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Municipal shellfish management using GIS

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Municipal Shellfish Management using Geographic Information Systems

Prepared for
Casco Bay Estuary Project

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1.0. Introduction

Over the past twenty years the value of shellfish, as all other seafood products, has increased dramatically. This increase in value is attributable to increased consumption, and thus demand, as a result of two principal factors: 1) an increase awareness of health and the importance of a healthy diet to overall health and 2) increased affluence that allows greater expenditure on food.

The increase in value of fisheries products has, predictably, led to more and more pressure on commercial fisheries stocks to the point where severe restrictions have had to be implemented to avoid the collapse of certain species. Many other commercial species, although not necessarily threatened with collapse, have seen their stocks substantially reduced. In either case, management efforts have had to be significantly expanded to ensure sustainability of the resources.

Most marine resources are managed at the federal level through the National Oceanic and Atmospheric Administration's National Marine Fisheries Service, NOAA/NMFS, and the Atlantic States Marine Fisheries Commission (ASMFC). Within waters of the State of Maine, marine resource management responsibility rests with the Department of Marine Resources (MDMR). The exception is the soft-shell clam, *Mya arenaria*, resource.

Soft-shell clams, have played an important role in the coastal economy throughout Maine's history as evidenced by the shell mounds and middens around the shoreline and on the many islands of the Bay left by the indigenous people hundreds of years ago. Active management of this resource is first documented in 1821, the year of the 1st Legislature, when laws were established to protect the rights of citizen of the then newly formed State of Maine to the taking of clams. Delegation of authority to individual towns for management of the resource began in 1895 when the Towns of North Yarmouth, Yarmouth, and Cumberland began managing their shellfish resources under the Private and Special Laws. These laws were amended and expanded until no less than 68 laws applied to shellfish management. By 1957 these laws had become sufficiently complicated and cumbersome that a special research study committee, created by the Legislature, recommended that the State, through the then Department of Sea and Shore Fisheries, assume cooperative management responsibility for shellfish resources, although in practicality control remained with the towns. In 1959, however, responsibility for enforcement of town boundaries by the State was withdrawn, leaving the towns to fend for themselves. This situation soon became untenable and in 1963 the legislature enacted enabling legislation that laid the groundwork for the management system that exists today.

Today, towns across Maine manage shellfish resources within their municipal boundaries through authority conferred by their respective Town Shellfish ordinances. These ordinances must be approved by the Maine Department of Marine Resources before enactment and are administered through local shellfish committees or commissions. Individual town ordinances are based on a Model Ordinance developed by the Maine Department of Marine resources and specifically describe how management will be carried out in the town.

Municipal soft-shell clam resource management falls essentially into two categories: 1) resource protection and 2) growing area protection. Considerable information is required in both of these categories to ensure proper management of the resource. Resource protection requires current, accurate information on the status of the resource within the municipality, an understanding of the nature of the shellfish industry within the community, as well as such factors as trends in recruitment, *i.e.* settlement of juvenile clams. Proper protection of shellfish growing areas relies principally on accurate and up-to-date information on the status of water quality within the growing areas and the potential impacts of land-use in the upland areas adjacent to important clam flats.

Collection and, in particular, the management of all of this information can be difficult, if not overwhelming, for both volunteer members of municipal shellfish committees as well as municipal officials and their staffs. This manual is, therefore, intended for use by those individuals within municipalities responsible for shellfish management and seeks to familiarize the reader with the resource management categories, collection methods for key information in each category, and how the information might best be managed, specifically using Geographic Information Systems (GIS). Extensive discussion and instruction on the material presented here is beyond the scope of this manual, however, references are made throughout the manual to additional information sources, including websites.

2.0. Overview of Resource and Growing Area Protection

2.1. Resource Protection

Shellfish resources, particularly intertidal resources, are, by their nature, susceptible to overexploitation. First, they are sedentary and consequently unable to avoid harvesting and are readily accessible. Second, by law, harvesting of soft-shell clams is limited to hand implements, thus significantly reducing the capital investment required for harvesting equipment, allowing relatively easy entry into the fishery. Therefore, to ensure sustainability of the resource, restrictions and controls on harvesting need to be imposed.

2.1.1. Restriction and Control Options

Limited Entry

Perhaps the most important tool in fishing effort control is the imposition of limits on the number of licenses that are issued granting individual rights to harvest shellfish. The Maine Department of Marine Resources does not limit the number of state shellfish harvesting licenses it issues. Towns operating under approved shellfish ordinances are granted the right to limit the number of licenses issued within the municipality, although certain restrictions apply. For example, since 1985, ten percent of the licenses issued by a municipality must be issued to non-resident harvesters and the fees charged for these licenses are limited by law.

Until recently, towns were required to assess the resource under municipal control to determine the appropriate number of licenses to issue and help evaluate the effectiveness of the towns management efforts. However, the cost of conducting a standard shellfish resource assessments can be substantial and for many towns, especially those in Downeast Maine with very limited budgets, such costs are prohibitively expensive. Consequently, for the past several years many towns have not been complying with the resource assessment requirement and have consequently been violating their own ordinances. Recognizing this dilemma, and at the suggestion of DMR, the Maine Soft-shell Clam Advisory Council (MSSCAC) has recommended that changes be made to Chapter 7 of the DMR regulations to eliminate the requirement for formal resource assessments.

Despite the elimination of the resource assessment requirement, towns must still develop information upon which to estimate appropriate fishing effort if limited entry is to be used as a management tool. The standard survey method can still be used, but alternatives do exist. One technique used in the past is the “cursory” or “walk-over” survey. This type of survey relies more on the personal observations and experience of the individual conducting the survey than on systematic sampling and statistical analysis. This method, therefore, is more subjective and open to individual interpretation. Shellfish survey methodologies are discussed in further detail in Section 3.1.

Harvester and dealer reports can also be used to gather production information. Unfortunately, harvester information is often more qualitative than quantitative, and sometimes

questionable. Dealer information, at least until relatively recently, has been general and difficult to assign to a specific area, or even town, since dealers often buy clams from harvesters working flats outside of the dealers town. The tagging requirement that went into effect in 1997 requires diggers to identify the source of every bushel of clams and the dealer to record and report that information. This requirement has vastly improved the quality of the data developed by dealers, yet according to the DMR, it remains difficult to tie yields to specific coves or bays.

Given the improved information provided by dealers, it may now be possible to estimate production from specific towns, if not specific areas within those towns. However, these data are of only limited value in determining appropriate license levels, for the information reflects what *was* in the flats, not what remains. Thus any effort limitation estimates based on this information would be applicable to current or recent season production rather than following season production to which effort limitation should apply.

Catch and Time Limits

In addition to limited entry, harvesting can be controlled by the imposition of restrictions on the number of days and/or times during which harvesting can take place or on the amount taken during any specific period of time, *i.e.* tide or day. For example, several communities have limited harvesting to daylight hours only while others have prohibited harvesting on Sundays. Alternatively, or in combination with these, catch can be limited to a certain number of bushels or pecks per tide. Since recreational harvesters usually dig for clams only during daylight and seek only enough clams for a meal, these control measures are often used to effectively control recreational digging. Commercial shellfish harvesters, however, strongly object to either time or catch restrictions, viewing these as unfair infringements on their right to work as hard and as much as they feel necessary in pursuit of their livelihoods. This argument is no different from that offered by other fishermen involved in similarly regulated fisheries. However, because of the comparatively minimal equipment and investment required to enter the soft-shell clam fishery, many shellfish harvesters, unlike their counterparts in other fisheries, often have few alternative fisheries opportunities to shift to. Shellfish harvesters have, therefore, been successful at arguing their position before municipal officials and catch and time limitations are consequently infrequently used as management tools.

Harvest-size restriction

The best-known and most extensively used resource protection measure is size limitation. Size restrictions are commonly used in fisheries management and are currently being applied to numerous species. The first reference to size limitation as applied to soft-shell clams in Maine came in 1917 when laws regarding “reservations”, essentially private leases, restricted the harvesting of clams at the time of opening to 22 inches or greater. In 1935, a law was passed which, for the first time, set a state-wide minimum size of 2 inches and allowed a 15% tolerance level, the level being reduced to 10% in 1943. The state-wide “2-inch clam law” was repealed in 1963 to increase resource availability due to the devastating effects of green crab, *Carcinus maenas*, predation during the 1950's and early 1960's. Also in 1963, the Private and Special laws were repealed and the Legislature authorized the establishment of Municipal Shellfish Conservation Programs which, upon State approval of a Shellfish Ordinance, allowed individual

towns to set size limits, among other things. However, the state-wide “2-inch clam law”, with a 10% tolerance, was reenacted in 1984. Interestingly, support for reinstatement of the 2-inch size limit came from industry, no so much as a conservation measure, but as a result of economic concerns that small clams were considered lower in quality and depressed market price, both in and out of state. Indeed, following re-enactment of the 2-inch law, prices rose and Maine regained its reputation for a premium product.

The 2-inch clam law has been challenged numerous times since 1984, but has withstood those challenges to-date. Today, support for the law is more for conservation rather than economic reasons since the distribution of 2-inch clams is used to determine commercial value of flats and the number of commercial licenses they can support. Although no formal scientific evidence exists that 2-inch clams are necessary to support clam populations along the coast, the industry generally believes that a 2-inch and greater clam spawning stock needs to be preserved in order to ensure continued production of larvae to support a healthy fishery.

Conservation closures/flat rotation

Conservation closures are routinely imposed on flats where clam density is low, usually <30 bushels/acre, due to over-harvesting, lack of recruitment, or a combination of the two. Such closures have proven successful in improving productivity, particularly when combined with resource enhancement measures. Unfortunately, difficulties are often encountered at the time of opening when harvesters descend on a flat *en mass*, each hoping to benefit from being the first to work the area. The result is often what has been described as a “moonscape”, the entire flat being turned over in a matter of a few tides. The impact of this intensive, post-opening “turning” of the flat has led many to question the true value and benefit of closures. One way to try and avoid this initial intensive harvesting is to open flats to commercial harvesting for a specific, limited period of time. Another is to alternately close and open several flats simultaneously, thus spreading the digging effort, a technique referred to as flat rotation. While this latter approach may appear to be sensible in theory, the fact that clams grow at different rates on different flats makes coordination difficult. Furthermore, if several flats within a town are closed to harvesting at any given time, the active digging effort is concentrated in the remaining open areas, often leading to overexploitation of the resources in those areas. As a consequence, many towns feel it is better to simply leave all areas open at all times, thus ensuring a more even distribution of the harvesting pressure.

Resource Enhancement - Seeding

The resource enhancement measure most widely used today to increase production is the seeding of flats. Two techniques currently receiving considerable attention in Maine are the transplanting of naturally-occurring seed from high density areas to low density areas and the planting of hatchery-raised seed (Clime and Townsend, 1993; Beal, 1991).

Each of these techniques, although reasonably effective, have both advantages and disadvantages. The transplantation of naturally-occurring seed has the advantage of requiring little monetary outlay, but is very labor-intensive. It requires, first, the identification of the high density source areas. Second, if these areas are not present within the municipality wishing to

conduct a transplanting operation, negotiations must take place between the source and target municipalities, negotiations that can often become difficult, particularly between rival communities. Following successful source identification and any necessary negotiations, the harvesting of seed requires a substantial, often massive, effort to obtain sufficient seed to make the effort worthwhile. Planting is usually accomplished by broadcasting harvested seed directly over the target area during high water, preferably in the late afternoon, thus ensuring that the next low water will occur during darkness to reduce avian predation. Nevertheless, considerable predation by crabs and finfish can occur if burrowing is delayed.

Hatchery production of soft-shell clam seed offers great promise, particularly for private-sector aquaculture, but the current production capacity in Maine falls far short of the needs. Furthermore, the cost of hatchery-produced seed can be high. As a result of budget and personnel constraints in State government over the past several years, Maine municipalities are now being asked to bear many of the resource management and water quality assessment costs previously covered by State programs. This added financial burden has created concern at the municipal level and the suggestion that municipalities absorb the additional costs associated with

purchasing hatchery-produced seed seems unreasonable and unrealistic, at least at this time. Furthermore, once spread, hatchery-produced seed is subject to the same risks of predation and

dessication as naturally-produced seed. In view of the substantial cost of the seed, these risks are often considered unacceptable, and the cost and labor required to properly protect large areas is prohibitive.

Recruitment enhancement - Structures

An alternative to transplanting is the installation of recruitment enhancement structures on target flats. Numerous observers, shellfish harvesters and scientist alike, have remarked on the fact that disproportionately heavy clam sets appear to occur adjacent to structures protruding from the sediment surface, *i.e.* stones, branches, tires, etc. Such increased settlement has also been observed in sections of flats where the sediment has been disturbed, as part of commercial harvesting activity, for example, thus increasing the "roughness" of the sediment surface. The increase in recruitment appears to be the result of either decreased current velocity, *i.e.* eddies, or increased turbulence in the immediate vicinity of these structures and roughened surface, both of which act to increase the number of contacts between late-stage larvae and the bottom. Based on these observations, it seems reasonable to assume that structures intentionally placed as vertical projections from the sediment surface also act to encourage settlement in the surrounding area. Indeed, there are numerous anecdotal references to a settlement-inducing practice termed "brushing" which refers to harvesters sticking branches of discarded Christmas trees into the mud in the Spring forming rows perpendicular to the advancing tide.

Use of recruitment enhancement structures may serve as an attractive alternative to both transplanting naturally-occurring seed and the planting of hatchery-produced seed since their use is much less labor-intensive than the former and less costly than the latter. However, the use of large quantities of brush is no longer considered acceptable and reusable, artificial materials therefore need to be used. Several studies are currently under way to investigate the

effectiveness of different materials, structures, and arrangements.

Predator control

Clam predators are many and varied and include the green crab, *Carcinus maenas*, their principal predator, the moon snails, *Euspira heros*, and *E. triseriata*, sand worms, *Nereis virens*, mud shrimp, *Crangon septemspinosa*, and the milky ribbon worm, *Cerebratulus lacteus*, to name but a few. All of these account for some mortality, but the green crab is by far, aside from man, the clam's most significant predator.

The most dramatic example of the effects of green crab predation is the impact of the crab population explosion that occurred in the 1950's that led to the precipitous decline of the resource that followed the late 1940's boom. The mild winter temperatures during the 1950's allowed the green crab to survive in unprecedented numbers. The green crabs devour small clams shortly after settlement as well as larger juveniles and are such effective 'green predators' that by the late 1950s and early 1960s the soft-shell clam resource up and down the entire Maine coast had been reduced to historically low levels.

The then Department of Sea and Shore Fisheries responded to the green crab emergency by implementing a predator exclusion program, more commonly referred to as the "crab fencing" program. Crab fences were erected along the mouths of selected coves known for their productivity to prevent green crabs from moving up the flats on the incoming tide. Crab traps were set and fished inside of the fenced-in area to remove existing crabs. These measures were very labor-intensive, but proved effective in protecting at least a small portion of the population.

Although the threat of another green crab population explosion still exists today, particularly given the unusually mild winters experienced here in Maine since the mid-1990's, no coordinated green crab program exists today. However, green crabs do exist in sufficiently large numbers in certain areas to pose a risk to seeding efforts. Consequently, in certain areas where seed is applied to the flats, the seeded area is covered with plastic mesh to exclude crabs. Obviously, care needs to be taken to ensure that no crabs are trapped under the mesh at the time of its application.

Recently, the U.S. Army Corps of Engineers (ACOE) has advised the State that many such protective measures, as well as the installation of certain semi-permanent recruitment enhancement structures, may require an ACOE permit. This being the case, towns may find it more difficult, or at least more complicated, to engage in such activities.

Conservation hour requirement

All of these resource enhancement measures are very labor-intensive and are consequently nearly always done as a volunteer effort. In order to ensure that sufficient labor is available to carry out their respective shellfish conservation programs, several municipalities now require commercial harvesters to perform a certain number of “conservation hours” in order to assure re-issuance of their harvesting licenses. Activities that qualify as conservation include participation in resource assessments, transplanting seed, water quality monitoring, shoreline clean-up, and predator/competitor control.

2.2. Growing Area Protection

The quality and productivity of shellfish growing areas can be impacted in various ways by land-use within the shoreland areas adjacent to the growing areas. Stormwater discharge from shoreland areas can impact shellfish growing areas in many ways, the principal being: 1) erosion and sedimentation and 2) reduction of water quality, *i.e.* bacterial contamination.

2.2.1. Erosion and Sedimentation

Sedimentation can become an issue where extensive development results in increased stormwater flow to the flats, both during and after construction. The threat of increased sedimentation can be significantly reduced, if not eliminated, through reduction of erosion during house and road construction, reduction and proper treatment of impervious surfaces, and the reduction of stormwater channelization using vegetated buffers. Such measures and regulations are usually required and described in municipal building and zoning ordinances. Municipal shellfish resource managers should be familiar with these ordinances. Although the issue of sedimentation in the vicinity of clam flats is a matter of concern for shellfish resource managers, responsibility for enforcement of these ordinances and correction of problems usually rests with the Codes Enforcement Officer (CEO) of the municipality.

A detailed discussion of erosion control and sedimentation reduction is beyond the scope of this manual, however, additional information can be obtained from the Maine Department of Environmental Protection (DEP), some of which can be found at the following Internet sites:

<http://janus.state.me.us/dep/blwq/stormwtr/otrecli2.htm>

<http://janus.state.me.us/dep/blwq/docwatershed/lp-nps1.ht>

2.2.2. Water Quality

Shellfish growing areas are classified and monitored in accordance with the National Shellfish Sanitation Program (NSSP) which is the federal/state cooperative program developed by the U.S. Food and Drug Administration (FDA) and the Interstate Shellfish Sanitation Conference (ISSC) to ensure sanitary control of shellfish produced and sold for human consumption. The ISSC is the voluntary national organization of representatives from state shellfish regulatory agencies, the shellfish industry, the FDA, and other federal agencies that meets annually to review the NSSP, to consider emerging issues related to the sanitary control of shellfish, and to recommend needed program amendments.

The ISSC has developed and adopted FDA-approved guidelines for the administration of shellfish sanitation programs in all states and foreign countries that are producing and shipping shellfish around and to the U.S.. These guidelines are published in the National Shellfish Sanitation Program Guide for the Control of Molluscan Shellfish. The Guide consists of a Model Ordinance, supporting guidance documents, recommended forms and other related materials associated with the Program. The Model Ordinance provides the standards and guidelines that define the minimum requirements necessary to regulate the interstate commerce of shellfish and to administer a program that protects public health by assuring that shellfish have not been contaminated during cultivation, harvesting, processing, shipping, or handling. The remaining sections of the Guide provide guidance documents and other supporting materials intended to provide background information and explanation of the standards and requirements presented in the Model Ordinance.

Each state must designate an Authority to implement the requirements of the Model Ordinance. In Maine, the Department of Marine Resources (DMR) administers the Shellfish Sanitation Program which regulates shellfish harvesting, processing, handling and shipping. DMR is responsible for classifying all of Maine's shellfish growing areas based on the classification scheme contained in the Model Ordinance. Each shellfish growing area is classified as approved, conditionally approved, restricted, conditionally restricted, or prohibited based upon a Sanitary Survey which includes 1) a shoreline survey of the land area within 500 feet of the high water line, and 2) water quality analysis for fecal coliform bacteria throughout the area.

Shellfish growing areas classification is accomplished according to the procedures contained in the Model Ordinance. Section IV, Shellstock Growing Areas, of the Model Ordinance defines the water quality standards required for each classification designation. An approved area is one in which all required conditions are consistently met. Conditionally approved areas meet the required standards except during certain *predictable conditions*, such as a rainfall event of >0.5 inch, when bacteriological contamination may occur. Each conditionally approved area is managed according to a DMR-approved area management plan which mandates that the area be closed to harvesting during conditions which may result in bacterial contamination. A restricted area is one in which contamination exists at such levels that the shellfish can be made safe for human consumption by relaying to an approved area *or* purified in

accordance with specific NSSP *depuration* procedures. A conditionally restricted area is similar to a restricted area, but one affected by a *predictable* and *measurable* pollution source, such as a municipal wastewater treatment facility, as described in the DMR-approved area management plan developed for each area so classified. A prohibited area is one which fails to meet sanitary survey criteria or where the level of bacterial contamination is unacceptably elevated; unpredictable, as in the case of a residential/commercial over-board discharge (OBD); or unknown due to insufficient data.

Classification is based on a **Sanitary Survey** of the area which consists of a written report summarizing the results of: 1) a shoreline survey of the surrounding area and 2) bacteriological testing of the waters over and/or adjacent to the area. These two aspects of the Sanitary Survey are discussed in detail in Section 3.2., following, and in Section IV of the Model Ordinance, but briefly, the shoreline survey is conducted by walking the shore and upland adjacent to the growing area and noting evidence of existing or potential pollution discharge sources such as pipes, streams or other water conveyances. The bacteriological analyses are based on a Multiple Tube Fermentation Test (MTFT) in which measured amounts of source water sample are diluted serially in growth media specifically formulated to promote the growth and differentiate fecal coliform bacteria. The number of positive tubes (indicating presence) in each dilution sequence represents a statistical probability of the number of bacteria in the source water, referred to as the Most Probable Number or MPN.

Prior to the early- to mid-1980s the MDMR conducted all shoreline surveys and collected and processed the requisite water quality samples. However, as a result of curtailed funding, over the past several years the MDMR has relied heavily on municipal and volunteer assistance with shoreline surveys and water sample collection. The MDMR, however, retains exclusive control of the processing of water samples and the analysis of all sanitary survey data utilized in determining the appropriate classification of shellfish growing areas. The MDMR has recently developed a program to train volunteers in shoreline survey and water sample collection procedures. Additional information on this training program is available from:

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Additional information on the NSSP, the ISSC and a copy of the Model Ordinance are available at: <http://www.issc.org/issc>

3.0 Data Collection

3.1. Shellfish resource surveys

Soft-shell clam resource, or population, assessments have been carried out for many years in Maine. These stock assessments are extremely valuable in the management of the resource. The information they generate can be used to: 1) support effort management decisions to insure sustainability of the resource, 2) establish economic value of the resource in the event of catastrophic loss and subsequent compensation, and 3) justify water and land use regulation.

3.1.1. Standard shellfish survey method

A standardized assessment method was developed by the MDMR many years ago and the extrapolation of survey results to production volumes were originally based on the work of Belding (1930). Belding's tables were later modified by Stevens and Sampson (1981) to better reflect morphological characteristics of the species and conditions in Maine, thus yielding more accurate extrapolations. An detailed explanation of this methodology is presented by Newell *et al.* (1983). A Quality Assurance Project Plan (QAPjP) for this methodology has been approved by the EPA.

According to the standard survey method, the area to be covered by the survey is initially estimated based on a reconnaissance of the selected flat and a prediction of the general configuration of the clam habitat. At the start of the survey, a point of origin is established from which a measured grid is developed across the tidal flat, extending shoreward to the boundary of the shellfish bed, and seaward to the boundary of the shellfish bed or the low water mark, whichever is reached first. Sampling stations are located at 100 foot (or 200 ft., depending on the size of the flat) intervals along imaginary lines that criss-cross, thus forming a grid pattern over the flat. Distances between samples along the grid are measured using a 100 ft. line attached to two stakes. Occasionally, an exception is made in particularly densely populated areas where the grid interval is reduced to 50 feet. If survey data is to be link to a GIS, each sampling station, *i.e.* grid intersection, must be identified with a geological reference, *e.g.*, latitude and longitude (refer to Section 4.3. Geo-referencing Data). Alternatively, it may be sufficient to collect location information for a benchmark from which the grid is laid out, thus allowing subsequent approximation of sampling station locations for use in the context of a GIS.

At each grid intersection, two side-by-side imprints of a 0.1 m² (~1 ft²) frame are made in the bottom to form a 0.2 m² (~1 ft. by ~2 ft., or ~2 ft²), rectangle for sampling. A 0.025 m² (~3 ft²) subsample of the top 1.0-2.0 cm (~2 to 1 inch) of sediment is then removed to estimate clam seed, or "spat", concentrations. This material is placed in a "Zip-Loc" bag bearing the sampling station number. A discrete cut is then made along one of the imprint edges to define the starting boundary. All of the substrate within the imprint boundaries is removed to a depth of at least 25-30 cm (~10-12 inches) and examined for clams. All clams collected from the sample plot are placed in the numbered bag for later measurement and counting.

All clams found in each sample, including spat found in the subsample, are measured to the nearest 5 mm interval on a 0 to 95 mm scale. The information for each stations is recorded on

a data sheet that is substantially similar in format to the spreadsheet input screen (refer to Appendix I). Using similar formats for field sheets and computer screen facilitates data input and reduces transcription errors. The data are then tabulated and entered into a spreadsheet used specifically for soft-shell clam population analyses. The analyses performed in the spreadsheets use equations developed by the Department of Marine Resources for the determination of bushels per acre and harvest yields. These equations are based on size frequency and yield tables developed by Belding, as modified by Stevenson and Sampson referenced above.

The upper portion of the spreadsheet is used to input the survey results for each sampling station or "Plot". The data from the individual sampling stations is then summed at the end of this portion of the spreadsheet to develop a size frequency distribution for the entire survey area. The size frequency distribution data are used to calculate current total standing crop in bushels and bushels per acre, current harvestable standing crop in bushels and bushels per acre, and current percentage of crop harvestable.

Although the standard survey method and extrapolation calculations have been used extensively in Maine, the method and results continue to be surrounded in controversy. The validity and use of stock information for establishment of economic value for use in determining compensation in the event of a catastrophe, *e.g.* an oil spill, or justification for water and land use regulation are the least controversial, at least from the shellfish industry's perspective. Considerable controversy, however, surrounds the use of this information in the effort management decision process, specifically effort limitation through license issuance restriction, *i.e.* limited entry. More often than not, harvesters holding valid licenses either agree with stock assessment results or argue that the assessments overestimate the stock and licenses should be reduced; those having been denied a license consistently argue that the assessments underestimate the stock and more licenses should be issued. Depending on the time of year assessments are carried out and the way in which the information is interpreted, either could be right. For example, surveys conducted in the spring for use in determining license levels for the following year's harvest season, *i.e.* May 2000 survey to establish licenses in 2001, will likely overestimate the resource available the following year since the legal-size clams will likely be harvested in the current year. Assessments carried out in the late-fall, however, will minimize this error since digging pressure over the winter will usually have a negligible effect on the stocks, particularly in years of heavy ice cover or low demand/price.

Regardless of the time of year when surveys are carried out, the failure to account for growth and consequent movement of just-sub-legal clams into the legal-size range during the following year will inevitably lead to underestimation of the stock. At least one projection model has been developed to predict "following-year" stock status based on current year survey data. As in any model, certain assumptions need to be made, specifically growth rate and mortality. Growth rate, both incremental and annual, is obviously subject to environmental conditions, particularly temperature and food availability, and is therefore regionally-, if not site-, specific, *e.g.* Casco Bay vs. Machiasport. Therefore, a model developed for Casco Bay will unlikely be applicable or suitable further east along the coast. Mortality has multiple components, including direct harvest mortality or "take", harvest-associated mortality, *e.g.* suffocation due to burial or exposure, predation, and natural attrition. These are very difficult to ascertain accurately and, as with growth, will vary considerably from one location to another.

Nevertheless, despite the complexities, such projections may be essential if proper management is to be achieved in the future.

A first attempt has been made to develop a model to estimate following year production for Casco Bay flats (MER Assessment Corp.) using specific assumptions for growth and a sliding scale for mortality (both natural and harvest-related) developed on the basis of 10 years of observations. By applying current population size distribution data to the model, following year projections can be made for a specific flat for both open harvested and closed/prohibited scenarios. In addition, the harvestable production estimates for the current year and the model-generated following year projections for open-harvested and/or closed- prohibited scenarios are used to calculate the ex-vessel dollar value of the resource using a matrix of ranges of bushel prices and local economic activity multipliers. The model requires considerable refinement, but on flats where information for two consecutive years is available, the model has been shown to project following year production with acceptable accuracy. However, it is incapable of projecting beyond the following year.

Unfortunately, since only a portion of any town's clam flats are usually surveyed in any given year, information with which to project following year production is limited and does not adequately respond to a town's need to know what overall production will be in order to match license issuance to production. Some other method of estimating overall production is therefore needed. To this end, the model referred to above has been reduced to a simpler equation which relates following year production to the volume of sub-legal clams present in the town's areas open to commercial harvesting.

Application of data from several different flats around the Bay to the model, along with field observations over the years, has shown that, during a growing season, the annual volumetric conversion of sub-legal bushels to harvestable bushels in open, harvested areas is in the order of ~0.4 to ~0.7, the rate of conversion varying according to the size frequency distribution of the population. That is, on flats where survey results show a population peak just below the 2-inch (52mm) legal size limit the conversion will be higher; where the population is composed primarily of small juveniles, the conversion will be smaller. Thus a simplified following year projection for an individual flat or group of flats can be expressed as:

$$\text{Eq. 1} \quad \text{Proj}_{hb} = H_b + ((T_b - H_b) * C)$$

where Proj_{hb} is the projected harvestable bushels, H_b the currently harvestable bushels, T_b the total bushels, and C the conversion factor. It is important to note that this equation does not suggest that a certain proportion of the sub-market bushels moves into the harvestable range, but that the volumetric increase resulting from growth of sub-legal clams reaching legal size is equivalent to the approximate volume of a proportion of the current sub-legal bushels. In most applications the number of Projected harvestable bushels is determined for the aggregated flats of a given town using Equation 1 and a rather conservative value of 0.5 for the variable C .

A word of caution on relying on averages is necessary. As the available data show, clam population densities on individual flats can change dramatically over relatively short periods of time, due in part to the dramatic differences in recruitment which can occur from year to year. In

view of this, the use of an average flat or average year should therefore be understood to be a crude comparison and used only for generalizations.

The number of commercial shellfish harvesting licenses that can be supported by the resource is determined on the basis of harvesting efficiency, the average number of tides a harvester normally digs, and the average number of bushels harvested per harvester per tide. The values used for these variables have been developed through interviews with harvesters and dealers and differ slightly from town to town. For example, the Town of Brunswick, Maine assumes 100% harvesting efficiency when calculating licenses. The number of tides normally harvested per year is estimated at 209 with 1.78 bushels harvested per tide, equivalent

to approximately 370 bu./harvester/year. The Towns of Freeport and Harpswell, Maine use a harvesting efficiency of 70%, 208 for the number of tides normally harvested per year, and 1.56 for the average number of bushels harvested per tide, equivalent to approximately 320 bushels/harvester/year.

3.1.2. Cursory shellfish surveys

Cursory surveys, also commonly referred to as “walk-over” surveys, are conducted by merely walking around and across flats occasionally turning the mud to sample the clam population. Samples can either be quantitative, *i.e.* using a consistent sampling area, or qualitative where a rake is inserted and the mud turned. Clams can be counted and measured or simply estimated. Clearly, this method is significantly less stringent than the standard method and is usually used to get a very general idea of the condition of the flat and clam population. The cursory survey is often used to establish the boundaries for a subsequent standard survey. It can also be used to delineate the extent and boundaries of the actual populated area within a larger intertidal area. Although useful for its intended purposes, this type of survey should never be used as a substitute for the standard survey or as the basis for determining appropriate licensing levels.

3.2. Sanitary Survey (see Appendix II NSSP Model Ordinance - Chapter IV. Shellstock Growing Areas)

Bacterial contamination of shellfish growing areas which could lead to illness or death in consumers, *e.g.* hepatitis, cholera, is the focus of the sanitary survey. There are several groups of bacteria which could cause illness and testing for each individually would be both time- and cost-prohibitive. Consequently, rather than test for individual pathogenic bacteria, fecal coliform are used as an indicator group of bacteria. Fecal coliform are part of the normal bacterial flora of mammals. Thus, detection of fecal coliform bacteria in growing area waters, or freshwater flowing to the growing area, indicates a potential for the existence of pathogenic bacteria. Shoreline surveys and water testing are therefore intended to detect and identify potential sources of fecal coliform bacteria contamination.

3.2.1. Shoreline surveys (refer to Appendix II NSSP Model Ordinance - Chapter IV Sec. @.01 Subsection D., p. 23)

Shoreline surveys are the foundation of the NSSP and are normally conducted by trained professionals familiar with potential bacterial contamination sources and the evidence of which to look for. However, as mentioned above, the MDMR is now using trained volunteers to assist

in expediting the identification of potential sources in order to survey shellfish areas.

The shoreline survey is conducted by, first, walking the shoreline immediately adjacent to the shellfish growing area to determine if potential fecal coliform bacteria contamination sources, or evidence of them, exist. Examples of potential sources include failing on-site septic systems, pipes discharging to the shore, metal or plastic pipes crossing the flat with no observable discharge point (*e.g.* discharge below the low water mark), above-ground holding tanks adjacent to the shoreline, outhouses in close proximity to the shore, wildlife and livestock, and earth mounds near the shoreline suggesting the presence of an on-site treatment system, *i.e.* septic system. Any potential sources identified during the survey should be clearly described and geo-referenced (refer to Section 4.3. Geo-referencing Data).

Less obvious potential sources are water discharges to the flat from natural drainage, either intermittent or perennial streams, road ditches, and diffuse groundwater breakout. It is often difficult to trace these discharges back to their point of origin, and in many cases, the flow at the point of discharge is an accumulated flow from numerous points of origin.

The potential threat of these less obvious discharges can be determined by testing the discharge water for fecal coliform bacteria. Samples taken of such discharges are termed Pollution Source (PS) samples. Pollution Source samples must not be confused with routine growing area water samples (see Section 3.3. Growing area water sampling, following); the MDMR uses different field data sheets to differentiate between PS and routine water samples. Although PS and routine growing area water samples are treated and tested in the same way, it is extremely important to clearly identify **PS** samples to avoid confusion and to keep results of these samples separate from routine sample results. PS samples results will likely reflect elevated concentrations of fecal coliform and, if incorporated into the routine sample data set, could affect the statistics upon which classification of the area is based, resulting in a lower classification. When taking PS samples, additional information that should be collected includes temperature of the water, estimated flow, and if possible, conductivity. All PS sampling locations should be clearly identified and geo-referenced.

The upper shoreland area, typically within 500 feet of HW, is also surveyed to identify potential sources within close enough proximity to affect the growing area, but not obvious from the immediate shore. The extent of this survey will vary based on the results of the immediate shoreline observations. If no obvious threats are seen along the shoreline and/or the PS sample results indicate only negligible concentrations of fecal coliform bacterial, the upper shoreland survey can be abbreviated. However, if the immediate shoreline survey PS sample reflects a significant concentration of fecal coliform bacteria, a more thorough survey will be required.

Since water is the principal conveyance of bacterial contamination from the upper shoreland area to the growing area, it is usually best to begin the survey at the point of discharge to the flat. The water flow is then followed up into the shoreland area with observations made along the way. If confluences of separate drainages are encountered, PS samples can be taken of each drainage, particularly if the PS sample taken at the discharge point adjacent to the growing area yielded a high fecal coliform score; unless both drainages are contaminated, this will allow identification of the more likely route to the source. As in immediate shoreline surveys, any potential sources identified during the survey should be clearly described and geo-referenced.

3.2.2. Growing area water sampling (refer to Appendix II NSSP Model Ordinance - Chapter IV Sec. @.02 Subsection D., p. 24)

Waters within and adjacent to growing areas are routinely sampled and tested for fecal coliform bacteria contamination as part of the areas' Sanitary Survey to ensure compliance with classification criteria. Samples can be collected using either an *adverse* or *systematic random* strategy. Under the *adverse* sampling strategy, water samples are collected to reflect fecal coliform concentration when contamination levels are expected to be high, *e.g.* following a major rainfall event, when human activity is at a peak, etc. As the term implies, *systematic random* strategy is one in which sampling occurs on a random basis irrespective of weather or pollution conditions. Sampling on a schedule of pre-selected dates, for example, constitutes random sampling since the weather and/or pollution conditions cannot be predicted for any given date. Sampling in Maine is conducted using the systematic random.

The NSSP has established threshold values, based on statistical probability, for fecal coliform contamination for each of the classification categories. According to the NSSP Model Ordinance, the statistical analysis of test results upon which an area is classified must be based on a minimum of thirty (30) samples taken over a period of years. Once an area has been classified as open, it must be randomly sampled at least 6 times annually. Other classifications require sampling at different frequencies. DMR treats open and conditionally approved areas as high priority for staff sampling efforts. However, because of budget and personnel staff constraints, restricted and closed areas may not be sampled as required. In such cases, volunteer assistance with water sampling can insure that area data is kept current so that these areas can be reviewed for reclassification if appropriate.

The NSSP requires a complete and up-to-date Sanitary Survey Report for all shellfish growing areas classified as approved, conditionally approved, restricted, or conditionally restricted. The Sanitary Survey Report for a specific classified growing area constitutes a complete record of all shoreline survey information and water quality data for that area. The Sanitary Survey Report also includes the analysis and interpretation of the data as justification for classification. Copies of Sanitary Survey Reports are readily available from the MDMR and interested parties should contact the appropriate MDMR water quality representative for their area. Within Casco Bay the contact person is: Laura Livingston - laura.livingston@state.me.us or 633-9533

4.0. Data Management and Presentation using Geographic Information Systems, GIS

As the previous sections have shown, the amount of information and data required to properly manage shellfish resources is substantial. Managing all of this information is difficult and relating it to both space and time can be very complicated, particularly if it is available only in paper form. Fortunately, technology now offers us the ability to manage these data electronically. Furthermore, advances in software development and the use of computer-based geography now allow us to analyze and present information in highly visual and useful ways using Geographic Information Systems, commonly referred to as GIS. An excellent overview can be found at: http://www.colorado.edu/geography/gcraft/notes/intro/intro_f.html

4.1. Definition

Defined simply, GIS is spatial, or location, data associated with a database specifically designed to manage spatially-related information. More broadly, GIS is an electronic means of linking information and data to a specific geographic location on a digital map. Once the information/data is linked to a geographic location (such as a point), the software can generate maps to visually present and analyze the information. Furthermore, the information can be stored in such a manner to allow selective viewing of specific types of information, either individually or as multiple overlays, over a pre-selected base map, a process known as “layering”.

4.2. Base maps

Base maps are the foundation of a GIS, for they establish a spatial framework to which subsequent data can be related and can provide a means to compile newly collected data. Until recently, most base map layers were derived from hardcopy maps. Today, United States Geological Survey (USGS) quadrangles (refer to Figure 1) and National Oceanic and Atmospheric Administration’s National Ocean Survey (NOAA/NOS) nautical charts (refer to Figure 2) are generated from digital files; these digital files can provide the general reference layers in a GIS application or map. Digital base maps are not intended to replace hardcopy maps and charts, but offer an entirely new way of dealing with spatial information.

Traditional hardcopy maps are produced at set scales, *i.e.* the 1:24000 scale of USGS 7½ minute quadrant map or the 1:40000 scale often found on NOAA/NOS nautical charts. Other map scales are available, but these two examples are the most readily available and provide a high level of detail. Digital base maps and layers also have a scale at which they are most appropriate depending on their intended use. However, while the scale of hardcopy maps is fixed, the scale of digital maps and charts can be readily changed depending on the detail and resolution required, irrespective of the original scale. Care must be taken in the interpretation of maps that are enlarged because the spatial accuracy of the original map can not be improved upon simply through enlargement. At the other extreme, digital base map files for highly accurate maps that cover a large area are often have a large file size and therefore can slow the performance of an application without any gain in information content. An example of this would be viewing the entire coastline of Maine using 1:24,000 scale data.

Figure 1.

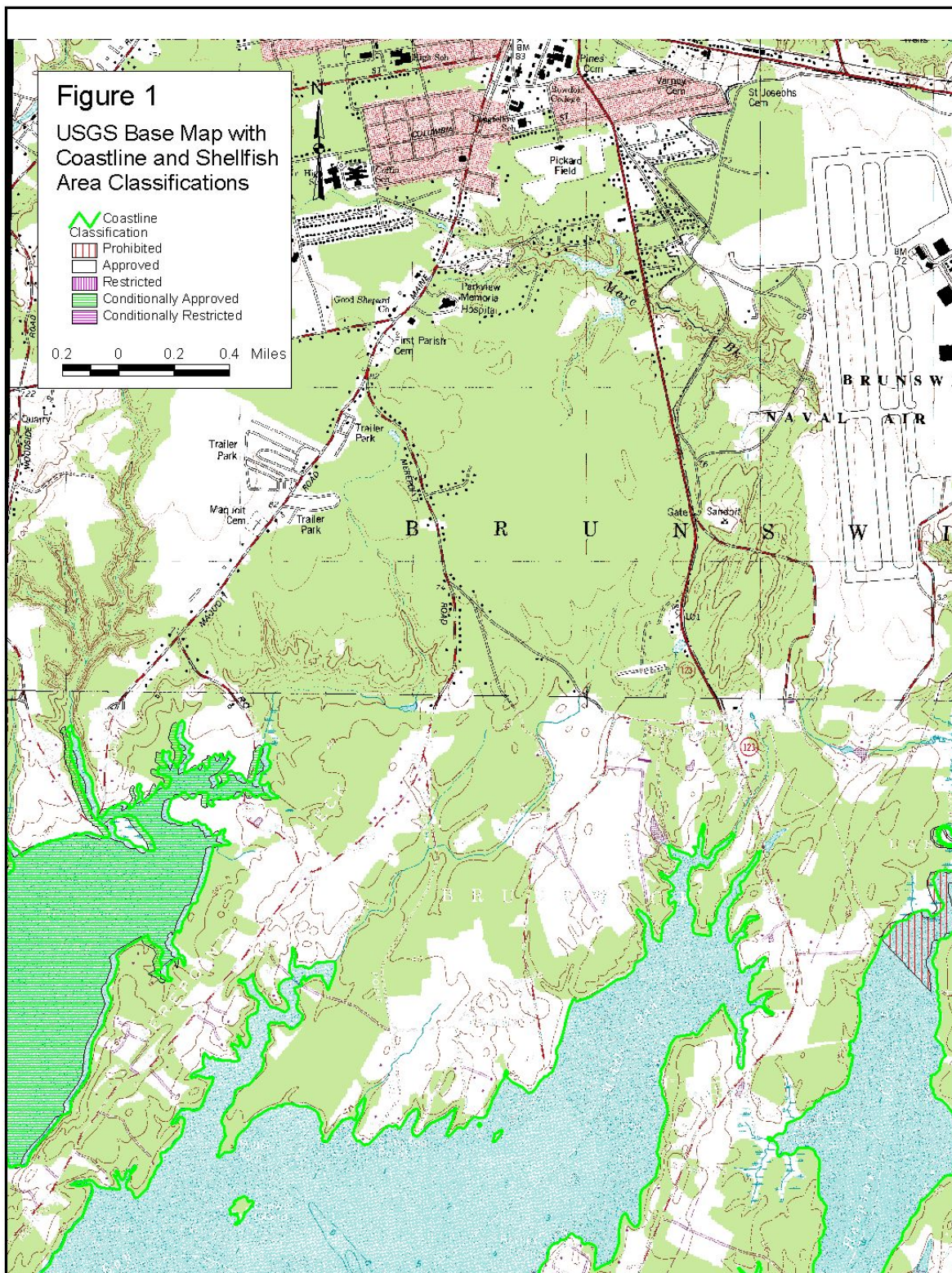
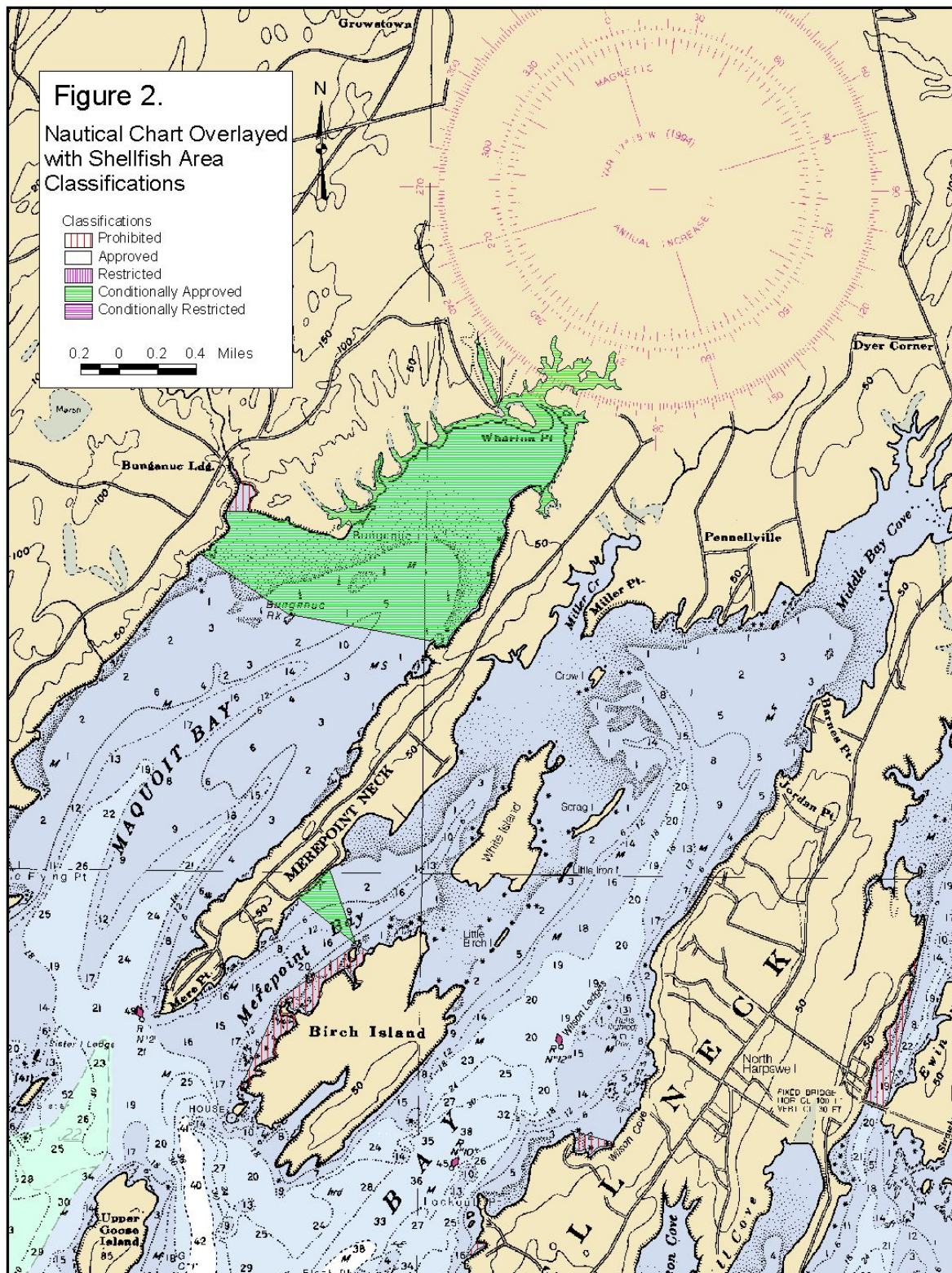


Figure 2.



USGS topographic maps are the most commonly used to generate base maps. Topographic maps are particularly useful if the information to be displayed is related to land topography and/or drainage. Standard digital base map, generated from USGS quadrangle maps, for the entire State of Maine are, in most cases, available through the Office of GIS (OGIS) and are provided as separate files. These standard base map files include:

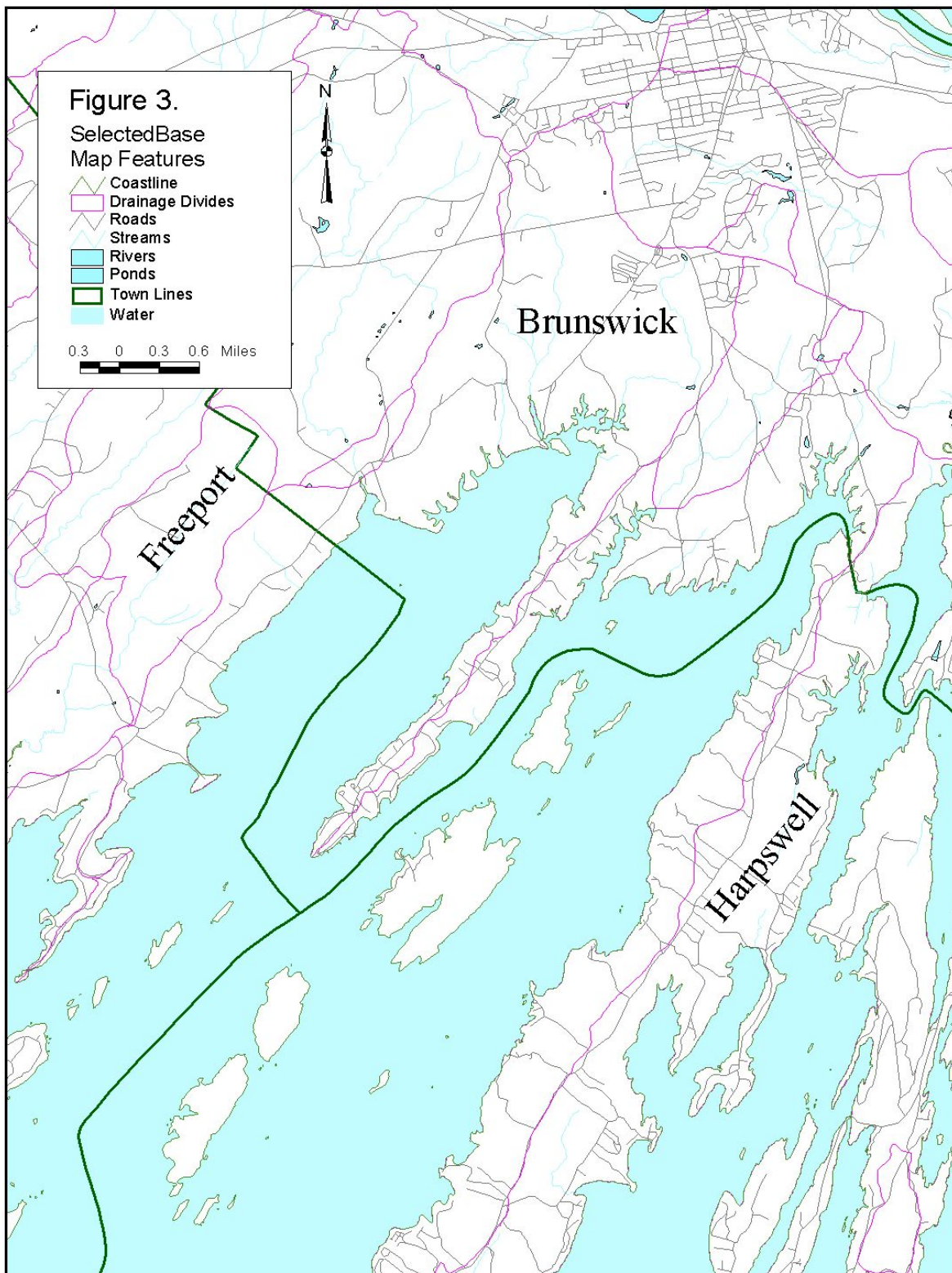
COAST: Mean high water coastline from USGS 1:24,000 scale quads.
CONTOURS: Contours scanned and vectorized from USGS 7.5 minute contour separates.
DRDVD: Drainage divides delineated using 1:24,000 scale topography.
GNIS-H: Names and point locations of most hydrologic features shown on USGS 1:24,000 quads.
GNIS-L: Names and point locations of most land form features shown on USGS 1:24,000 quads.
GNIS-P: Names and point locations of most place-name features shown on USGS 1:24,000 quads.
INDEX24: 1:24,000 scale neatlines for USGS 7.5 minute quadrangles.
MERAIL24: A statewide coverage of all the railroads in Maine from 1:24,000 DLG files.
METWP24: Political boundaries, common town names, Maine geocodes at 1:24,000 scale.
NWI: National Wetland Inventory polygon data with Cowardin classification coding.
OTRANS: Other transportation features - electric, pipeline, railroad, and telephone lines
PONDS: Pond and lake features from USGS 1:24,000 scale quads.
RIVERS: Double line rivers from USGS 1:24,000 scale quads.
ROADS: Roads and trails from USGS 1:24,000 scale quads.
SCHLIB: Point locations of libraries and educational institutions in the state of Maine
STREAMS: Single line streams from USGS 1:24,000 scale quads.

Other files are available from the OGIS at scales such as 1:100000 and 1:250000. Additional data layers are also available from other sources including the CBEP, although many of these files are no longer maintained, that is, the information is no longer updated.

Selection of the proper type and scale of the base map is extremely important and will vary according to the information to be displayed and the level of accuracy desired. As a first step, it is important to take stock of the hard copy maps that are currently used on a routine basis and assess where digital maps can aid in the process of information management. For example, shellfish surveys are often conducted using nautical charts as reference. Shoreline surveys and pollution source sampling, on the other hand, are usually carried out using topographic maps as a reference. Topographic maps, however, also depict tidal areas, and can therefore also be used in shellfish surveys. Consequently, topographic base maps may be the best overall choice. Selected base map features are shown in Figure 3 on the following page.

Once the base map type has been selected, the second step is to decide on the projection and datum that will be used. The State OGIS has selected Universal Transverse Mercator (UTM), zone 19 as the standard projection and NAD83 datum as the standard for all data. Projections (see Section 4.3, below) can be changed for display purposes or on the fly with some software packages. Data files can also be permanently converted to different projections and

Figure 3.



datums, but considerable care must be taken in doing these conversions. The process can also often be very time-consuming. It is therefore advisable to set UTM, zone 19 projection, NAD83 datum, as the standard for base map and location data, respectively, to ensure maximum compatibility with existing data and files. This will require that GPS data be collected as UTM coordinates or converted from latitude and longitude to the correct projection and datum.

A word of caution: if digital tax maps are used, depending on the source and care taken in the conversion from paper maps to digital files, some maps may be inaccurate and should not be used as base maps. Such inaccuracies will become apparent when these files are used as overlays on standard base map files. However, tax maps and other files such as point locations for overboard discharges can be used as overlays on a variety of base maps.

4.3. Geo-referencing

Geographic referencing, or geo-referencing, is the means by which locations on a flat map are linked to real world coordinates. In practice, this requires the inclusion of geographic location data for each piece, or set, of information. The initial location data can be as simple as a mark on a paper map or chart, a distance and bearing to a specified structure or landmark, distance and bearing to a known Geological Survey mark, compass bearings from two or more landmarks, or, preferably, geographic coordinates as latitude and longitude (lat/long) or UTM eastings and northings. Marine location data is often collected as latitude and longitude that must be converted to UTM coordinates to used with OGIS basemap files.

Until relatively recently, determining the latitude and longitude of a location or position in the field was rather complicated and required triangulation using compass bearings, transcription of the triangulation to a map or chart, and finally estimation of the latitude and longitude from the scales on the edge of the map or chart using rules and dividers. The introduction of the Global Positioning System, or GPS, for general public use in the mid- to late-1980s significantly simplified this task.

GPS is a system of low-orbit satellites that orbit the earth every 12 hours, each of which emits a specific, individual signal that is recognized by a receiver located on Earth. By receiving signals from several satellites overhead and calculating their positions relative to each other, the receiver can pinpoint its own location and displays that location in any of a number of operator-selectable formats. The better the geometry of the satellite locations the greater the accuracy of the position. Most consumer-level GPS units available today are equipped as 12-channel receivers, each channel tracking a single satellite, that automatically select the best satellites.

Until just recently, a handheld, 12-channel GPS receiver had an Estimated Position Error (EPE) of ± 50 -75 feet due to intentional scrambling of the satellite transmissions by the government. De-scrambling units known as Differential Correction devices, or D-GPS, could be used to "correct" the effects of scrambling and yielded EPEs in the range of ± 20 -40 feet. As of May 2000, the government is no longer scrambling satellite transmissions and EPEs for a 12-channel receiver can now be in the order of ± 10 -15 feet, more than adequate accuracy for the purposes discussed here. It is therefore now possible to generate highly accurate location data at a very reasonable cost. This degree of accuracy is not always obtained during any given day. It is therefore important to be aware of periods during the day or locations where the signal may be less accurate.

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Several manufactures¹, including Garmin, Magellan, Lowrance, and DeLorme, currently produce very affordable 12-channel, handheld GPS receivers in the \$150-\$200 range capable of ± 10 -15 foot accuracy. All provide multiple functions and many, if not all, offer computer connection capability for downloading data from the unit to desktop and laptop computers using accessory software, usually not included in the purchase price of the unit. Information on GPS units is readily available at most marine supply and sporting goods stores. Additional information² on specific manufactures is available over the Internet at:

<http://www.thegpsstore.com/>
<http://www.sni.net/~lwjames/GGPS.html>

Operation of handheld GPS receivers is relatively simple and needs no further discussion here. Nevertheless, it is strongly recommended that the operator be familiar with the manufacturer's manual of operation for the unit to ensure proper operation and accuracy of the location data generated.

When collecting latitude and longitude or UTM data with a GPS unit it is important to include certain additional information. First, the datum used to collect the position must be selected and reported along with the position itself. Commonly used datum types are NAD27, NAD83, and WGS84. As stated previously, the Maine Office of GIS has set NAD83 datum as the standard for all data. Although the Office of GIS can provide data in NAD27, it discontinued maintenance of those files in 1999, therefore recent changes are not reflected in the data. Failure to report the datum used for collection will likely result in inaccurate plotting of the location. Second, the Estimated Position Error (EPE) should also be reported since this indicates the level of accuracy of the position estimate at the time it was taken.

Geographic coordinates, *i.e.* lat/long or UTM, should be collected for all resource management data that may eventually be viewed using GIS, including shellfish survey sample locations, water quality sampling stations, pollution source sampling stations, known or suspected pollution sources, etc.

¹ Reference to a specific product(s) or manufacturer(s) is in no way intended as an endorsement of the product(s) or manufacturer(s) but is intended solely as an example.

² Reference to a specific website(s), product(s), or retailer(s) is in no way intended as an endorsement of the website(s), product(s), or retailer(s) but is intended solely as an example.

4.4. Types of data or layers

The types of data collected and the ways in which they are layered and displayed will vary from one municipality to another depending on the needs. For example, a town planner analyzing land development over time and the effect such development has had on infrastructure demand over time will likely want to look at building construction, road network, municipal sewer line, and public water supply patterns, to name just a few, all separated into individual layers, perhaps even further separated into 10-year intervals. By having each set of data as a separate layer, the planner can view all layers together for all years, just the road network and building construction patterns for all years, sewer line and public water supply for a specific 10-year interval, or any of the possible combinations of layers.

Clearly, the more detailed the data is, the greater the flexibility of analysis and usefulness of the resulting display. Depending on the level of analysis desired, GIS analyses can be very complex involving multiple data layers, but yield exceptionally useful maps. The State of Massachusetts Office of GIS has developed a process for handling complex GIS analyses, an explanation of which can be found at:

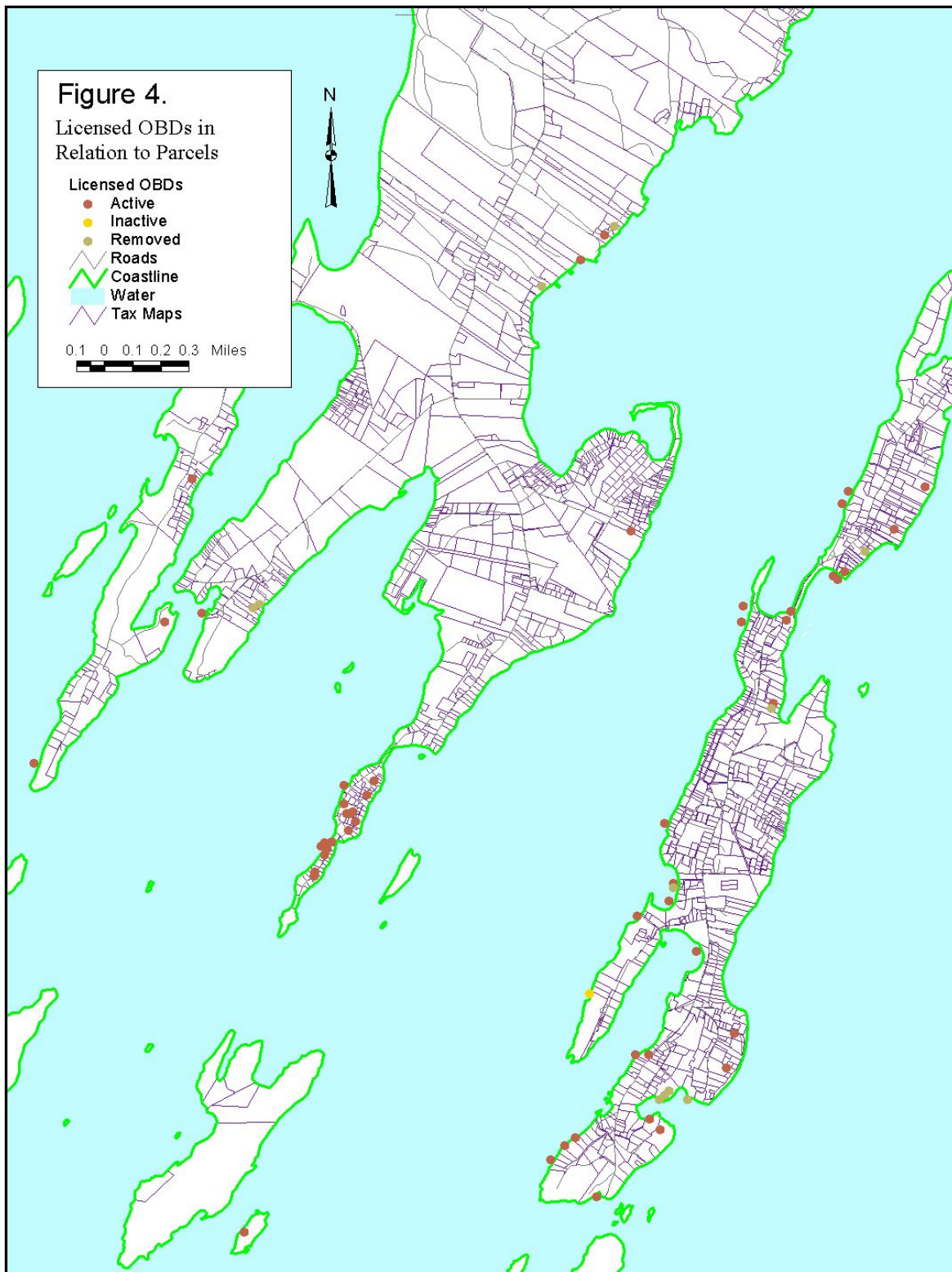
<http://www.magnet.state.ma.us/mgis/buildout.htm>

The types of data commonly used in shellfish management include shellfish habitat (both potential and productive), shellfish surveys, MDMR water quality sampling stations, PS sampling stations, location of potential pollution sources (including nearshore septic systems, licensed overboard discharges [OBDs]), tax maps, and critical drainage. The amount of information collected for each data type will depend on the management emphasis. If *resource* management is emphasized, then shellfish habitat and shellfish survey data will be the priorities. If shellfish habitat management and/or public health protection is emphasized, then the location of MDMR water quality sampling stations, PS sampling stations, potential pollution sources, and critical drainage will be prioritized. A comprehensive GIS-based management program will require data for all of these.

Similar data types should be kept together, *i.e.* point data for pollution sources, can be kept in a single file and coding developed to identify different types of sources and allow other critical information to be tracked. Features that represent liner or linear data can be separated by feature type such as resource survey transect lines or grids with associated identifying information. Data of the feature type that describes areas, otherwise known as polygons, can also be maintained in files which are separate from linear features. Examples of polygon data that would be kept separate are tax maps and drainage areas. Those that could be combined include potential and actual distributions of shellfish.

The display of data can be controlled by the associated attribute or database information thereby using the same data layer for multiple purposes. An example of this is the location information provided by the Maine DEP on licensed Overboard Discharges (OBDs). The Maine DEP keeps track of systems which have been installed as well as those that have been removed. Figure 4 shows locations of these two categories along with those which have not been removed but are inactive.

Figure 4.



4.5. Data format

The basic GIS data formats can be divided between raster data, which is in the form of pixels or discrete elements, and vector data, which is generally in the form of points, lines, or irregular shapes termed polygons. Most GIS software can use both raster and vector *data formats* with certain limitations. Raster data can be used as a base map over which vector data is overlain. An example of this type of raster data is the combination of digital color and ortho photographs as in the case shown in Figure 5. Vector data can be used very effectively as overlays as demonstrated with tax map parcels in Figure 6. Most GIS software can handle a variety of *file types* and formats but often with limitations if it is not a format native to the software being used. GIS data usually also has attribute data associated with it. This attribute data can either be integrated with the spatial file or maintained separately and linked to the spatial file.

Data, particularly attribute data, must be in a form that can be used effectively in a GIS. There is no universal GIS data format, however text data, if formatted properly in an ASCII file, can often be used directly or imported into a GIS application. Text data in the form of fixed length columns or columns that are separated by tabs or commas are most readily taken into a GIS. The following is an example of data in a variable length field ASCII file:

```
ID,structure,type,age,color   (This is the description or header information)
1,house,camp,50,blue
2,house,residence,24,red
3,garage,2_car,greys
...
254,shed,utility,brown
```

In this example, the “ID” is used to link the data to a spatial point based on a common identifier; the ID can be a number, such as the “1”, “2” used here, a letter, or a word. The example file above contains no geographic information. The spatial location information could be added to this file as additional comma delimited fields or this information could be contained in a separate file with, with “1” being the link for all information related to this structure. It is very important to note that commas (“,”) must not be used in descriptions since these are used to separate individual data fields. Similarly, although not as critical, spaces should be avoided, substituting instead an underscore “_”. This will help to insure data file compatibility with various softwares.

A spreadsheet program can be used to maintain data, import data from other formats such as ASCII files, change the data for ease of use in GIS, and export it in a file format that is best suited for the particular GIS application such as dBase files in the case of ArcView. Some GIS applications can use database and spreadsheet files directly without importing them into the specific GIS format. Most desktop GIS software can use a variety of file types such as those generated by dBase, Excel, Access, and others.

Figure 5.

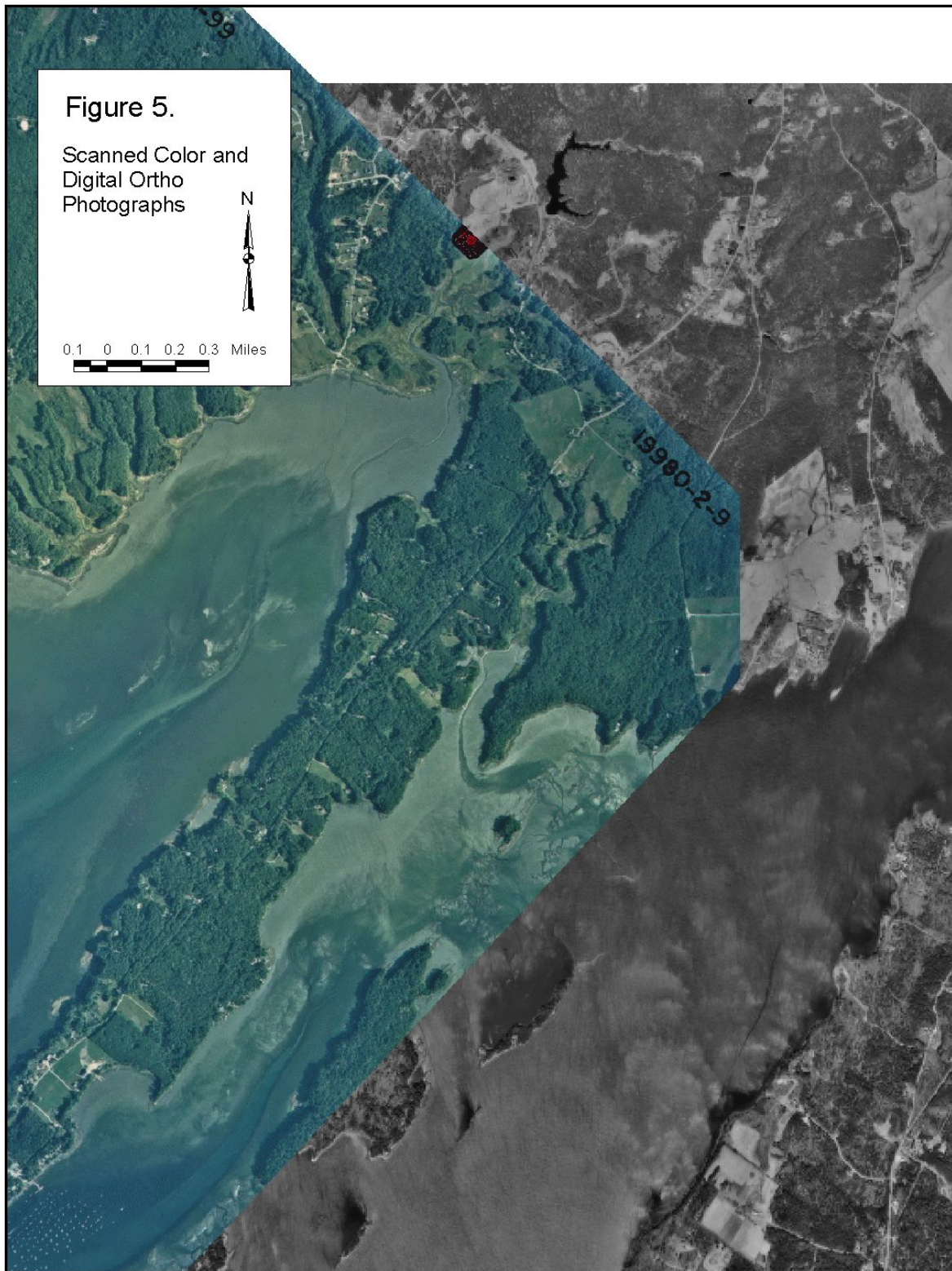
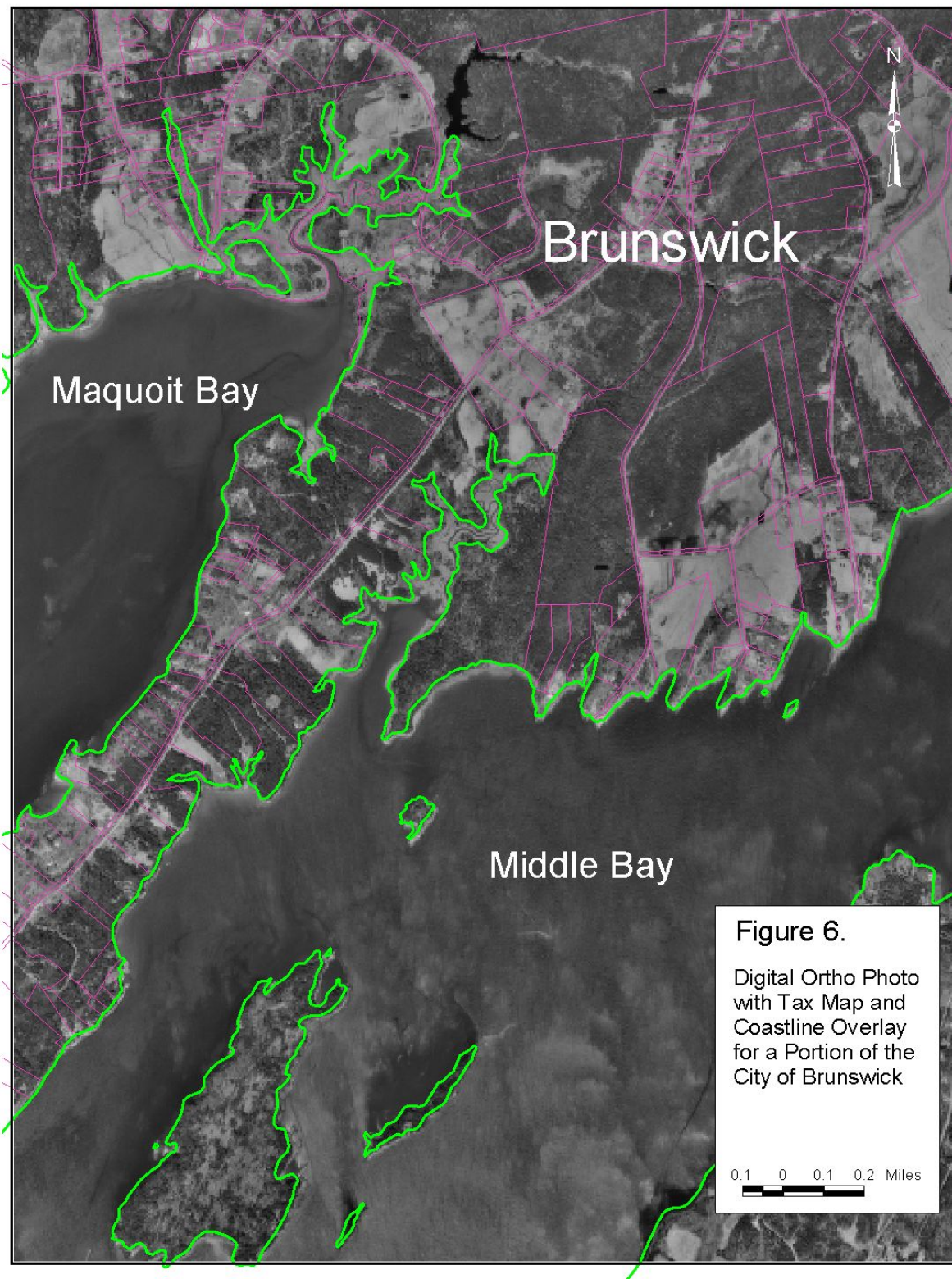


Figure 6.



4.6. Symbolology and Displaying Layers

The key to effective GIS data presentation and map production is the use of good cartographic techniques. This includes such things as symbols that represent the data well and which, when displayed with other associated GIS data (layers), present a clear picture of the data. Most people are familiar with the conventions used in cartography through a life-long exposure to maps. The skills required for the most basic presentations can be acquired by studying examples of good presentations developed by others. A good discussion of the basic elements of cartography or map making can be found at:

<http://www.colorado.edu/geography/gcraft/notes/cartocom/cartocomf.html>

4.7 Querying

Queries are a basic form of GIS data analysis and can be simple or complex. Simple queries can be an effective way of quickly displaying information on a specific area. The most basic query is one where a feature is selected with a click of a mouse button and database information associated with that feature is displayed. In this case features such as points can be identified individually in an interactive manner.

An example of a simple query is the case where all of the features of a like type in a specific geographic area are identified. With a good GIS this can be done interactively by specifying geographic limits, or bounds, and then specifying the value(s), or codes, associated with the feature of interest. As an example, if one wanted to know all of the active *licensed* OBD discharges in the town of Harpswell, the base map polygon which represents the Town of Harpswell could be selected and all OBD locations having a feature attribute “active” requested to be displayed. These locations would appear highlighted automatically on a map displayed on a CRT or printed for a hardcopy reference. Thus, what could otherwise be a tedious process of manually marking a paper map using information from a database not associated with a digital map, is greatly simplified using a GIS. Figure 7 offers an example display resulting from a slightly more complicated query where the status of all licensed OBDs is shown along with active OBDs for surrounding towns.

Although structured queries of a database can be complicated, they can be quite powerful. An example of a relatively complicated query is given in Figure 8. In this case the question is: “What is the relationship between geometric means of the concentration of bacteria and potential pollution sources that have been identified.” In this hypothetical case, the drainage area for the Quahog Bay side of Cundys Harbor was used to identify pollution sources that could potentially affect the water quality of Quahog Bay. These pollution sources are shown as orange triangles. While these are not actual pollution sources in this case, the example shows the power of the selection process and the visual association that can be made with fecal coliform concentrations at monitoring stations that are shown as graduated green and red circles.

Figure 7.

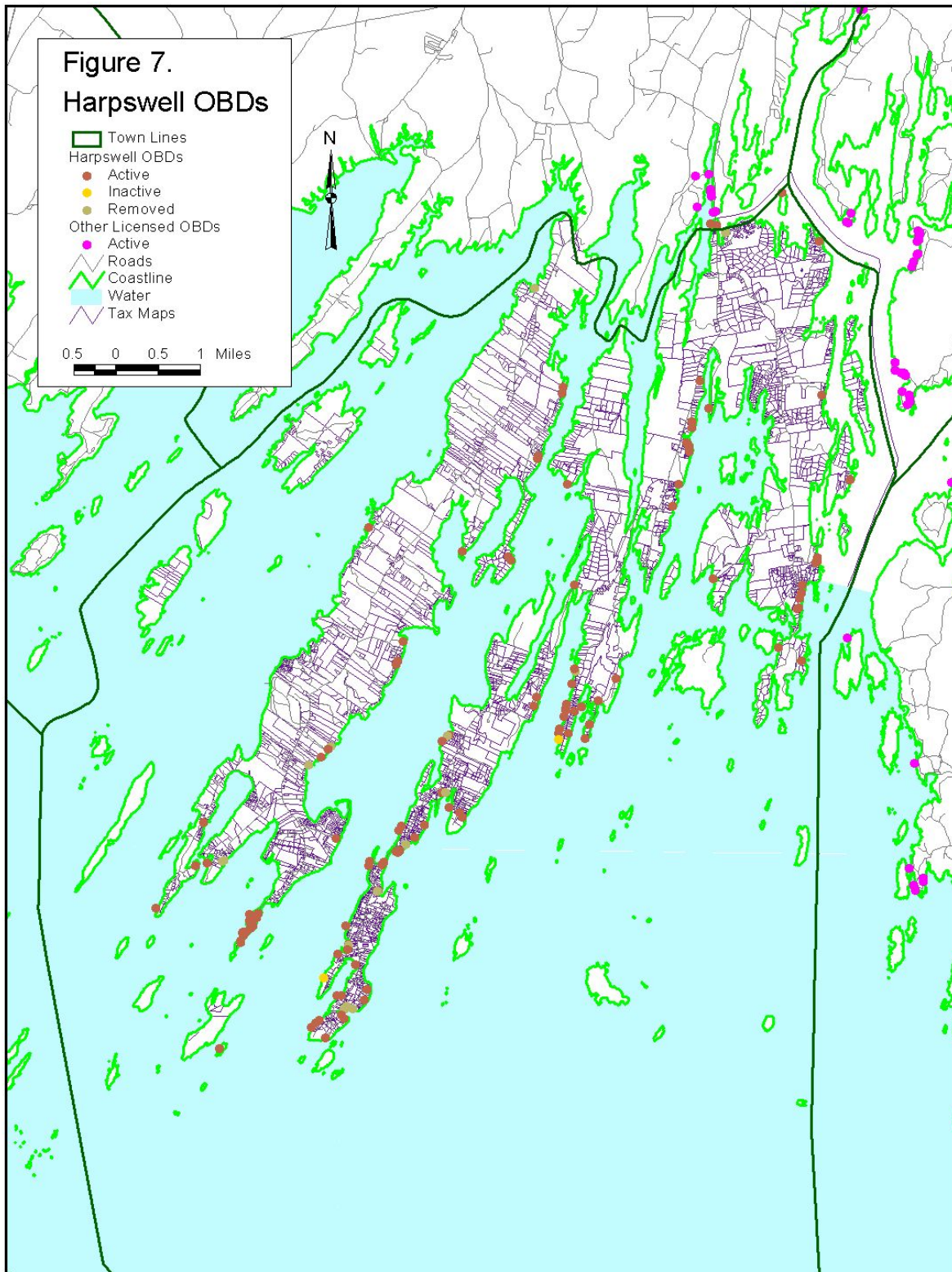
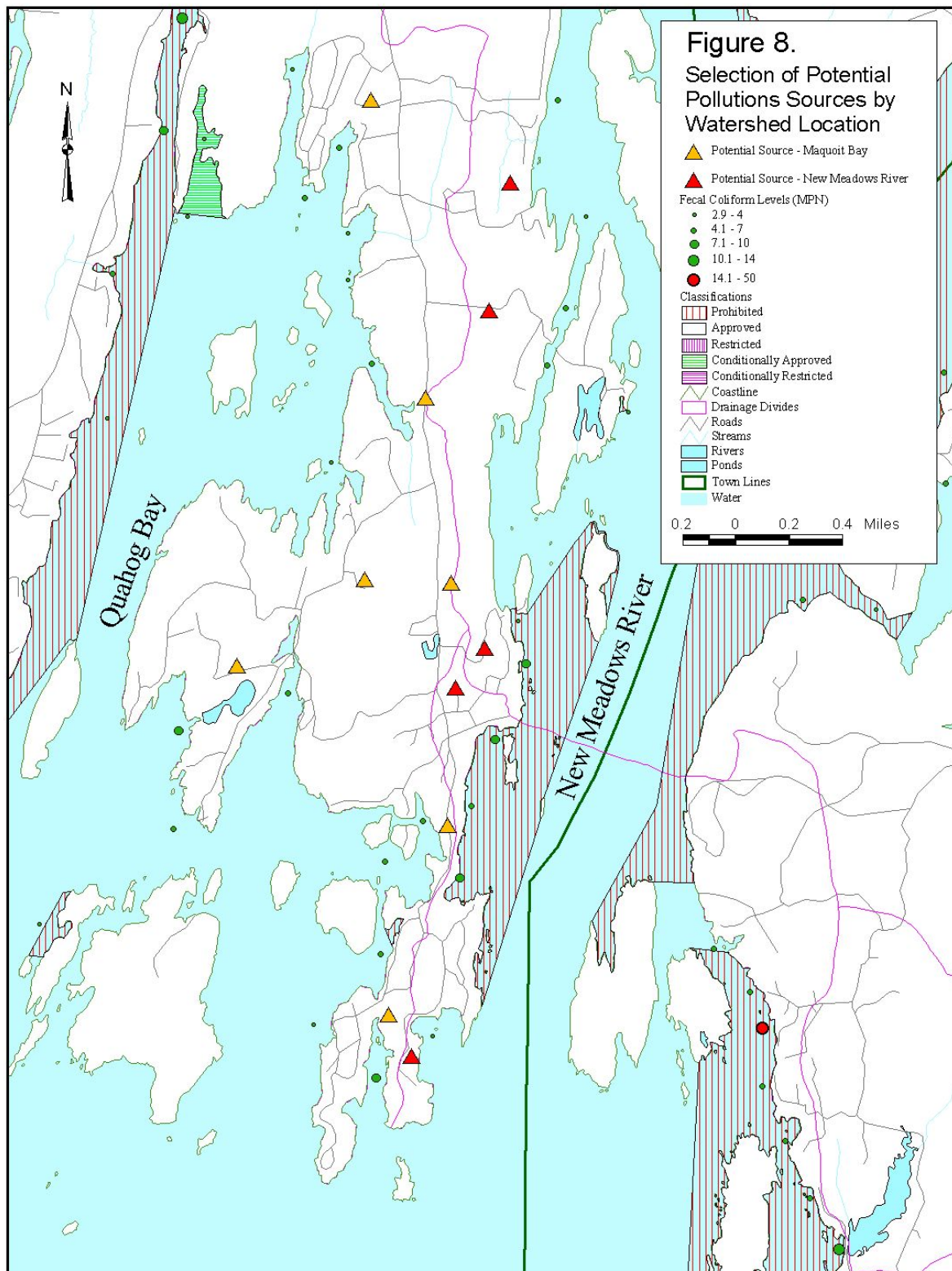


Figure 8.



4.8. GIS Options

GIS software and the computer hardware required for the creation and generation of maps are both sophisticated and expensive. Furthermore, learning how to properly use the software and hardware takes considerable time, even for those with strong computing background. Fortunately for the end-user of GIS, software and hardware designed specifically for viewing GIS outputs is comparatively simple. Several GIS “viewing” software packages, such as ArcView and ArcExplorer, featuring basic GIS capabilities that allow the user to view, but not alter, maps created by others, are readily available and relatively inexpensive compared to full-capability GIS software. These “viewing” software packages allow the user to query the data, display basemaps and desired information on a monitor, and print hardcopies of maps. As the Environmental Systems Research Institute web site explains: “ArcExplorer is a lightweight GIS data viewer developed by ESRI. This freely available software offers an easy way to perform basic GIS functions. ArcExplorer is used for a variety of display, query, and data retrieval applications and supports a wide variety of standard data sources. It can be used on its own with local data sets or as a client to Internet data and map servers”. Additional information on ArcExplorer, as well as the software itself, can be obtained at:

<http://www.esri.com/software/arcexplorer/index.html>

Selection of appropriate viewing software is best made in consultation with the GIS professional with whom the end-user, i.e. municipalities, intends to work. This will ensure coordination and compatibility between producer and end-user.

Recent advances in technology now allow maps to be produced at distant locations and viewed with a web browser via the Internet. In addition some software packages now allow data on an individual’s PC to be displayed with the maps that are provided, or served, from other locations. This technology generally falls under the category of Internet Map Server (IMS) applications. Some good examples can be found at:

<http://apollo.ogis.state.me.us/mapping/mapintro.htm>

Another option that may be considered is the use of Internet connections to remote servers for GIS using “thin client” technology. In this case the full power of GIS can be made available from a powerful server at another location. The PC in the local office or home must have a fast modem connection, or better yet, a or digital subscriber line (DSL), authorization to access the server, and the local application software. With this, GIS operations can be carried out as if the software and computing power of the server was sitting on the desktop.

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Glossary