contamination, aquifer characteristics, and well integrity. It was determined that Ocean City's water supply is not susceptible contaminants originating at the land surface due to the protected nature of confined aquifers. The water supply is susceptible to naturally occurring iron in the aquifers, chlorides due to salt water intrusion, and triahalomethanes and haloacetic acids which are disinfection by-products.

INTRODUCTION

The Maryland Department of the Environment's Water Supply Program (WSP) has conducted a Source Water Assessment for the Town of Ocean City. The Town of Ocean City is located on a barrier island at the eastern edge of Worcester County. The Town owns and operates its water supply system that serves a year round population of 30,000. Ocean City is a summer resort and the average summer population is estimated to be around 300,000. Currently, the system owns and operates a network of twenty-four wells that pump water for treatment to three water treatment plants located at 15th Street, 44th Street and Gorman Avenue, respectively. In 1977, Whitman, Requardt and Associates (WRA) prepared the Comprehensive Water Supply Study for the Town of Ocean City. The study was updated in 1985, 1991 and 1997. A lot of information presented in this report is taken from WRA's 1997 study.

WELL INFORMATION

Well information was obtained from the Water Supply Program's database, site visits, well completion reports, sanitary survey inspection reports and published reports. A review of the well data and sanitary surveys of the system indicates that thirteen of the wells were drilled prior to 1973, when the State's well construction regulations went into effect, and may not meet current construction standards. The remaining wells should meet construction standards for grouting and casing. According to data provided by Ocean City to MDE during a site visit in 2004, several wells - South Well A, 33rd Street Well G, South Well D and 15th Street Well A, had significant loss in well yield and these wells were being redeveloped to increase the yields. The Town may need to replace Gorman Well B. The 15th Street plant treats water from 11 wells, the 44th Street plant from 6 wells and Gorman Avenue plant from 7 wells. The wells, which are not Gorman Avenue wells, may pump to either of the other water plants. In general, the Town is not using the Manokin Aquifer wells at the 15th Street plant or the 44th Street plant due to the difficulty of blending the Manokin Aquifer water with the Ocean City Aquifer water (high iron vs. low iron, respectively); however these particular wells are available if needed. Table 1 contains a summary of the well construction data.

PLANT CODE	USE CODE	WELL NAME	PERMIT NO	TOTAL DEPTH (ft)	CASING DEPTH (ft)	COMPLETION DATE	AQUIFER NAME
01	P	SOUTH WELL A	WO018528	300	250	1955	OCEAN CITY AQUIFER
01	P	SOUTH WELL B	WO018529	290	253	1967	OCEAN CITY AQUIFER
01	P	SOUTH WELL C	WO650057	345	226	1965	OCEAN CITY AQUIFER
01	S	SOUTH WELL D	WO810615	450	363	1984	MANOKIN AQUIFER
01	P	NORTH DIV ST WELL E	WO941178	312	245	1999	OCEAN CITY AQUIFER
01	P	15TH ST WELL A	WO027645	365	250	1957	OCEAN CITY AQUIFER
01	P	15TH ST WELL B	WO037861	295	248	1960	OCEAN CITY AQUIFER
01	P	15TH ST WELL C	WO670056	325	232	1967	OCEAN CITY AQUIFER
01	S	15TH ST WELL D	WO810615	433	367	1984	MANOKIN AQUIFER
01	P	THIRD ST WELL E		285	231	1996	OCEAN CITY AQUIFER
01	P	28TH ST WELL F	WO940883	312	244	1998	OCEAN CITY AQUIFER
02	P	44TH ST WELL A	WO050667	305	248	1963	OCEAN CITY AQUIFER
02	P	45TH ST WELL B	WO050668	303	248	1963	OCEAN CITY AQUIFER
02	P	42ND ST WELL C	WO690001	322	255	1969	OCEAN CITY AQUIFER
02	P	42ND ST WELL D	WO690002	352	250	1969	OCEAN CITY AQUIFER
02	P	39TH ST. WELL F	WO710080	308	268	1969	OCEAN CITY AQUIFER
02	P	33RD ST WELL G		300	226	1992	OCEAN CITY AQUIFER
03	P	GORMAN AVE WELL A	WO720059	450	340	1972	MANOKIN AQUIFER
03	P	GORMAN AVE WELL B	WO720062	450	339	1972	MANOKIN AQUIFER
03	P	FOUNTAIN RD WELL C	WO730689	430	293	1976	MANOKIN AQUIFER
03	P	141ST WELL D	WO730690	420	320	1976	MANOKIN AQUIFER
03	P	130TH WELL E	WO812433	400	310	1989	MANOKIN AQUIFER
03	P	125TH WELL F	WO880648	402	330	1991	MANOKIN AQUIFER
03	P	120TH STREET WELL G	WO942987	425	342	2004	MANOKIN AQUIFER

Table 1. Town of Ocean City Well Information

Plant Code:

01- 15th Street Plant

02- 44th Street Plant

03- Gorman Avenue Plant

Use Code:

P- Production Well

S- Standby Well

HYDROGEOLOGY

The Maryland Geological Survey (MGS) and the U.S. Geological Survey (USGS) have conducted several hydrogeologic studies in the Ocean City area. Reports of these studies are listed in the references section. Most of this section is from WRA's 1997 report. The barrier island upon which Ocean City is built marks the present easternmost edge of the emerged part of thick wedge of sediments. The wedge forms the Atlantic Coastal Plain, which thickness from a few feet over bedrock over the Fall Line (I-95 is the location) to over 7,700 feet at Ocean City. A generalized cross-section beneath Ocean City and a stratigraphic column for Ocean City are shown in Appendix 1 and 2 of this report. The cross-section shows that layers of sand generally alternate with layers of silt and clay. The sandy unit s form aquifers, while the finer-grained units act as confining layers. The Coastal Plain deposits continue offshore for as many as 70 miles.

The uppermost aquifer is the unconfined Columbia aquifer which is made of the Beaverdam Sand and overlying surficial sediments. Beneath the Columbia aquifer, in order of increasing depth and age, the following aquifers are present: the Pocomoke aquifer, the Ocean City aquifer, the Manokin aquifer and the Choptank aquifer. The Ocean City aquifer and the Manokin aquifer are the aquifers of use for Ocean City. As can be seen from table 1, fourteen of the City's wells are screened in the Ocean City aquifer and nine in the Manokin aquifer. Due to the presence of a leaky confining unit between the two aquifers, they are hydrogeologically connected and may be considered as the Ocean City-Manokin aquifer system. The recharge area for the Ocean City-Manokin aquifer systems is located approximately 25 miles west /northwest of Ocean City. It generally consists of the subcrop area of the Manokin aquifer beneath the Columbia aquifer sediments and is directly recharge vertically by infiltration. The general direction of ground water flow is from the northwest to southeast with a gradient of 1 ft/mile.

The Manokin formation ranges in thickness from 145 to 195 feet beneath Ocean City. It was deposited as a mostly sandy delta which was constructed over the fine-grained continental shelf deposits of the St. Mary's formation during the Miocene Epoch. Transmissivities of the Manokin aquifer ranger from about 2,500 to 10,000 ft^2/day. Coarse-grained sediments typically have higher transmissivities for a given aquifer thickness. The transmissivity of the Manokin is four to ten times higher in the northern part of the Town than the transmissivity in the central and southern parts of the Town. Gamma logs indicate that there are fewer fine-grained internal confining units within the Manokin in the higher transmissivity area.

Overlying the Manokin formation are the "Ocean City Beds" which consist of the sandy Ocean City aquifer, and the associated clayey silts that constitute the confining layers above, below, and within the Ocean City aquifer. The thickness of the Ocean City aquifer beneath the Town ranges from 20 to 100 feet. The Ocean City beds pinch out east of the Manokin subcrop area. The Ocean City beds vary in composition beneath the Town. In the Town, south of approximately 61st Street, the Ocean City beds consist of fine to coarse, grayish-tan and orange-tan sand, with shells (except between 44th and 61st Streets where the shell is generally absent). Between 61st and 100th Streets, the composition of the Ocean City beds changes to gray, shelly glauconitic, fine clayey sand and clayey silt with discontinuous, fine to medium, 10 to 25 foot thick sand units. The muddier Ocean City beds north of 61st Street may be an older delta deposit that was truncated by a younger delta deposit made up of the "cleaner" sands south of 61st Street. North of approximately 100th Street, the Ocean City aquifer becomes discontinuous. Transmissivities of the Ocean City aquifer range from a high of 5,300 ft^2/day at 44th Street to less than 2,700 ft^2/day in the area from 61st to 100th Streets.

SOURCE WATER ASSESSMENT AREA DELINEATION

For ground water systems the Source Water Assessment Area is considered to be the Wellhead Protection Area (WHPA). WHPAs were delineated for the Ocean City wells using the methodology described in Maryland's Source Water Assessment Plan (1999) for confined aquifers in the Coastal Plain, often referred to as the "Florida Method". The area is a radial zone of transport within the aquifer and is based on a 10 year time of travel (TOT), pumping rate and the screened interval(s) of the well or wells included in the SWAA, and the porosity of the aquifer (see illustration below for conceptual model). The Florida Method is a modification of Darcy's Law for radial flow to a well and the SWAA's were calculated using the following volumetric equation:

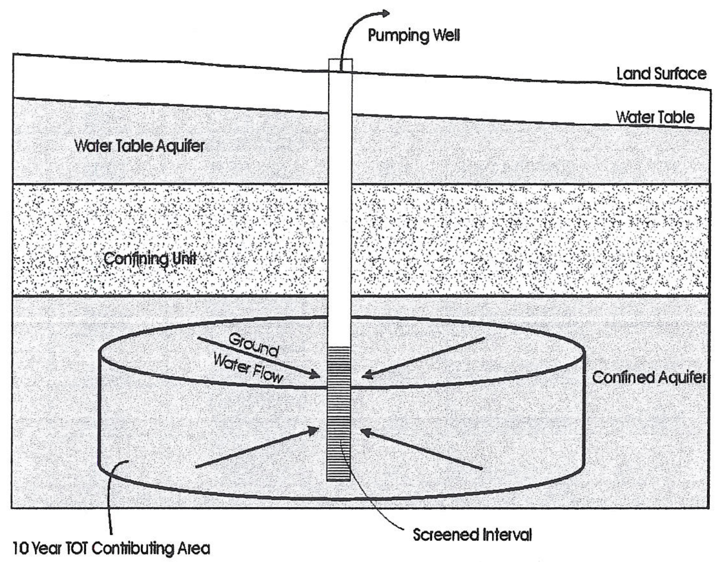
$$r = \sqrt{\frac{Qt}{\pi n H}}$$

where r = calculated fixed radius (ft)
Q = pumping rate of well (ft^3/yr)
n = aquifer porosity (dimensionless)
H = length of well screen (ft)
t = time of travel (yr.)

Ocean City has two water appropriation permits, one for each aquifer. Permit WO1971G005 allows the Town to use a daily average of 3.6 million gallons on an annual basis and 7.9 million gallons a day during the month of maximum use from the Ocean City aquifer. WO1971G105 allows the Town to use a daily average of 4.4 million gallons on an annual basis and 9.7 million gallons a day (mgd) during the month of maximum use from the Manokin aquifer. The two water appropriation permits are supplementary, which allows the Town to use water from either aquifer, provided the total for both aquifers in not exceeded.

In order to determine how much water was being pumped from each aquifer, the system's monthly operating reports for the past two years were reviewed. As indicated earlier, Ocean City summer population is almost 10 times the year- round population. As a result the maximum water use is during the summer months. A review of the monthly operating reports (MORs) for 2003 and 2004 indicated that the highest usage occurred in July. In July 2004 the combined pumpage from both the Manokin and Ocean City aquifers was 10.13 mgd and in July 2003 it was 10.16 mgd. The maximum reported pumpage for the Manokin aquifer was 5.29 mgd in July 2004, and the maximum reported pumpage for the Ocean City aquifer was 5.94 mgd in August 2004. The maximum pumpage for the Manokin aquifer of 5.29 mgd was divided equally between the seven Gorman Ave. wells that are screened in this aquifer. Two other Manokin wells are currently not being used by the system. This resulted in assigning each of these wells a pumping rate (Q) of 755,714 gpd. The maximum pumpage for the Ocean City aquifer of 5.94 mgd was divided equally between the fourteen wells screened in this aquifer. This resulted in assigning each of these wells a pumping rate (Q) of 424,286 gpd. At the time that MDE conducted the field survey for this assessment, one of the wells in the Ocean City Aquifer, the 39th Street Well F, was not in use, and was therefore not included in the calculation for the delineation. Since the total appropriation for the Ocean City Aquifer has not changed, the addition of the 39th Street Well F would not significantly alter the area of the WHPA for Ocean City's 15th Street and 44th Street Plant Wells. Aquifer without the inclusion of this well. A conservative estimate of porosity (n) of 25% was used for each of the aquifers based on published reports. The lengths of the well screen (H) were obtained form well completion reports. In the instance that there were multiple screens, the sum of the individual screen lengths was used. Using these parameters the radius for each well was calculated using the above equation for the WHPA delineation. Table 2 provides the values used and the calculated radius for each well.

The circles for wells in the same aquifer were merged to form one larger WHPA. This resulted in one WHPA for each aquifer as shown in Figures 1 and 2. The circles represent the aquifer zone of transport in the subsurface as illustrated below.



Conceptual illustration of a zone of transport for a confined aquifer

Well Name	Well pumpage (Q) in gpd	Well pumpage (Q) in ft3/yr	Screened interval in feet	Aquifer	Calculated radius for SWAA in feet	Acreage of WHPA	Comments on the WHPA
15TH ST WELL A	424286	19987402.07	36	OCEAN CITY AQUIFER	2700	3185	Circles from the 15th St Plant and 44th St Plant Wells merged
15TH ST WELL B	424286	19987402.07	17	OCEAN CITY AQUIFER	3900		
15TH ST WELL C	424286	19987402.07	27	OCEAN CITY AQUIFER	3100		
THIRD ST WELL E	424286	19987402.07	11	OCEAN CITY AQUIFER	4900		
NORTH DIV ST WELL E	424286	19987402.07	56	OCEAN CITY AQUIFER	2200		
28TH ST WELL F	424286	19987402.07	53	OCEAN CITY AQUIFER	2200		
SOUTH WELL A	424286	19987402.07	35	OCEAN CITY AQUIFER	2700		
SOUTH WELL C	424286	19987402.07	35	OCEAN CITY AQUIFER	2700		
SOUTH WELL B	424286	19987402.07	37	OCEAN CITY AQUIFER	2700		
44TH ST WELL A	424286	19987402.07	46	OCEAN CITY AQUIFER	2400		
45TH ST WELL B	424286	19987402.07	46	OCEAN CITY AQUIFER	2400		
42ND ST WELL C	424286	19987402.07	40	OCEAN CITY AQUIFER	2600		
33RD ST WELL G	424286	19987402.07	52	OCEAN CITY AQUIFER	2300		
42ND ST WELL D	424286	19987402.07	40	OCEAN CITY AQUIFER	2600		
GORMAN AVE WELL A	755714	35600419.46	100	MANOKIN AQUIFER	2200	1416	Circles from the Gorman Ave Plant Wells
GORMAN AVE WELL B	755714	35600419.46	104	MANOKIN AQUIFER	2100		
FOUNTAIN RD WELL C	755714	35600419.46	100	MANOKIN AQUIFER	2200		
141ST WELL D	755714	35600419.46	100	MANOKIN AQUIFER	2200		
130TH WELL E	755714	35600419.46	92	MANOKIN AQUIFER	2300		
125TH WELL F	755714	35600419.46	43	MANOKIN AQUIFER	3300		
120TH STREET WELL G	755714	35600419.46	79	MANOKIN AQUIFER	2400		

Table 2. Parameters used for the Wellhead Protection Area Delineations

POTENTIAL SOURCES OF CONTAMINATION

In confined aquifer settings, sources of contamination at the land surface are generally not a threat unless there is a pathway for direct injection into the deeper aquifer such as unused wells or along well casing that are not intact or have no grout seal. Wells that are not being used or maintained will eventually corrode and provide a pathway for contaminants present in the shallow aquifers at higher-pressure heads to migrate to the deeper aquifers.

Potential sources of contamination are classified as either point or non-point sources. Examples of point sources of contamination are leaking underground storage tanks, landfills, ground water discharge permits, large scale feeding operations and Superfund sites. These sites are generally associated with commercial or industrial facilities that use chemical substances that may, if inappropriately handled, contaminate ground water via discrete point location. Non-point sources of contamination are associated with certain types of land use practices such as the use of pesticides, application of fertilizers or animal wastes, or septic systems that may lead to ground water contamination over a larger area. All potential sources of contamination are identified at the land surface and therefore have the potential to impact the shallow water table aquifer. As long as there is no potential for direct injection into the deeper confined aquifers, Ocean City's water supply should be well protected from ground water contamination.

Potential contaminant sources are identified if they fall within the WHPAs for awareness and to ensure that the deep aquifers do not become affected by unused wells or poorly constructed wells in the water supply aquifers. Table 3 lists the facilities identified from MDE databases, as potential sources of contamination and their locations are shown in figures 1 and 2. Underground Storage Tanks (UST) sites were the only ones identified in the WHPAs. These are facilities that store petroleum or heating oil on site in underground tanks registered with the MDE Waste Management Administration.

ID	Type	Site Name	Address	Potential Contaminant	Status
1	UST	Bridge Texaco	5 North Philadelphia Ave*	VOC	4 tanks
2	UST	White Marlin Marina	205 Somerset St*	VOC	4 tanks
3	UST	Talbot Street Pier	311 Talbot St*	VOC	2 tanks
4	USR	Musa LLC	1206 North Philadelphia Ave*	VOC	4 tanks
5	UST	Worcester Co. Library	200 14th Street*	VOC	1 tank
6	UST	Harbour Island Fuel Dock	419 14th Street*	VOC	2 tanks
7	UST	Seascape Motel	1510 N. Baltimore Ave*	VOC	1 tank
8	UST	Bahia Marina	2107 Herring Way*	VOC	4 tanks
9	UST	Ocean City Amoco #162	4309 Coastal Hwy*	VOC	4 tanks
10	UST	Anderson Exxon	5201 Coastal Hwy*	VOC	3 tanks
11	UST	Greenwood Brothers	5601 Coastal Hwy*	VOC	4 tanks
12	UST	Route 50 Exxon	12827 Ocean Gtwy*	VOC	5 tanks
13	UST	Ocean City Fishing Ctr	12934 Kelly Bridge Ln*	VOC	1 tank
14	UST	Wawa # 550	12502 Ocean Gtwy*	VOC	3 tanks
15	UST	129th Street Sunoco	12900 Coastal Hwy**	VOC	3 tanks
16	UST	Oceans Market	14107 Coastal Hwy**	VOC	2 tanks
17	UST	Shore Stop #127	14400 Coastal Hwy**	VOC	4 tanks

Table 3. Potential Contaminant Point Sources within the Ocean City WHPAs (see figures 1* and 2 for locations).**

WATER QUALITY DATA

Water Quality data was reviewed from the Water Supply Program's database and system files for Safe Drinking Water Act contaminants. The State's SWAP defines a threshold for reporting water quality data as 50% of the Maximum Contaminant Level (MCL). If a monitoring result is at or greater than 50% of a MCL, this assessment will describe the sources of such a contaminant and, if possible, locate the specific sources which are the cause of the elevated contaminant level. All data reported is from the finished (treated) water unless otherwise noted. The treatment currently used at Ocean City is gaseous chlorination for iron oxidation, flocculation, coagulation, sedimentation and filtration for iron removal, pH adjustment for corrosion control, addition of potassium permanganate for taste and odor problems, and final chlorination for maintaining a disinfectant residual within the water distribution system.

A review of the monitoring data since 1993 for Ocean City's water supply indicates that it meets the current drinking water standards. The water quality sampling results are summarized in Table 4.

Plant Name	IOCS		SOCs		VOCs (except THMs)		Radionuclides		Trihalomethanes (THMs)	
	No. of Samples Collected	No. of samples > 50% MCL	No. of Samples Collected	No. of samples > 50% MCL	No. of Samples Collected	No. of samples > 50% MCL	No. of Samples Collected	No. of samples > 50% MCL	No. of Samples Collected	No. of samples > 50% MCL
15th Street	40	0	5	0	9	0	2	0	25	12
44th Street	18	0	5	0	4	0	2	0	8*	2
Gorman Ave	22	0	5	0	8	0	2	0	7	1

*distribution sample

Table 4. Summary of Water Quality Samples for Ocean City's Water Supply

Inorganic Compounds (IOCs)

No IOCs above 50% of the MCL have been detected in Ocean City's water supply since 1993. However, high levels of iron are present in the raw water. There is no MCL for iron but EPA has established a Secondary Maximum Contaminant Level (SMCL) of 0.3 mg/l for aesthetic purposes. Raw water iron levels are typically twice as high from the Manokin aquifer well as from the Ocean City aquifer wells (WRA, 1997). The iron concentration in water from wells serving the 15th Street Plant (mostly Ocean City aquifer) has averaged 1.5 to 3 mg/l. The iron concentration in water from wells serving the 44th Street Plant (mostly Ocean City aquifer) has averaged 3.5 to 6.5 mg/l. The iron concentration in water from wells serving the Gorman Avenue Plant (Manokin aquifer) has averaged 9 to 17 mg/l.

Salt water intrusion to the fresh water aquifers at Ocean City has been of concern for the City and MDE. Fresh water has a chloride concentration of 0 to 250 mg/l, which corresponds to the 250 mg/l SMCL set for chloride. Saltwater intrusion is occurring in three ways in the Ocean City area: intrusion into the Columbia aquifer, upcoming of brackish water in the 44th Street area, and shoreward encroachment. A detailed description and analysis of these factors can be found in the 1997 WRA Report and the MGS study (Achmad and Wilson, 1993). The presence of high salinity in the Columbia aquifer is not a threat to the City well fields except duet to potential migration from improperly constructed wells or wells which are not maintained. Chloride concentrations in Well A at the 44th Street Plant screened in the Ocean City aquifer rose from about 75 mg/l in 1975 to 215 mg/l in 1988. Other wells in at the 44th Street Plant also showed increases in chloride in that time period. The increase in chloride s in the Ocean City aquifer at the 44th Street well field is caused by upcoming of brackish water from the underlying Manokin aquifer. "Upconing" refers to the situation in which a layer of salt water is pulled upward through the overlying layer of fresh water in an aquifer (WRA, 1997). Salt water is present beneath the fresh water aquifers in Ocean City. The trend of rising chlorides in the 44th Street wells correlate with the increase in pumpage from the 44th Street Plant. Upconing of brackish water at the 44th Street well field is caused by the absence of an effective confining unit between the Ocean City and Manokin aquifers in the 44th Street area, and water level (pressure head) differences between the Ocean City and Manokin aquifers caused by pumpage from the Ocean City aquifer. The reduction of pumpage at the 44th Street well field halted the rise in chloride concentrations at the 44th Street well field and the chloride concentrations in Well A had stabilized at 180 mg/l. Based on current monitoring of chlorides by Ocean City, the chloride levels for August 2004 for the 44th Street Plant ranged from 122 to 183 mg/l (appendix 3).

Due to the increasing chloride levels in the 44th Street Plant wells, there was a shift in pumpage to the Gorman Avenue Plant in 1989. This increase in pumpage caused marginal increases in some wells and no changes in the others. The August 2004 chloride monitoring data (see appendix 3) shows chloride levels ranging from 72 to 142 mg/l. The MGS study reported that the principal source of chlorides in the Gorman well field is from the offshore portion of the fresh water- salt water mixing zone. The chloride concentrations in water from wells serving the 15th Street Plant have remained stable through the years. In the mid 1990s due to increased pumping, chloride levels rose slightly, approximately 10 to 20 mg/l. The August 2004 monitoring data (see appendix 2) shows chloride levels ranging from 38 to 70 mg/l.

WRA (1997) has reported that it is likely that there is shoreward encroachment of the fresh water-salt water mixing zone which is caused by pumping from the Ocean City-Manokin aquifer system. MGS (Achmad and Wilson, 1993) analyzed salt water intrusion using computer modeling. WRA (1997) conducted a simplified volumetric analysis of salt water intrusion based on offshore drilling data from a well drilled in 1976, and assuming that a 250 mg/l isochlor (line of equal chloride concentration) is located approximately 2 miles offshore of Ocean City. WRA concluded that both their volumetric calculations and the MGS model show similar results with respect to the shoreward encroachment. Both methods indicate shoreward encroachment at rates between 1 and 2 feet per day towards the well fields.

The rate of shoreward movement of salt water requires further study, modeling and strategic monitoring. Key strategies to minimize the rate of encroachment are water conservation and distribution of pumping along the length of the island. MGS is currently conducting a three-year study to update and revise its 1993 saltwater intrusion model. The study will be completed in 2006.

Volatile Organic Compounds (VOCs)

Trihalomethanes (THMs) and Haloacetic Acids are the only VOCs that were detected above 50% of their MCLs. THMs and Haloacetic Acids (HAA) are disinfection by-products formed as a result of the reaction between chlorine and organic material in the aquifer. The MCL for THMs is 80 ppb and is based on the total detections of four THMs and the average of quarterly samples taken annually. The MCL for the HAAs is 60 ppb and like the THMs is based on the total detections of five acids and the average of quarterly samples taken annually. Table 5 lists the THMs samples that were detected 50% of the MCL and table 6 lists the one sample for HAAs that had a detection above 50% of the MCL.

Plant	Sample Date	Bromodichloromethane (ppb)	Bromoform (ppb)	Chloroform (ppb)	Dibromochlormethane (ppb)	Total THMs (ppb)
Distribution	9-April-96	16.0	2.0	18.0	13.0	49.0
Gorman Ave	15-Oct-97	15.0	4.0	14.0	14.0	47.0
15th Street	6-Mar-00	15.9	1.3	13.2	12.4	42.8
15th Street	12-Apr-00	15.1	1.4	14.7	11.6	42.8
15th Street	11-Jul-00	19.5	2.9	16.7	16.7	55.8
15th Street	12-Oct-00	21.0	4.3	15.9	19.9	61.1
15th Street	9-Apr-01	15.4	1.5	16.6	11.8	45.3
15th Street	14-Jan-01	19.58	2.08	15.5	15.68	51.84
15th Street	9-Apr-02	15.7	1.43	15.9	11.6	44.63
15th Street	1-Aug-02	14.3	1.65	15.7	11.8	43.45
15th Street	24-Oct-02	13.9	0.54	18.8	8.17	41.41
Distribution	8-Jan-03	31.1	7.85	23.3	33.5	95.7
15th Street	5-Aug-03	17.2	1.22	19.7	12.1	50.22
15th Street	7-Oct-03	19.5	1.53	19.8	14.4	55.23
15th Street	11-May-04	18.1	2.0	22.3	15.6	58.0

Table 5. Trihalomethanes detected above 50% of the MCL

Plant	Sample Date	Monochloroacetic acid (ppb)	Monobromoacetic acid (ppb)	Dichoroacetic acid (ppb)	Trichloroacetic acid (ppb)	Dibromoacetic acid (ppb)	Total HAAs (ppb)
15th Street	10-Oct-01	22.57	3.40	3.31	4.77	0.50	34.05

Table 6. Haloacetic Acids detected 50% above the MCL

The above reported values are higher than the typical for Maryland's ground water supplies. Sampling of individual wells for bromide, total organic carbon and total trihalomethane (TTHM) formation potential would help determine the cause and source of the elevated disinfection by-products. Bromide sampling is suggested as it stimulates TTHM formation and is present in brackish water.

Synthetic Organic Compounds (SOCs)

No SOCs above 50% of the MCL were detected in Ocean City's water supply since 1994. Very Low levels of dalapon, decachorobiphenyl, and 3-hydroxycarbofuran have been detected one time in each plant. Low levels of phthalate were also detected few times in the water supply. Phthalate was also detected in laboratory blanks and does not represent the water quality.

Radionuclides

No radionuclides above 50% of the MCL were detected in Ocean City's water supply. Low levels of gross beta radiation have been detected in the water supply.

Microbiological Contaminants

Routine bacteriological monitoring is conducted in the finished water for each community water system on a monthly basis and measures Total Coliform bacteria. Since Ocean City's water supply uses disinfection for its treatment, the finished water data does not give much indication of the quality of raw water directly from the wells. Total Coliform bacteria are not pathogenic, but are used as an indicator organism for other disease-causing microorganisms. A major breach of the system or the aquifers would likely cause a positive Total Coliform result despite disinfection and would require follow-up Total and Fecal Coliform analysis. Since 1997 Ocean City has conducted routine bacteriological sampling 98 times, but no samples had any detections of Total Coliform bacteria.

SUSCEPTIBILITY ANALYSIS

The wells serving Ocean City's water supply pump water from confined aquifers. Confined aquifers are naturally well protected from activity on the land surface due to the confining layers that provide a barrier for water movement from the surface into the aquifer below. A properly constructed well with the casing extended to the confining layer above the aquifer and with sufficient grout should be well protected from contamination at the land surface. Wells that are not being used or maintained will eventually corrode and provide a pathway for contaminants present in the shallow aquifers at higher-pressure heads to migrate to the deeper aquifers. Only direct injection into the aquifers from point sources within the SWAA like underground injection wells or improperly abandoned wells could cause a potential contamination threat to the supply. The information that was used to conduct the susceptibility analysis is as follows: (1) available water quality data (2) presence of potential contaminant sources in the WHPA (3) aquifer characteristics (4) well integrity and (5) the likelihood of change to the natural conditions. The susceptibility of Ocean City's water supply to the various contaminant groups in shown in table 7 at the end of this section.

Inorganic Compound (IOCs)

No IOCs above 50% of the MCL have been detected in the Ocean City water supply. Based on the natural occurrence of iron in the Manokin and Ocean City aquifers that supply Ocean City, and high levels of iron in the raw water, Ocean City's water supply **is** susceptible to iron.

Due to increased pumpage in the 44th Street wells during between 1975 and 1988 chloride levels increased from 75 mg/l to 215 mg/l due to salt water intrusion. These chloride levels in these wells have decreased and stabilized due to transfer the increased to the Gorman Avenue plant wells. The system is currently carefully monitoring the pumpage at each plant and monitoring the chloride levels in the production wells. Based on a study by MGS and volumetric calculations the salt water-fresh water interface is predicted to move towards the well fields at about 1 to 2 ft per year. Based on the above discussion Ocean City's water supply **is** susceptible to chloride.

Due to the naturally protected characteristics of the confined aquifers, the water quality data, and the lack of potential sources of contamination, Ocean City's water supply **is not** susceptible to the other inorganic compounds.

Volatile Organic Compounds (VOCs)

THMs and HAAs have been detected at levels above 50% of the MCL in Ocean City's water supply. These VOCs are disinfection by-products formed as a result of the reaction between organic material and chlorine. Based on the water quality results, Ocean City's water supply **is** susceptible to trihalomethanes and haloacetic acids.

Due to the naturally protected characteristics of the confined aquifers, the water quality data, and the lack of potential sources of contamination in the aquifers, Ocean City's water supply **is not** susceptible to the other volatile organic compounds.

Synthetic Organic Compounds (SOCs)

No SOCs above 50% of the MCL were detected in Ocean City's water supply.

Due to the naturally protected characteristics of the confined aquifers, the water quality data, and the lack of potential sources of contamination, Ocean City's water supply **is not** susceptible to synthetic organic compounds.

Radionuclides

No radionuclides above 50% of the MCL were detected in Ocean City's water supply. Only low levels of naturally occurring radium, radon, gross alpha and gross beta radiation have been detected in Ocean City's water supply.

Based on the water quality data, Ocean City's water supply **is not** susceptible to radiological contaminants.

Microbiological Contaminants

Raw water monitoring for microbiological contaminants is not required of water systems in confined aquifers because they are considered naturally protected from sources of pathogens at the land surface. Routine bacteriological testing for these plants revealed no positive Total Coliform in the water supply. Therefore, Ocean City's water supply **is not** susceptible to microbiological contaminants.

CONTAMINANT TYPE	Are Contaminant Sources present in the WHPA?	Are Contaminants detected in WQ samples at 50% of the MCL	Is Well Integrity a Factor?	Is the Aquifer Vulnerable?	Is the System Susceptible to the Contaminant
Iron	YES*	NO**	NO	NO	YES
Chlorides	YES	YES	NO	NO	YES
Other Inorganic Compounds	NO	NO	NO	NO	NO
Trihalomethanes and Haloacetic Acids	YES	YES	NO	NO	YES
Other Volatile Organic Compounds	NO	NO	NO	NO	YES
Synthetic Organic Compounds	NO	NO	NO	NO	NO
Radionuclides	NO	NO	NO	NO	NO
Microbiological Contaminants	NO	NO	NO	NO	NO

Table 7. Susceptibility Chart for Ocean City's Water Supply

**Naturally occurring in the aquifer*

** *Present in raw (untreated) water*

MANAGEMENT OF THE WELLHEAD PROTECTION AREA

With the information contained in this report, the individual community water systems in Ocean City is in a position to protect its water supply by staying aware of the areas delineated for source water protection. Specific management recommendations for consideration are listed below:

Public Awareness and Outreach

- The Consumer Confidence Report should report should list that this report is available to the general public through their county library, or by contacting the operator or MDE.

Monitoring

- Continue to monitor for all required Safe Drinking Water Act contaminants.
- Annual raw water bacteriological testing is a good check on well integrity.
- Continue to carefully monitor chloride levels and pay special attention to any increase in chloride levels.
- Test individual wells for bromide, total organic carbon, total trihalomethane
- formation potential in individual wells to identify the source of elevated THMS in the water supply and consider well usage and treatment options to reduce these levels.
- Update previous chloride modeling efforts and establish a monitoring program to track the offshore salt water-fresh water interface.

Contaminant Source Inventory Updates

- Conduct a survey of the WHPA and inventory any potential sources of contamination, including unused wells that may not have been included in this report.

Well Inspection/Maintenance

- Work with the County Health Department to ensure that there are no unused wells within the WHPA. An improperly abandoned well can be a potential source of contamination to the aquifer. All unused wells must be abandoned and sealed as per State well construction regulations.
- Water operation personnel should have a program for periodic inspections and maintenance of the supply wells and backup wells to ensure their integrity and protect the aquifer from contamination with special attention for wells predating the 1973 well construction regulations.
- TV the wells for integrity of casings particularly due to elevated chloride in the Columbia aquifer.

Changes in Use

- Water system owners are required to notify the MDE Water Supply Program if new wells are to be added or if they wish to increase their water usage. An increase in use or the addition of new wells may require revision the WHPA.

Prevention Measures

- Continue to work with MDE and Worcester County to ensure that wells drilled for ground heat pump systems do not penetrate into the Ocean City and Manokin aquifers.
- Employ water conservation measures to reduce water demand. Annual water audits are important to identify water leaks in the distribution system.

REFERENCES

Achmad, G. and Wilson, J. M., 1993, Hydrogeologic Framework and the Distribution and Movement of Brackish Water in the Ocean City-Manokin Aquifer System at Ocean City, Maryland, Maryland Geologic Survey Report of Investigations No. 57,125 p.

Maryland Department of the Environment, Water Supply Program, 1999, Maryland's Source Water Assessment Plan, 36 p.

United States Environmental Protection Agency, Office of Ground-Water Protection, 1987, Guidelines for Delineation of Wellhead Protection Areas.

Weigle, J. M., 1974, Availability of Fresh Ground Water in Northeaster Worcester County, Maryland: With Special Emphasis on the Ocean City Area, Maryland Geologic Survey Report of Investigations, No. 24, 64 p.

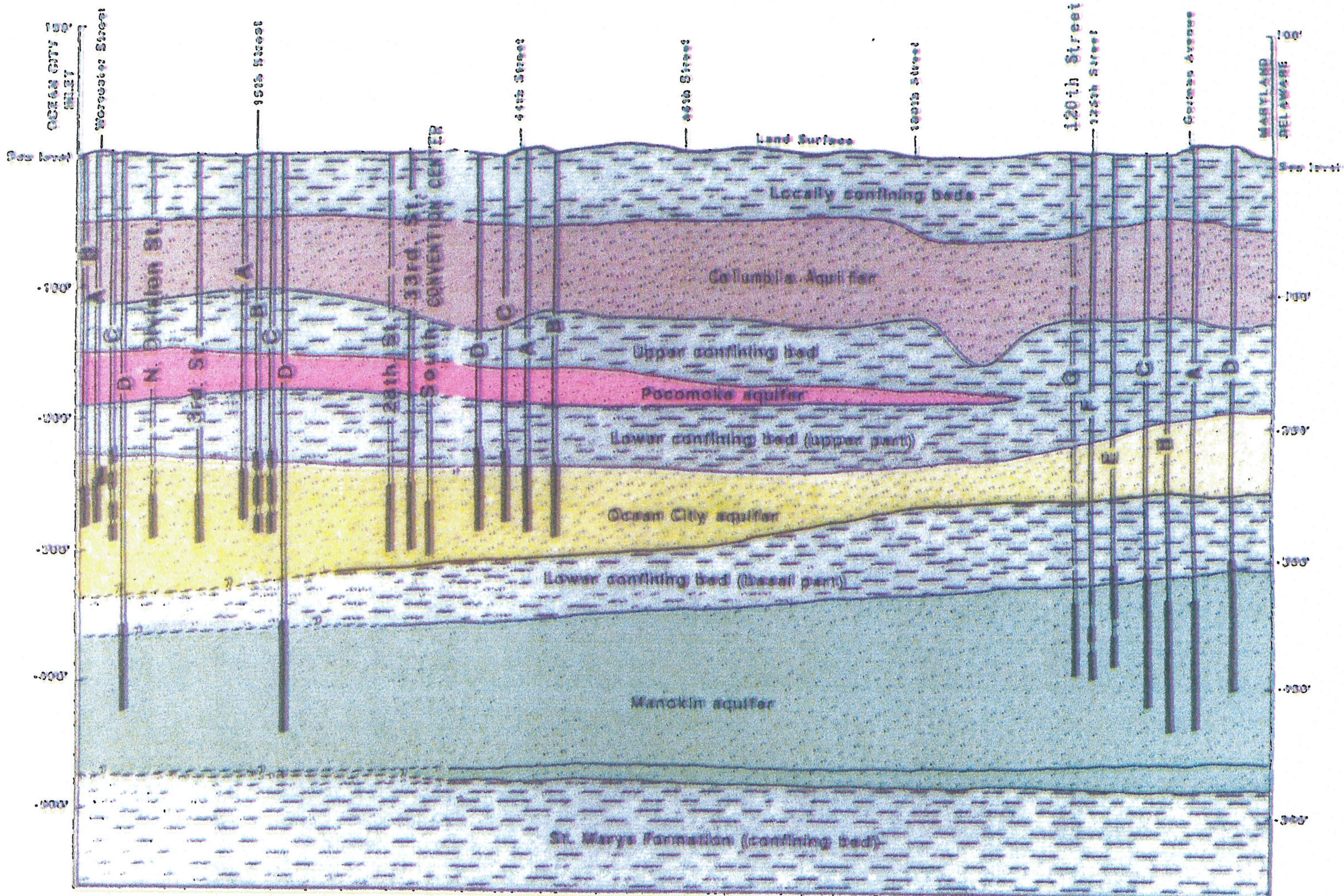
Weigle, J.M., and Achmad, G., 1982, Geohydrology of the Fresh-Water Aquifer Systems In the Vicinity of Ocean City, Maryland, with a Section on Simulated Water-Level Changes, Maryland Geologic Survey Report of Investigations No. 37, 55 p.

Whitman, Requardt, and Associates, 1997, Town of Ocean City, Maryland-Comprehensive Water Supply Study, 1997 Update.

SOURCES OF DATA

Water Appropriation and Use Permit No. WO1971G005, WO1971G105
Public Water Supply Inspection Reports
Monthly Operating Reports
Monitoring Reports
MDE Water Supply Program Oracle Database
MDE Waste Management Sites Database
DNR DOQQs Ocean City and Assawoman Bay (2000)

FIGURES



MODIFIED FROM THE MARYLAND GEOLOGICAL SURVEY,
REPORT OF INVESTIGATION NO.24.

0 ½ 1 2 3 Miles

EXPLANATION

LEGEND

Ex. Well Casing | Ex. Well Screen | Future Well

CONFINING BED clay, silt and fine sand

AQUIFER sand or sand and gravel

WRA

WHITMAN, REQUARDT AND ASSSOCIATES, LLP
Engineers And Planners
Baltimore, Maryland

GEOLOGICAL CROSS SECTION AND WELL FIELDS

COMPREHENSIVE
WATER SUPPLY STUDY
TOWN OF OCEAN CITY, MARYLAND

DATE: OCT.1997 FIGURE NO. 3-2

APPENDIX 1

Table 1.—Generalized stratigraphic column for Ocean City, Maryland

ERA	SYSTEM	SUBSYSTEM	SERIES/STAGE	GROUP	FORMATION/ INFORMAL UNIT	LITHOLOGY	HYDROLOGIC PROPERTIES	APPROXIMATE THICKNESS OF UNIT (FEET)	APPROXIMATE DEPTH TO BASE (FEET)
CENOZOIC	QUATERNARY		Holocene		Recent deposits	Gray to white, fine to medium, shelly sands and dark gray, silty muds.	Generally unsaturated. Permits leakage to underlying units.	20	20
			Pleistocene	COLUMBIA	Sinepuxent	Dark gray, poorly sorted fine to medium sand; more clayey near base.	Unconfined to semi-confined water-table aquifer and leaky confining unit. Water is mostly fresh; some brackish water intrusion from surface.	30	50
	TERTIARY	NEOGENE	? Pliocene		Beaverdam Sand	Light blue-gray to white, and pale orange, fine to coarse and gravelly feldspathic sand.	Semi-confined water-table aquifer; part of the Columbia aquifer. Water is generally fresh; susceptible to brackish water intrusion from surface.	70	120
			?	CHESAPEAKE	Pocomoke beds	Grayish-green to orange brown; fine to coarse sand; some gravels and clayey silts. Lignite, glauconite, and shell bearing in places.	Pocomoke aquifer and associated confining units. Water is fresh.	80	200
			Upper Miocene		Ocean City beds	Fine to coarse, orange tan sands; and greenish gray, glauconite bearing clayey silts and fine sands; lignite and shell bearing in places.	Ocean City aquifer and underlying confining unit. Water is fresh, but subject to upconing of brackish water in places.	125	325
					Manokin	Light gray to orange brown, fine to coarse and gravelly sand and clayey silts and fine sands; shell, lignite, and glauconite bearing in places.	The Manokin aquifer and associated confining units. Contains brackish water in some areas; chlorides range from less than 50 to 1,000 mg/L.	175	500
			?		St. Marys	Light gray to olive gray, fine sand, and silty clay; mica, glauconite, and shell bearing, minor lignite.	Confining unit. Pore water is brackish. Chlorides range from 1,000 to 2,000 mg/L	200	700
			Middle Miocene		Choptank	Light olive gray, fine to coarse sands; shelly, lignite bearing.	Choptank aquifer. Water is brackish. Chlorides range over 2,700 mg/L.	330	1,030
			? Lower Miocene		Calvert	Pale olive gray to pale brown, silty, clays; sands are fine to medium where present; shell fairly common.	Predominantly a confining unit. Water is brackish at Ocean City.	630	1,660
		PALEO-GENE	Oligocene Eocene Paleocene	PAMUNKEY	Undivided at Ocean City	Light olive gray and brown clays; subordinate fine to medium glauconitic sands.	Predominantly a confining unit at the coast.	440	2,100
MESOZOIC	CRETACEOUS		Upper and Lower undifferentiated	INCLUDES POTOMAC	Cretaceous not divided in this report; see Anderson (1948), Hansen and Doyle (1982) for detailed stratigraphy.	Marine clays and glauconitic sands in upper part of section; nonmarine brown, red and gray clays, and sands in lower part of section.	Confining units and aquifers. Water is salty.	5,150	7,250
	Jurassic (?) and/or Triassic (?)				--	Sandstones and shales.	Confining unit	>460	>7,700
Precambrian (?) and Paleozoic					--	Igneous and metamorphic rocks.	Confining unit	?	?

from MGS Report of Investigations No. 57 (1993)

APPENDIX 2

Appendix 3

2004

1-Nov	8-Nov	15-Nov	22-Nov	29-Nov	6-Dec	13-Dec	20-Dec	
								South / A
		37	38		39	39	38	South / B
								South / C
								South / D
								3rd / E
56	53			53				North / E
								15th / A
								15th / B
								15th / C
								15th / D
31	30	32	32	32	30	33	31	28th / F
								44th / A
								45th / B
								42nd / C
								42nd / D
								33rd / G
								Gorman / A
								Gorman / B
								Fountain / C
								141st / D
								120th / G
								125th / F
								130th / E
								E. Biscayne
								Caroline
								25th

2004

023-0003 Town of Ocean City Saltwater Intrusion Monitoring: **CHLORIDE**

	29-Mar	5-Apr	12-Apr	19-Apr	26-Apr	18-May
South / A				38		
South / B			40	38	39	
South / C						
South / D						
3rd / E				37	37	
North / E	58		48			
15th / A						
15th / B	42					
15th / C						
15th / D						
28th / F		30	32	32	32	
44th / A						
45th / B						
42nd / C						
42nd / D						
33rd / G						
Gorman / A						
Gorman / B						
Fountain / C						
141st / D						
120th / G						
125th / F						
130th / E						
E. Biscayne						
Caroline		54				
25th	32					

023-0003 Town of Ocean City Saltwater Intrusion Monitoring: **CHLORIDE**

	2-Aug	9-Aug	16-Aug	23-Aug	30-Aug	7-Sep	13-Sep	20-Sep	27-Sep		Oct	Oct	Oct
South / A										South / A			
South / B	38	50	4[illegible]	40	44	44	41	44		South / B			
South / C	39	48								South / C			
South / D										South / D			
3rd / E	38	48	46	62						3rd / E			
North / E			6[illegible]		60	70	65	62		North / E			
15th / A	53									15th / A			
15th / B		52	4[illegible]	48	52	52	34	75		15th / B			
15th / C										15th / C			
15th / D										15th / D			
28th / F	33		3[illegible]	32	36	36	54	30		28th / F			
44th / A		183								44th / A			
45th / B		120								45th / B			
42nd / C	130		12[illegible]	128						42nd / C			
42nd / D	128	175	136	132						42nd / D			
33rd / G										33rd / G			
Gorman / A	112									Gorman / A			
Gorman / B										Gorman / B			
Fountain / C	106									Fountain / C			
141st / D	80			74	72	76				141st / D			
120th / G										120th / G			
125th / F	76		8[illegible]	74	80	116	84			125th / F			
130th / E	130	130	12[illegible]	130	136	142	142			130th / E			
E. Biscayne										E. Biscayne			
Caroline										Caroline			
25th										25th			