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Guidance for Identification and Evaluation of the Nature and Extent of Pollution from Salt Water Intrusion

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Guidance for Identification and Evaluation of the Nature and Extent of Pollution from Salt Water Intrusion

Introduction

The following sections contain informational guidelines for identifying and evaluating the nature and extent of pollution from salt water intrusion. The circumstances surrounding local salt water intrusion problems vary widely and a uniform "cook book" approach to problem identification and evaluation is not possible. Accordingly, these guidelines are not intended to provide a step-by-step procedure for field reconnaissance or sampling techniques. Knowledge of the existence and delineation of the spatial distribution of waters contaminated by salt water intrusion will serve little useful purpose by itself. If salt water intrusion is to be effectively controlled it must be understood and evaluated in the context of the causal factors within the drainage basin. The intent of these guidelines is to provide a basic framework for assessment of salt water intrusion problems and their relationship to the total hydrologic system, and to aid State authorities in developing areawide waste treatment management plans in

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accordance with the provisions of Section 208 of the Federal Water Pollution Control Act as Amended.

Causes of Salt Water Intrusion

Salt water intrusion whether into surface or ground water is a complex situation controlled by the geologic and hydrologic characteristics of the area. Natural water systems are dynamic. They respond in quality and quantity to natural phenomena and to man's activities such as changes in land use, stream channel linings, and consumptive withdrawal. Identification and evaluation of the nature and extent of salt water intrusion begins with an understanding of the general mechanisms by which intrusion occurs.

Sea Water Intrusion in Coastal Aquifers

Under natural conditions fresh ground water in coastal aquifers is discharged into the ocean at or seaward of the coastline. Where coastal aquifers are overpumped, lowered by natural drainage, or natural recharge is impeded by construction or other activities, the ground water level, whether water table in unconfined aquifers or piezometric surface in confined aquifers, is lowered thereby reducing the fresh water flow to the ocean. The interface between the fresh and saline water has a parabolic form with the saline water tending to underride the less dense fresh water. The reversal or reduction of fresh water flow allows the heavier saline water to move into areas where only fresh water previously existed. Thus, even with a seaward pressure gradient, sea water can advance inland. Because of the high salt content of sea water, as little as two percent of it in fresh ground water will make the water unusable in relation to U.S. Public Health Service drinking water standard for total dissolved solids. Only a small amount of intrusion can have serious implications regarding the future use of an aquifer as a water supply source.

Upstream Encroachment of Sea Water

The interaction of river flow and tidal currents results in a net upstream movement of sea water along the bottom with fresh water overriding this wedge in a seaward direction. The position of the interface between the fresh water and the sea water is dependent on channel geometry, river discharge, and high tide height. A change in any of

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these parameters will cause the salt water/fresh water interface to migrate. The most common causes of upstream encroachment of sea water are deepening of navigation channels, construction of sea level canals, and reduction of stream flow. Reduction of stream flow or deepening of channels results in landward migration of the sea water wedge while increased stream flow results in a seaward migration. Sea water encroachment can contaminate both surface and subsurface water supplies, render fish and wildlife habitats unsuitable for native populations, and through increased corrosion shorten the life expectancy of engineering structures.

Intrusion in Inland Aquifers

Large quantities of saline water exist under diverse geologic and hydrologic environments in the United States. Most of the Nation's largest sources of fresh ground water are in close proximity to natural bodies of saline ground water. Interaquifer transfer of saline waters results from two basic mechanisms. One involves the upward migration of saline waters into fresh water aquifers as a result of man-induced changes in the hydrologic pressure regime. The

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other involves the direct transfer of saline waters vertically through wells or other penetrations. Because of the relatively slow movement of ground water, any saline water intrusion may produce detrimental effects on ground water quality that could persist for months or years after the intrusion has ceased.

Extent of Pollution from Salt Water Intrusion

Salt water intrusion problems are ubiquitous in coastal areas and surprisingly widespread in inland areas. On the highly populated Atlantic Coast, between Massachusetts and Florida, each of the States has reported problems with sea water intrusion. The seriousness of the problem is usually dependent on the intensity of urban and industrial development with its attendant withdrawal and non-return of water.

On the West Coast, California has had many problems with sea water intrusion and has spent considerable effort trying to solve or ameliorate the problem. Approximately two thirds of the conterminous United States are underlain by saline waters containing more than 1,000 mg/l dissolved solids, and the problem of salt water intrusion in inland aquifers can be the same as in coastal areas. Only eight of the fifty States do not report significant salt water intrusion problems.

Identification of Pollution from Salt Water Intrusion

Most intrusion of salt water into fresh water can be ascribed to one of three primary mechanisms: the reversal or reduction of fresh water discharge which allows the heavier saline water to move into an area where only fresh water previously existed; the accidental or inadvertant destruction of natural barriers that formerly separated bodies of fresh and saline waters; or the accidental or inadvertant results of the disposal of waste saline water.

Major elements in an assessment of the occurrence and extent of salt water intrusion should include:

1. spatial delineation of primary aquifers and streams,
2. analysis of historical water quality (salinity) data for suspect areas,

3. establishment of a salinity monitoring network for surface and ground water,
4. monitoring of the fresh water/salt water interface,
5. basin wide hydrogeologic investigations where saline intrusion occurs,
6. identification of causal factors.

Prime areas for consideration should include rapidly developing coastal areas where demands for fresh water result in a reduction or reversal of flow gradient; and areas of coastal waterway or embayment construction, or deepening of navigation channels where natural barriers to salt water flow may be breached. Another prime example of breaching of confining strata is encountered in drilling operations, especially in oil producing areas where salt water may move great distances along broken or corroded well casings or improperly abandonded wells. Not to be overlooked as a source of pollution is any operation that disposes of waste saline waters, whether disposal is directly to surface streams or to the ground water through evaporation pits or other methods.

In other than oil producing areas salt water intrusion is seldom the direct result of waste disposal. More often it is the natural adjustment of the hydrologic system to the many stresses placed upon it. Fundamental to an evaluation of the extent of salt water intrusion is the need for comprehensive hydrogeological investigations of the surface and subsurface water systems. Identification and evaluation of the extent of salt water intrusion should be an integral part of each State's water quality monitoring program required under section 106(e)(1) of the Act, with salinity one of the parameters routinely monitored throughout the water quality network.

As an initial step in the evaluation of the nature and extent of salt water intrusion principal aquifers must be spatially defined, and historical water quality records for both surface and ground waters should be collected and contour maps of salt concentration compiled. In this way, natural or base line conditions can be established and the location of the salt water/fresh water interface can be displayed in relation to the water requirements of the hydrologic basin. Updating of such maps from current monitoring data provides a rapid indication of the advance

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or retreat of the salt water wedge. Under normal conditions monitoring points should be measured for salinity (or total dissolved solids) or checked for electrical conductivity at one to two month intervals. More frequent measurements may be warranted if encroachment is in the proximity of major water supply sources.

Most salt water intrusion problems will be encountered in heavily populated coastal areas. In many cases extensive water quality monitoring programs will have been in effect and will provide most or all of the water quality data required for determining the present extent of salt water intrusion in that area. Salinity measurements of both surface and ground waters should be an integral part of the State's water quality monitoring program and forms the basic data input for continuous evaluation of the extent of salt water intrusion.

An inventory of existing monitoring points for both surface and ground waters which may be used in determining the salinity of streams and principal aquifers should be undertaken by each State, and additional monitoring stations installed as part of the State's water quality monitoring network where necessary for adequate spatial coverage. In situ measurement of electrical conductivity can provide an indication of salt content in surface and ground waters without collecting water samples for laboratory analysis.

Sampling information for each surface or subsurface monitoring station should include:

1. location by latitude, longitude and elevation,
2. stream or aquifer identification and date,
3. depth or depths of samples,
4. stream velocity,
5. temperature,
6. electrical conductivity, TDS, or chloride concentration.

Where a rise in electrical conductivity is noted, samples should be analyzed for increased salinity. Automatic recording devices can be installed for continuous electrical conductivity monitoring, and should be incorporated in the State's water quality monitoring network. Any water samples that are taken for laboratory analysis should be secured and preserved according to standard methods as described in <u>Methods for Examination of</u>

Water and Wastes, (U.S. Environmental Protection Agency, 1971).

Where salt water intrusion in either surface or ground water is suspected or know to exist, a comprehensive hydrogeological investigation should be designed to provide requisite information for planning and control programs. The type of information that may be required could include:

1. the geologic structure of the surface and ground water basins and their boundaries;

2. the nature and hydraulic characteristics of the subsurface formations including:

   a. rock type
   b. degree and type of porosity
   c. permeability
   d. reservoir pressure
   e. degree of hydraulic continuity with surface waters.

3. surface water and ground water levels, and directions and rates of movement and seasonal fluctuations;

4. surface water and ground water quality, particularly natural chlorides content;

5. sources, locations, amounts, and quality of natural recharge;

6. locations, amounts, and quality of artificial recharge;

7. locations and amounts of extractions.

Historical information of this type is generally available, to some degree, in published form from Federal, State, and local agencies that are concerned with water resources. Additional information of this type can be derived from a variety of investigative techniques including but not limited to:

1. geologic reconnaissance,

2. geophysical surveys,
3. examination of well logs,
4. test holes,
5. well pumping tests,
6. measurement of surface and ground water levels,
7. chemical analysis of samples of surface and ground waters,
8. analysis of precipitation and runoff records.

Techniques for predicting the location and extent of salt water intrusion mainly rely on mathematical analysis of aquifer and stream parameters, and tidal characteristics. The level of sophistication and predictive ability of analytical techniques varies from simple extrapolation of the time of arrival of the salt water/fresh water interface at successive observation wells to highly complex numerical models of the entire hydrologic system. Discussion of the application of these techniques is beyond the scope of this report but selected references to detailed explanations are included at the end of the document.

The areal extent and depth of detail of the investigations will vary with the extent of the water basin or aquifer that has been or may be affected, and the present and prospective uses of the water resources. The investigations should be designed to define the water budget of the basin or aquifer in sufficient detail to allow prediction of the volumes and rates of surface and ground water flow necessary to arrest and reverse the salt water advance. Such information will be an integral part of the data base used in basin wide water use planning, management, and pollution control programs.

Evaluation of the Effects of Salt Water Intrusion

Surface and ground waters are integral parts of the same hydrologic whole, changes in the salinity concentration of one will most likely affect the salinity concentration of the other. Ideally the objective of any salt water intrusion control program should be to maintain zero increase in the salinity of fresh water resources. This objective is seldom attainable, however, especially in areas of high water use. Nor is it possible to define a single optimal or tolerable salinity concentration for "fresh

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waters". These concentrations are dependent on the use that is to be made of the water. Water devoid of dissolved materials is intolerable in nature because pure water will not support life. Natural waters contain endless varieties of dissolved materials in concentrations that differ widely from one locality to another as well as from time to time. The chlorides, carbonates, and silicates of sodium, potassium, calcium, and magnesium are generally the most common salts present. Different organisms vary in their optimum salinity requirements as well as in their ability to live and thrive under variations from the optimum.

Any evaluation of the potential effects of salt water intrusion must be performed in the context of its effect on the total dissolved solids of the receiving water and the water use requirements.

Optimal and tolerable salinity concentrations will be different for such uses as: public water supplies, fish and wildlife production, and agricultural uses. Waters with less than about 500 mg/l total dissolved solids are generally considered suitable for domestic purposes, while waters with greater than about 5,000 mg/l TDS generally are unsuitable for irrigation purposes. Maximum salinity concentrations for livestock consumption vary from less than 3,000 mg/l TDS for poultry to as much as 12,000 mg/l TDS for sheep. A more detailed analysis of salinity requirements for various water uses is contained in Water Quality Criteria, (U.S. Environmental Protection Agency, 1972).

Evaluation of the nature, extent and effects of salt water intrusion may vary from simple plots of water quality that indicate the position of the salt water/fresh water interface to sophisticated mathematical models of the entire surface and ground water basin. Such models can be used to predict the response of the salinity concentration to various types of stresses at any point in the system and allow for long-range basin planning and comprehensive intrusion control programs. The degree of sophistication of analysis required will vary in proportion to the complexity of the hydrologic system and the water demands for the area. Regardless of the level of analysis involved the objective of the water quality monitoring and hydrogeologic investigations should always be to relate salt water intrusion to its causal factors. Only in this way can water use planning be accomplished in a manner that will maintain the hydrologic balances necessary to control salt water intrusion.

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