Options for Mapping Rhode Island's Wetlands

Recommendations Based on User Needs and Technical, Logistical, and Fiscal Considerations

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EXECUTIVE SUMMARY

This investigation into statewide wetland mapping options was conducted at the request of the Department of Environmental Management's Office of Water Resources under a Section 104(b)(3) grant from Region 1 of the U.S. Environmental Protection Agency. We used a multi-step process. First, we assessed the needs and opinions of map users. Out of approximately 500 questionnaires distributed to potential Rhode Island map users (i.e., State and Federal regulators and planners, private consultants, municipal officials, builders, academicians, and private conservation organizations) we received 140 responses. We found that wetland map data are used regularly by a wide range of users; those users clearly prefer up-to-date, large-scale maps with a high degree of positional accuracy. Although RIGIS wetland data are the best available, people are generally dissatisfied with them. The great majority of users feel that improved maps are needed, but many realize that maps will never replace field investigations.

We also consulted 13 regional mapping experts to identify suitable methods to meet various map user needs. The consensus among experts is that color-infrared (CIR) aerial transparencies are best for wetland mapping. Most experts recommended 1:12,000 or larger-scale photographs. The use of satellite imagery for wetland mapping was not recommended. The Digital Transfer Scope—an instrument used to register photo-interpreted delineations to an accurate base map—has recently become available. This new technology, which eliminates several sources of error, has been used successfully in major mapping projects. Most experts recommended creating new maps instead of improving the existing RIGIS wetland dataset. All of the experts felt very strongly that maps should never be used as the sole means for determining wetland regulatory boundaries, regardless of the map scale. A number of experts recommended modeling a Rhode Island wetland mapping project after an ongoing project of the Massachusetts Wetland Conservancy Program.

Based on the input of map users and the advice of map experts, we developed a series of options for improving Rhode Island's wetland map data. These included options for creating new wetland maps and for improving existing maps. After considering the

pros, cons, and relative expense of each option, we developed the following recommendations.

1. We strongly recommend that the State undertake an effort to improve upon existing wetland map resources. This recommendation is based on widespread user dissatisfaction with existing maps and technical problems with those maps. Specifically, we recommend that:
   - 1:12,000-scale, color-infrared aerial photography should be used as the source imagery.
     - If funds are available, 1:5,000-scale, color-infrared aerial photography could be used to create more accurate, detailed maps.
     - If funding is very limited, 1:24,000-scale, color-infrared aerial photography could be used as a substitute.
   - Procedures should be modeled after current wetland mapping efforts in Massachusetts, with the addition of Digital Transfer Scope (DTS) technology.

2. If funding opportunities are extremely limited, and creation of new wetland maps is not feasible, the existing RIGIS wetland dataset should be improved by re-transferring the delineations from the 1988, 1:24,000-scale, black-and-white aerial photographs, using a DTS. However, because of the limitations of map data created from panchromatic, small-scale photography, it would be highly preferable to create new maps.

3. Wetland maps should not serve as the sole source for determining the exact location of regulatory boundaries, regardless of the map scale. However, the larger the scale, the more accurate the map is likely to be and the more useful it will be for land development planning and regulatory guidance. The role large-scale wetland maps might serve in the regulatory process requires further study.

4. The State should produce and distribute maps to encourage use of the most accurate wetland map data available by the widest possible array of users.

5. Maps distributed or endorsed by the State should indicate the level of accuracy, as determined by National Map Accuracy Standards. This precautionary measure could reduce misuse of maps by users who are not aware of the inherent limitations of maps.

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INTRODUCTION

Ever since the Rhode Island Freshwater Wetlands Act and the Rhode Island Coastal Resources Management Council Act were passed in 1971, the desirability of having accurate maps depicting wetland locations and types has been expressed repeatedly by the regulated community, municipal officials, and others. Such maps might be used for a variety of purposes; some of these include construction planning, regulatory reviews, real estate transactions, tax assessment, conservation or open space planning, scientific research, wildlife habitat assessment, Natural Heritage Program inventories, and wetland restoration planning. The lack of "official" wetland maps has been a major criticism of RIDEM that has been voiced at public meetings and in State wetland task forces for 30 years.

In the early 1980's, 1:24,000-scale maps of Rhode Island's wetlands were prepared from 1975, 1:80,000-scale, panchromatic aerial photographs as part of the U.S. Fish and Wildlife Service's National Wetlands Inventory (NWI). NWI maps were distributed by RIDEM (formerly RIDNR) to all municipalities and to others on request. Wetland delineations on these maps were generalized as a result of the small scale of the aerial photographs; wetland classifications were often inaccurate because of very limited field-checking. The minimum map unit varied from 1 to 3 acres. For all of these reasons, the NWI maps could only be used to locate wetlands approximately and for general planning or inventory purposes. A disclaimer on each map stated that it was not intended for determining the limits of regulatory agency jurisdiction.

A more detailed set of 1:24,000-scale, statewide wetland maps was created from 1:24,000-scale, panchromatic aerial photographs taken in 1988. The minimum map unit in this case was ¼ acre. The original purpose of these maps was to assist the Rhode Island Solid Waste Management Corporation in their search for potential sites for a new State landfill, but both RIDEM and RICRMC provided input during the drafting of the wetlands mapping protocol; the hope was that the maps might serve a regulatory purpose as well. Wetland delineations were digitized and entered into the Rhode Island Geographic Information System (RIGIS) and made available to anyone with access to

RIGIS. Although the RIGIS wetland maps are more recent, more detailed, and more accurate than the NWI maps—and far more detailed than wetland maps in most other states—the methodology used to transfer delineations from photographs to base maps was imprecise and led to significant positional errors. Users of RIGIS maps have pointed to frequent errors in wetland classification as well. Clearly, the demand for accurate wetland maps that can serve a wide range of purposes has not yet been satisfied. This report presents specific recommendations for creating more accurate maps. Recommendations are based on wetland map user needs, the advice of local and regional mapping experts, previous investigations into wetland mapping options in other states, and fiscal considerations.

METHODS

This investigation into wetland mapping options was a multi-step process. First, we assessed the needs and opinions of map users. Next, we consulted mapping experts within Rhode Island and in other areas of the Northeast to identify available methods to meet various map user needs. Then we determined the relative cost of each potential mapping method. Finally, we developed specific recommendations based on the previous steps.

Before attempting to create more accurate wetland maps, it is important to understand the needs and opinions of the agencies, companies, organizations, and individuals who would use those maps. To that end, we developed a questionnaire and distributed it to approximately 500 wetland map users throughout the State (Appendix A). Recipients included engineering and environmental consultants; State regulators and planners; Federal regulators and planners; municipal officials (i.e., directors of public works, engineers, building officials, conservation commissioners, planners, and tax assessors); watershed associations; realtors; builders; academicians; and private conservation organizations. The questionnaire was designed to determine the current uses of wetland maps, the specific problems people have with those maps, and what users would require of improved maps.

Our interviews with mapping experts focused primarily on states and programs that have recently been involved in the creation of wetland maps. Experts were asked for their opinions about source imagery, delineation techniques, data transfer processes, data quality assurance, field verification, and map distribution options. They were asked to recommend the best available methods for creating wetland maps, cost-effective alternatives, and techniques for improving the current RIGIS wetland maps. Experts were also questioned about the use of wetland maps for regulatory purposes.

We obtained approximate cost estimates for the proposed mapping methods by conferring with contractors and mapping experts. Cost estimates for statewide wetland mapping efforts have previously been reported for Massachusetts (MacConnell et al. 1989, MacConnell et al. 1992); these sources were also used to derive certain cost estimates for Rhode Island.

RESULTS

Map user questionnaire

Out of the approximately 500 questionnaires that were distributed, we received 140 responses from 8 user groups (Figure 1). The responses to each question are described in Appendix B. For each question, we present the results for the entire population of respondents. For the majority of the questions we also provide results for the five user groups with the largest number of respondents: Town 1, Town 2, Consultant, S&F Reg, and S&F Plan. The number of respondents in the other three user groups was too small to warrant analysis of results by individual group; for that reason, we included those results only in the "overall" analyses (see Appendix B).

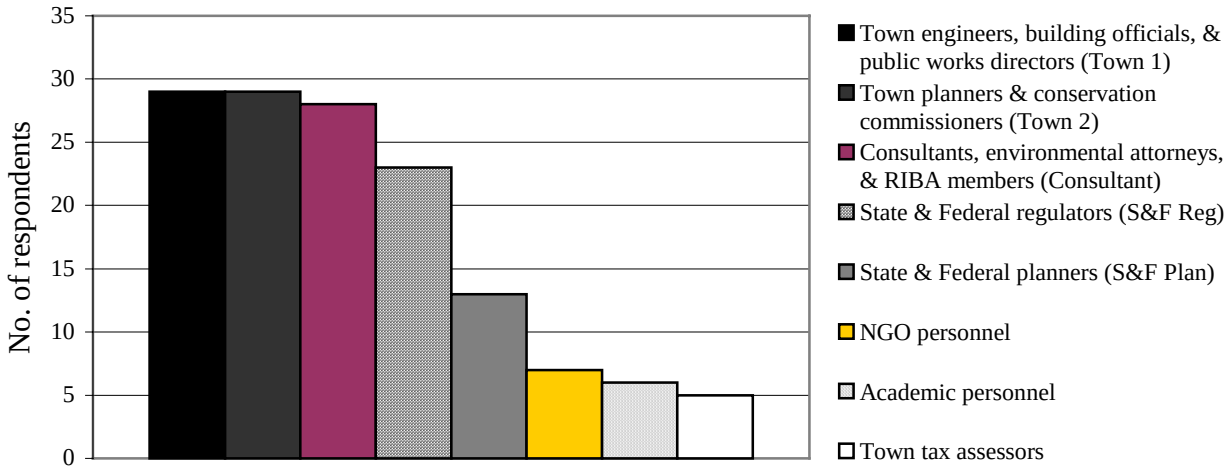

Figure 1. Distribution of survey respondents by map user group.

The following section summarizes the results of the map user survey. Comments are provided in the same order in which the questions occurred in the questionnaire (Appendix A). Refer to Appendix B for a more detailed presentation of survey results.

Current use of wetland maps and data

1. Eighty-nine percent of the respondents use wetland maps or data in their work.

2. In general, USGS topographic maps, the Rhode Island Soil Survey (RISS), and aerial photos are used most often to obtain wetland information; National Wetland Inventory (NWI) maps are used the least. Two-thirds of the respondents use wetland maps or data at least weekly. Regulators, consultants, and planners use such data most frequently.
3. The RISS is considered most accurate among wetland maps, followed by topographic maps and RIGIS wetland and land use maps. Aerial photos and digital orthophotos were viewed as providing more accurate information than any wetland maps, on average. This implies that many people trust their own photo-interpretation ability more than maps made by others.
4. Nearly half of the respondents use aerial photos owned by their organization or agency; 40% use photos owned by the State. The great majority of the respondents said that improving access to State-owned photos was important. Most people feel that statewide aerial photos should be taken every 2-5 years.
5. Topographic maps, RISS, and aerial photos are the tools that are most often used for wetland regulatory purposes.
6. RIGIS wetland maps are used more than any other data source for calculating wetland statistics and for GIS analyses; they also are often used for determining wetland type.
7. Forty percent of the respondents said that existing maps and data sources are inadequate; 62% of regulators feel that way.
8. Ninety percent of the respondents have Internet access.
9. Seventy-one percent have access to ArcView or other GIS software.

Use of RIGIS digital wetland maps

10. Planners generally are more satisfied with RIGIS map scale than other respondents. Most groups feel that the scale of RIGIS maps is usually or sometimes adequate.
11. Fewer than 30% of the respondents said that RIGIS maps were usually accurate in classification. Regulators appeared to be least satisfied, along with some town planners and conservation commissioners.
12. Only 25% of the respondents said that the positional accuracy of RIGIS maps was usually adequate; none of them was “always” satisfied. Consultants and regulators were least satisfied.
13. Only one-quarter of the respondents found the age of RIGIS map data to be adequate most of the time. Age seemed to be a significant issue for State and Federal planners and consultants.

Wetland map data needs

14. Seventy percent of the regulators want map scales to be 1:12,000 or larger. Town officials (nearly 50%) want map scales of 1:2,400 or larger. All groups would favor the largest scale possible (1:2,400) if it were available.
15. Classification accuracy is most important to regulators, then to consultants; it is least important to town officials and State and Federal planners.
16. Nearly two-thirds of the respondents said they need positional accuracy within ± 6.7 feet. Consultants and town officials feel they need highly accurate maps; State and Federal planners are least concerned about positional accuracy.

17. Hard-copy maps were preferred by most groups (except State and Federal planners).
18. Overall, seventy-six percent of the respondents felt that improvement of wetland map data should be a State priority. State and Federal planners (92%) and town engineers, directors of public works, and building officials (83%) felt most strongly about this, but all individual groups scored 68% or higher.

How improved wetland map data would assist map users in their work

19. More than 50% of the respondents felt that improved wetland maps would help them extensively or quite a bit in their work; regulators would benefit most, but town officials also see great benefits.
20. Most users said they would use improved maps at least weekly; more than 80% of the regulators were in that category.
21. People were most dissatisfied with current maps for review of wetland development plans, permit applications, and edge determination.

Additional comments

22. Key issues raised in additional comments (out of 82 total):
    - positional accuracy should be better (16 respondents);
    - maps cannot replace field visits (10 respondents); and
    - maps should be updated more often (5 respondents).

Map expert interviews

We consulted 12 mapping experts from throughout the Northeast, including specialists in wetland delineation, Geographic Information Systems, and remote sensing technology (Appendix C). Our recommendations are based, to a significant degree, on input from wetland map makers in Massachusetts. The Northeast (Region 5) Office of the U.S. Fish and Wildlife Service's National Wetlands Inventory is based in Hadley, Massachusetts. In addition, highly accurate, large-scale, statewide wetland maps are currently being produced by the Massachusetts Department of Environmental Protection's Wetland Conservancy Program (WCP). Researchers at the University of Massachusetts, in Amherst, developed the methodology for that project. The UMass Natural Resources Assessment Group (NRAG), a prominent team of regional mapping experts, is conducting the aerial photo-interpretation for WCP; members of NRAG also have mapped wetlands in Rhode Island on several occasions. All of these groups have supplied us with advice, insights, map products, and pertinent reports. A summary of the major issues addressed during the interviews with mapping experts is provided below.

Source imagery

- The consensus among experts is that color-infrared (CIR) aerial transparencies are best for wetland mapping. Soil moisture is easier to detect in CIR photos than in black-and-white (i.e., panchromatic) photos, thereby enhancing accurate determination of wetland type and boundaries.
- Recommended scales of source imagery ranged from 1:1,200 to 1:40,000. 1:1,200-scale maps would be extremely accurate, and could be used for many purposes, but would be costly to produce. 1:40,000-scale maps would have limited uses (e.g., wetland inventories, statewide planning) but would be inexpensive to produce.
- Most experts recommend using 1:12,000-scale aerial photography for statewide mapping, because:
  - it is possible to delineate very small wetlands (e.g., many vernal pools) at this scale;
  - this scale is being used to map wetlands statewide in Massachusetts; and
  - studies focusing on the pros and cons of mapping wetlands at various scales have concluded that 1:12,000 is most efficient and cost-effective.
- Several experts felt strongly that, if funding is limited, it is better to opt for a smaller scale than to sacrifice CIR for black-and-white photography.
- All wetland map experts agreed that photography should be taken in the spring, before trees leaf out. This enables examination of soil moisture at the wettest time of the year.
- Although the classification process with satellite imagery can be cheaper and faster—because it is automated—the cost of such imagery with an adequate spatial resolution (e.g., IKONOS) could be prohibitive.
- In general, satellite imagery is not recommended for wetland mapping, because:
  - classifications and boundary determinations are based on computer-automated processes, rather than the informed conclusions of experienced wetland delineators;
  - the classification process is not based on stereo (i.e., three-dimensional) interpretation of images, as with aerial photography;
  - classification accuracy (i.e., identification of wetland) using satellite imagery is not likely to exceed 80%; and
  - distinguishing among wetland types is likely to be even more problematic.

Using a Digital Transfer Scope (DTS)

Note: See Appendix D for more information about what a DTS is, and how it functions.

- Use of DTS technology has the potential to reduce the overall costs of mapping. A scope is relatively inexpensive (approximately $15,000 to $20,000 per unit), and it eliminates the need for costly scanning, digitizing, geo-referencing, and rubber-sheeting of delineations.
- DTS technology also has the potential to reduce map error by eliminating many of the steps associated with the transfer of delineations into a digital format (i.e., the recompilation process).

- A few map experts that have not used a DTS expressed reservations because it is a relatively new instrument. However, map experts that have used DTS technology highly recommend it. DTS's are used by Region 5 of the U.S. Fish and Wildlife Service's National Wetlands Inventory.
- DTS's could be used to create new statewide wetland maps or to improve the positional accuracy of the existing RIGIS wetland dataset.
- DTS optics appear to be of high quality.

Improving the positional accuracy of the existing RIGIS dataset

- Most map experts recommended creating new maps instead of improving the positional accuracy of the existing RIGIS wetland dataset.
- This alternative would address only the correction of errors in positional accuracy associated with the original transfer of delineations to a digital format. The underlying—and perhaps incorrect—assumption is that the classifications and delineations on the original, annotated, 1988, 1:24,000-scale, aerial photographs are sufficiently accurate.
- Because CIR photos were not used as the source imagery, the accuracy of wetland classifications and boundary delineations may have been compromised to some degree.
- Positional accuracy could be improved to a greater degree by creating new maps at larger scales (e.g., between 1:1,200 and 1:12,000).
- The RIGIS wetland dataset is already 13 years old; for this reason most map experts recommend creating new maps.
- Several of the experts felt that, considering the amount of effort required to improve the positional accuracy of existing maps, it would make more sense to create new maps.
- After creation of the original RIGIS wetland dataset, significant effort was expended to correct errors (see Baker et al. 1994). If an attempt was made to re-transfer the original delineations, many of those errors would need to be identified and corrected once again.
- Despite the problems associated with this alternative, it could be done more cheaply and quickly than alternatives involving the creation of new maps.
- The RIGIS wetland dataset would need to be registered to the most accurate base maps available. Currently, the 1997, 1:5,000-scale, digital orthophotographs provide the most accurate base.
- DTS technology would provide the best means for improving the existing RIGIS dataset.

Using maps to identify regulatory boundaries

- All of the wetland mapping experts felt very strongly that maps should never be used as the sole means for determining regulatory boundaries, regardless of the scale of the map.
- New York is the only state in the northeast that has created official regulatory maps. However, the maps are used simply to indicate the location of jurisdictional wetlands $\geq$ 12.4 acres; for individual projects, boundaries still must be identified in the field by agency biologists.

- One GIS expert suggested that the utility of maps for regulatory guidance purposes could be enhanced. For example, RIGIS soils data could be combined with wetland data to generate a "confidence level" for the certainty that a given polygon is actually wetland.
- Another GIS expert felt that the possibility of using large-scale (i.e., 1:5,000-scale or larger) wetland maps for jurisdictional purposes should be left open for discussion.

Cost-saving alternatives

- The best way to cut costs when creating new maps is to obtain imagery at a smaller scale. The source imagery would be cheaper and the cost of delineating and transferring those images would be reduced because there would be fewer exposures. However, experts stressed that using smaller scales would limit the positional and classification accuracy of maps and would decrease the usefulness of maps for finer-scale applications (e.g., development planning, regulatory review).
- Costs could be reduced by using a DTS.
- Costs could be reduced by limiting the minimum mapping unit (MMU). The Massachusetts WCP limits their MMU to ¼ acre, even though much smaller wetlands could be mapped at the scale they use (1:12,000).
- There are other groups that might have an interest in obtaining new imagery for other purposes; costs could be shared with them. Such groups might include RIDEM Divisions of Forest Environment, Fish and Wildlife, and Planning and Development; Rhode Island Natural Heritage Program; RIDEM Office of Strategic Planning and Policy; RI Department of Transportation; RI Coastal Resources Management Council; U.S. Environmental Protection Agency; U.S. Fish and Wildlife Service; U.S. Natural Resources Conservation Service; The Nature Conservancy; Save The Bay; and the Office of Statewide Planning.
- It might be possible to reduce short-term costs by "tiling" the State and purchasing aerial photographs separately for each tile, as funding allows. However, long-term costs would be increased because it is more efficient for a contractor to obtain all of the images at once. From a logistic and economic standpoint, it is better to tile by rectangular areas that correspond with north-south flight lines. The convoluted edges of watershed or municipal boundaries would decrease the efficiency and increase the costs of tiling. There may be additional problems with this approach. For example, there may be significant hydrologic differences among the years in which the imagery is obtained; this could result in photo-interpretation inconsistencies. Most map experts agreed that, although tiling can be convenient in large states, it may not be necessary in a state with less land area, such as Rhode Island.

Miscellaneous recommendations and comments

- One expert recommended using the Cowardin et al. (1979) classification system used by NWI, including special modifiers. This could increase the usefulness of the maps (e.g., for restoration planning), and wouldn't require much additional effort.
- Some experts recommended selecting a pilot area in Rhode Island in which to test different mapping methods, and different scales and types of photography. This technique has been used in other states (MacConnell et al. 1989, MacConnell et al. 1992, Tiner and Smith 1992).

- The project staff should be kept small—not only to reduce costs, but also to ensure consistency.
- Several experts recommended adapting methods currently being used in Massachusetts by the WCP to create statewide wetland maps (Appendix E).
- Several experts stressed the need for field verification of delineations. By verifying boundaries and wetland types in the field, maps can be made much more accurate. A representative of the Massachusetts WCP stated that 5-10% of the wetland polygons on their maps have been verified in the field, and that more field verification would result in even greater map accuracy.

DISCUSSION AND CONCLUSIONS

Factors affecting wetland map accuracy

Many factors affect map accuracy. Some of those factors can be controlled, to varying degrees, during the creation of maps. Others are inherent limitations that must be taken into consideration as the maps are used. To avoid misuse of maps, it is paramount for users to understand that maps are abstractions of reality; boundaries and other features of maps are merely graphic representations of those features on the ground. The following paragraphs briefly describe the primary factors that affect wetland map accuracy; resulting errors may be cumulative.

Photo-interpretation error

Although wetland boundaries are traditionally represented on maps by a thin line, such distinct boundaries rarely occur in nature. In reality, wetland-upland edges are often indistinct gradients. It is the task of the photo-interpreter to draw a line at an appropriate point within that gradient using his/her best judgement. Determination of wetland boundaries can be difficult even for experienced wetland biologists conducting site visits. Those boundaries are much more difficult to determine using only aerial photographs. Determination of wetland type can also be problematic during photo-interpretation. The best way to reduce map error associated with these problems is to conduct extensive field verification of photo delineations. However, it is not possible to verify every portion of every wetland edge. Field verification efforts are often reserved for the wetland types and boundaries that are known to be difficult to determine (e.g., slope wetland, evergreen forested wetland). Thus, some amount of photo-interpretation error is to be expected.

Recompilation error

Aerial photographic images on which delineations are made contain varying amounts of distortion due to camera lens curvature, tip and tilt of the aircraft, and differences in terrain elevation. A Zoom Transfer Scope (ZTS) has traditionally been used to register delineations to a planimetrically-correct base map, thereby correcting those distortions. This transfer, or recompilation, process involves a number of steps in which error may be introduced. For

example, delineations may be incorrectly traced onto the base map. Digitization of the base map may introduce additional errors. Instead of using a ZTS, delineations are sometimes digitally scanned; the digital images are then georeferenced and rubbersheeted to a base map using an algorithm that incorporates elevation data. However, the accuracy of this process depends to a large extent on the accuracy of the elevation data associated with the base map.

New technology—the Digital Transfer Scope (DTS)—has recently become available. The DTS is used to eliminate steps (and therefore potential sources of error) by integrating the recompilation process into the photo-interpretation process. See Appendix D for more details about DTS technology.

Cartographic error

One of the measures of map accuracy is how closely the coordinates of map features match real-world coordinates of the same features on the ground. To that end, the Federal Geographic Data Committee has endorsed National Map Accuracy Standards (NMAS). Under those standards, on maps produced at scales larger than 1:20,000 (e.g., 1:12,000) 90% of all features should fall within $1/30^{th}$ inch of their true location. On maps produced at scales smaller than 1:20,000 (e.g., 1:24,000), 90% of all features should fall within $1/50^{th}$ inch of their true location. Thus, 90% of wetland boundaries on a map produced at a scale of 1:12,000 should fall within 33.3 feet of their true location on the ground. For a map produced at 1:2,400-scale, that margin of error would be reduced to 6.7 feet.

The amount of error, as measured by NMAS, stems only from cartographic issues. As indicated above, large-scale maps normally have greater positional accuracy than small-scale maps. The error introduced by the width of a photo-interpreter's pen point varies with the scale at which the mapping occurs. For example, the width of a very fine pen line (i.e., 0.18 mm) used to delineate wetlands on 1:12,000-scale aerial photographs translates to more than 7 feet on the ground; that same pen line on 1:40,000-scale photographs would be approximately 23 feet wide on the ground.

There is another potential error associated with scale: the omission of very small map features. It is possible to map very small wetlands on very large-scale maps, but not on small-scale maps. For example, many vernal pools can be mapped using 1:5,000- or 1:12,000-scale photographs; they cannot be reliably mapped using 1:24,000-scale photographs. Mapmakers

generally declare a minimum mapping unit (MMU) before photo-interpretation. The MMU may be dictated by the constraints of the scale of the source imagery or by the project budget; mapping can be done more quickly and efficiently when very small polygons are excluded from the process. The MMU of the Massachusetts WCP is ¼ acre. NWI maps also limit isolated polygons to ¼ acre; the smallest polygons within wetlands generally range from 1 to 3 acres in size.

Using maps to identify regulatory boundaries

Due to all of the potential sources of error, maps should never be used as the sole means to identify wetland regulatory boundaries. That statement represents the opinion of the great majority of mapping experts consulted during the course of this study. A map cannot provide the same degree of accuracy, or be as comprehensive, as field investigations can, regardless of the scale of the map. The original intent of the Massachusetts WCP's mapping effort was to create statewide wetland regulatory maps. After experimentation and deliberation, Massachusetts DEP concluded that, although their map products are highly accurate, they should not be used as the sole source for identifying regulatory boundaries. Their printed maps bear disclaimers to that effect.

Among the Rhode Island map users surveyed, opinions differed on the use of wetland maps for the identification of regulatory boundaries. Many people seemed to be aware of the inherent limitations of maps; these users turn to maps mainly for general information, guidance, and planning purposes. Others desire maps that would allow them to forego boundary determinations in the field.

Despite the above caveats, high-quality wetland maps are extremely important tools for a variety of purposes. High-quality wetland maps can be used to increase the accuracy and reliability of planning efforts by municipal personnel, builders, consultants, and engineers. They can also be used to indicate wetland presence, type, and extent. Other potential uses of wetland maps include functional assessments, landscape and watershed analyses, development of habitat management plans, land acquisition planning, and wetland trend analyses.

Limitations of the existing RIGIS wetland maps

The most common complaint about RIGIS wetland maps—expressed by map users and map experts alike—is the degree of positional inaccuracy in the dataset. Unfortunately, a transfer scope was not used during the recompilation process. To quantify the resulting degree of positional shift, researchers at URI re-transferred delineations within a small area of southern Rhode Island using a Zoom Transfer Scope (ZTS) (Baker et al. 1994). Comparison of the new dataset with the original RIGIS dataset revealed a 5- to 50-meter shift; the shift was not unidirectional. Field biologists have reported positional shifts of up to 200 feet. RIDEM biologists have found wetlands where none are indicated on the RIGIS maps and upland where isolated wetlands are indicated; they have also reported classification inaccuracies.

In 1993, significant efforts were made to review, correct, and update the existing RIGIS wetland dataset (Baker et al. 1994). The procedures used to accomplish those tasks primarily involved proofing the statewide maps against the delineated aerial photographs and making necessary corrections within ARC/INFO. Errors fell into 7 categories: (1) missing polygons, (2) miscoded polygons, (3) split polygons, (4) poorly digitized polygons, (5) uncoded polygons, (6) neatline mismatch, and (7) positional shift. The first six types of error were corrected; the seventh, which was a byproduct of the recompilation process, was considered to be beyond the scope of the project.

There are additional problems with the RIGIS wetland maps. The source imagery for the photo-interpretation was 1:24,000-scale, black-and-white aerial photography. Most map experts recommend 1:12,000 or larger-scale photography; this would enable more accurate and detailed mapping (in terms of classification and position) and would enhance detection of very small wetlands (e.g., vernal pools). Map experts almost unanimously stressed the need for color-infrared (CIR) photography. CIR photos greatly enhance the ability to detect soil moisture, and thus to accurately delineate wetland boundaries.

Although the current RIGIS wetland maps constitute the best data available in the State, they are apparently not meeting the needs of map users. When map users were asked how often the positional accuracy of the RIGIS wetland maps met their needs, only 25% responded “usually” (Appendix B). None of the map users answered “always.” Regulators and private consultants, in particular, were dissatisfied with RIGIS wetland positional accuracy. Only 30% of all respondents were “usually” satisfied with the age of the data; again, none of them was

"always" satisfied. Many of the map users also reported dissatisfaction with map scale and classification accuracy.

Options

Below is a series of options for re-mapping Rhode Island's wetlands and for improving the existing RIGIS wetland maps. Options are listed in descending order of recommendation. Each description contains a brief overview, a step-by-step list of procedures, a list of pros and cons based on the input of map users and mapping experts, and a breakdown of projected costs. Cost estimates are approximations based on input from regional mapping experts; studies that compared wetland mapping options and costs at different scales and levels of effort (MacConnell et al. 1989, MacConnell et al. 1992, Tiner and Smith 1992); and quotes for new imagery from a private contractor (J.W. Sewall Co.). The figures are provided to enable comparisons among the different methods; more detailed cost estimates should be obtained before pursuing any of the options.

Option A. Create new wetland maps

Description

This option is based on methods developed for the Massachusetts Wetland Conservancy Program (WCP) to create high-quality, large-scale, statewide wetland maps (see Appendix E). However, we recommend that WCP methods be modified to incorporate new technology—i.e., a Digital Transfer Scope (DTS)—which was not available at the inception of their mapping efforts. A DTS reduces the potential for map error by eliminating steps from the transfer process. Use of a DTS also has the potential to expedite the mapping process and to make the process more cost-effective. For DTS specifications and an overview of the technology, see Appendix D. Option A has been divided into three sub-options to reflect different scales of source imagery: 1:12,000, 1:5,000, and 1:24,000.

Procedures

- Obtain new statewide aerial photography.
- Purchase 1-3 Digital Transfer Scopes from Optem (sole source).
- Purchase 2-5 GIS workstations.

- View the following data, simultaneously, through the DTS:
  - a base map that has been registered to the latest State orthophotography;
  - the digital RIGIS wetlands dataset as a shape (.shp) file;
  - the digital RIGIS soils dataset as a shape (.shp) file; and
  - the aerial photography, in stereo.
- Using the DTS extension for ArcView, "warp" the base map to fit the aerial photography.
- While viewing in stereo, delineate wetland polygons on-screen, using the existing RIGIS wetland and soils datasets as collateral information.
- Code the attributes table of the resulting GIS coverage, while the photo-interpretation is being conducted.
- "Warp" the delineations back into planimetric space.
- Conduct field verification and quality assurance checks and make any necessary corrections.
- Prepare data for distribution:
  - hardcopy maps (wetland boundaries on top of digital orthophotography); and
  - raw digital data (.e00 files, shape files).

Pros and cons of Option A

- **PRO**: The best available wetland maps (i.e., RIGIS wetland maps) do not have the positional accuracy required by most users.
- **PRO**: In general, map users perceive the RIGIS wetland maps as being outdated.
- **PRO**: Overall, map users require wetland maps that are larger-scale than what is currently available.
- **PRO:** Most map users desire wetland maps with greater classification accuracy.
- **PRO**: Map experts familiar with the RIGIS wetlands dataset have advised against trying to improve that dataset; they state that improving existing datasets would require a high level of effort, effort that is better expended toward the creation of new maps.
- **PRO**: This option is based on interpretation of CIR photos, which are vastly superior to black-and-white photos for wetland delineation.
- **PRO**: The CIR photos would be useful for a wide variety of other purposes; therefore, it might be possible to find groups or agencies willing to share the costs of obtaining the imagery.
- **PRO**: Mapping wetlands using similar methods and CIR photography is being done successfully in Massachusetts; their methods can be adapted and applied successfully within Rhode Island.
- **CON**: This option is more expensive than the others.

Sub-option A-1: 2-year project using current 1:12,000-scale imagery

Sub-option A-1: Estimated costs[1]

$45,000	Aerial photos (1:12K CIR transparencies)
18,000	1 Optem DTS + accessories
15,000	3 GIS Workstations + software and accessories
10,000	Equipment and supplies ($5,000/year)
146,000	1 Project Manager (2 years @ $50,000 + benefits[2])
131,400	1 Wetland Delineator (2 years @ $45,000 + benefits)
102,200	1 GIS Technician (2 years @ $35,000 + benefits)
175,200	2 Wetland Field Biologists (2 years @ 30,000 + benefits)
15,000	Travel to field sites ($7,500/year)
296,010	Overhead @ 45%
$953,810	**Total**

[1]Costs of map printing and distribution not included.
[2]Benefit rate averaged to 46% of salary for all positions.

Sub-option A-1: Pros and cons

- **PRO**: 70% of the State and Federal regulators surveyed said that 1:12,000-scale maps would suffice for their needs.
- **PRO**: This scale is larger than the scale of any of our current wetland maps.
- **PRO**: This scale is the most frequently and highly recommended scale by map experts.
- **PRO**: This scale is being used to create accurate, detailed wetland maps in Massachusetts.
- **PRO**: This scale is more cost-effective than Sub-option A-2.
- **PRO**: Even many small wetlands (e.g., vernal pools) could be mapped.
- **CON**: The vast majority of respondents suggested that they would prefer a scale as large as 1:2,400; Sub-option A-2 could better meet those needs.
- **CON**: Certain map users might be satisfied with smaller-scale maps (e.g., 1:24,000).

Sub-option A-1: Conclusions

- This sub-option appears to provide the best combination of map accuracy, map detail, and cost effectiveness.

Sub-option A-2: 3-year project using current 1:5,000-scale imagery

Sub-option A-2: Estimated costs[1]

$164,000	Statewide aerial photos (1:5K CIR transparencies)
54,000	3 Optem DTS's + accessories
25,000	5 GIS Workstations + software and accessories
15,000	Equipment and supplies ($5,000/year)
219,000	1 Project Manager (3 years @ $50,000 + benefits[2])
591,300	3 Wetland Delineators (3 years @ $45,000 + benefits)
153,300	1 GIS Technician (3 years @ $35,000 + benefits)
262,800	2 Wetland Field Biologists (3 years @ 30,000 + benefits)
22,500	Travel to field sites ($7,500/year)
678,105	Overhead @ 45%
$2,185,005	**Total**

[1]Costs of map printing and distribution not included.
[2]Benefit rate averaged to 46% of salary for all positions.

Sub-option A-2: Pros and cons

- **PRO**: There is an economy of scale with this sub-option. Even though there are more than five times the number of aerial photos statewide at 1:5,000 as there are at 1:12,000, the cost of producing maps is only slightly over double.
- **PRO**: The vast majority of respondents suggested that they would prefer a scale as large as 1:2,400; this sub-option approaches the preferred scale most closely.
- **PRO**: Maps produced at this scale would be state-of-the-art.
- **PRO**: Certain map experts feel that 1:5,000- or larger-scale maps could be used for regulatory purposes.
- **PRO**: The 1:5,000-scale CIR photos would be useful for a wide variety of other purposes; therefore, it might be possible to find groups or agencies willing to share the costs of obtaining the imagery.
- **PRO**: The small wetlands (e.g., vernal pools) could be mapped.
- **CON**: Certain map users might be satisfied with smaller-scale maps (e.g., 1:12,000 or 1:24,000).
- **CON**: In certain situations, mapping at such a large scale may actually make wetland identification and delineation more difficult.
- **CON**: This sub-option is more than twice as expensive as Sub-option A-1.
- **CON**: The expectations of map users for such large-scale maps might be difficult to satisfy.

Sub-option A-2: Conclusions

- Although this sub-option is more expensive than the previous one, the benefits of such large-scale mapping might offset the additional costs.

Sub-option A-3: 1-year project using current 1:24,000-scale imagery

Sub-option A-3: Estimated costs[1]

$18,000	Statewide aerial photos (1:24K CIR transparencies)
18,000	1 Optem DTS + accessories
15,000	3 GIS Workstations + software and accessories
5,000	Equipment and supplies ($5,000/year)
73,000	1 Project Manager (1 year @ $50,000 + benefits[2])
65,700	1 Wetland Delineator (1 year @ $45,000 + benefits)
51,100	1 GIS Technician (1 year @ $35,000 + benefits)
87,600	2 Wetland Field Biologists (1 year @ 30,000 + benefits)
7,500	Travel to field sites ($7,500/year)
153,405	Overhead @ 45%
$494,305	**Total**

[1]Costs of map printing and distribution not included.
[2]Benefit rate averaged to 46% of salary for all positions.

Sub-option A-3: Pros and cons

- **PRO**: Certain map users might be satisfied with the small scale of these maps.
- **PRO**: This sub-option is substantially more cost-effective than the others.
- **CON**: The vast majority of respondents suggested that they would prefer a scale as large as 1:2,400; Sub-options A-1 and A-2 would better meet those needs.

Sub-option A-3: Conclusions

- Although Sub-options A-1 and A-2 are preferable to this sub-option, using 1:24,000-scale CIR photos and a DTS would enable production of maps that are superior to existing RIGIS wetland maps.

Option B. Improve the positional accuracy of RIGIS wetland maps

Description

This option involves correcting the positional accuracy of the existing RIGIS wetland dataset, using a Digital Transfer Scope (DTS). The positional inaccuracies of that dataset—resulting from the fact that a transfer scope was not used during the recompilation process—would be corrected. However, this method cannot address other issues, such as scale, photo-interpretation (delineation and classification) errors, or the age of the data.

Procedures

- Purchase a Digital Transfer Scope from Optem (sole source).
- Purchase 2 GIS workstations.
- Assemble the entire set of delineated/annotated 1988 aerial photographs.
- View the following data, simultaneously, through the DTS:
  - a base map that has been registered to the latest State orthophotography;
  - the digital RIGIS wetlands dataset as a shape (.shp) file; and
  - the delineated aerial photography in stereo.
- Using the DTS extension for ArcView, "warp" the base map to fit the aerial photography.
- Correct the RIGIS wetlands dataset by:
  - dragging-and-dropping the RIGIS wetland polygons to their proper locations (i.e., to where they match up with the delineations on the photos);
  - stretching polygon boundaries to ensure a perfect match with the photo delineations;
  - digitizing polygons that exist on the photo, but not in the RIGIS wetland dataset;
  - rectifying coding errors; and
  - correcting other errors as they are identified.
- "Warp" the corrected wetland dataset back into planimetric space.
- Prepare data for distribution:
  - hardcopy maps (wetland boundaries on top of digital orthophotography); and
  - raw digital data (.e00 files, shape files).

Pros and cons of Option B

- **PRO**: This is far less expensive than Option A.
- **CON**: In general, map users perceive the RIGIS wetland maps as being outdated.
- **CON**: Overall, map users require wetland maps that are larger-scale than the existing RIGIS wetland dataset.
- **CON:** Most map users desire wetland maps with greater classification accuracy. This option would address only the correction of positional accuracy associated with the transfer process.
- **CON**: Map experts familiar with the RIGIS wetlands dataset have advised against trying to improve that dataset; they state that improving existing datasets would require a high level of effort, effort that is better expended toward the creation of new maps.
- **CON**: The original RIGIS wetlands dataset was created via interpretation of black-and-white photos; most experts agree that CIR aerials are required to accurately determine soil moisture during the photo-interpretation process.
- **CON**: The positional and classification accuracy levels of an improved RIGIS wetland dataset would not rival those of newly created maps.

Estimated costs: 1-year project using 1988 1:24,000-scale imagery[1]

$18,000	1 Optem DTS + accessories
10,000	2 GIS workstations + software and accessories
5,000	Equipment and supplies ($5,000/year)
36,500	½-time Project Manager (1 year @ 25,000 + benefits[2])
51,100	1 GIS Technician (1 year @ $35,000 + benefits)
54,270	Overhead @ 45%
$174,870	**Total**

[1]Costs of map printing and distribution not included.
[2]Benefit rate averaged to 46% of salary for all positions.

Option C. No action

Pros and cons of Option C

- **PRO**: No direct financial cost is incurred.
- **CON**: Developers, builders, planners, and regulators would continue to have only outdated, inadequate resources at their disposal.
- **CON**: The technology is available to produce better maps.
- **CON**: Rhode Island map users should not be required to use inefficient and inaccurate tools if the technology and funds are available to produce better tools.
- **CON**: The majority of map users (especially State and Federal regulators) said that they would benefit "quite a bit" or "extensively" from improvements in wetland maps.

Conclusion

- Option C is not in the best interests of the wetland resource or its users.

RECOMMENDATIONS

1. Given the limitations and errors inherent in the existing RIGIS wetland maps and the need for greater map accuracy expressed by map users, we strongly recommend that the State undertake creation of new wetland maps. Specifically, we recommend that:
   - 1:12,000-scale, color-infrared aerial photography should be used as the source imagery.
     - If funds are available, 1:5,000-scale, color-infrared aerial photography could be used to create more accurate, detailed maps.
     - If funding is very limited, 1:24,000-scale, color-infrared aerial photography could be used as a substitute.
   - Procedures should be modeled after current wetland mapping efforts in Massachusetts, with the addition of Digital Transfer Scope (DTS) technology.

2. If funding opportunities are extremely limited, and creation of new wetland maps is not feasible, the existing RIGIS wetland dataset should be improved by re-transferring the delineations from the 1988 1:24,000-scale black-and-white aerial photographs, using a DTS. However, because of the limitations of map data created from panchromatic, small-scale photography, it would be highly preferable to create new maps.

3. Wetland maps should not serve as the sole source for determining the exact location of regulatory boundaries, regardless of the map scale. However, the larger the scale, the more accurate the map is likely to be and the more useful it will be for land development planning and regulatory guidance. The role large-scale wetland maps might serve in the regulatory process requires further study.

4. The State should produce and distribute maps to encourage use of the most accurate wetland map data available by the widest possible array of users.
   - Hardcopy maps should be created that display wetland boundaries on top of digital orthophotography. Such maps would allow users to easily interpret surrounding upland conditions and land use, identify streets and landmarks, and visually assess the accuracy of the wetland delineations. By providing an orthophoto base, there may also be reduced demand for access to State-owned aerial photography.
   - Digital wetland map data should continue to be made available to GIS users via download from the RIGIS web site, and via CD-ROM.

5. Maps distributed or endorsed by the State should indicate the level of accuracy, as determined by National Map Accuracy Standards. This precautionary measure could reduce misuse of maps by users who are not aware of the inherent limitations of maps.

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Appendix A. Wetland Map Questionnaire Used to Survey Rhode Island Wetland Map Users.

Rhode Island Wetland Map Questionnaire

Professional & contact information

Name _____

Position title/Job category _____

Agency or affiliation _____

Address _____

_____

Phone number _____

Email address _____

Your current use of wetland data

1. Do you use wetland maps or data sources in your work? (Check one.)

___ yes
___ no *(proceed directly to question #14)*

2. How often do you use wetland maps or data sources? (Check applicable boxes.)

Wetland data source	Daily	Weekly	Monthly	Yearly	Never
National Wetlands Inventory maps (**NWI**)[1]					
USGS topographic maps (**TOPO**)					
Rhode Island Soil Survey (**RISS**)					
RIGIS digital wetland maps (**RIGIS-WET**)[2]					
RIGIS digital land use coverage (**RIGIS-LU**)					
Aerial photographs (**PHOTO**)					
Digital orthophotos (**DOQ**)					
Other (please specify) _____					

[1]*Prepared by the U.S. Fish and Wildlife Service from 1975, 1:80,000-scale, panchromatic aerial photographs. Minimum map unit ranges from 1 to 3 acres.*

[2]*Prepared by the State of Rhode Island from 1988, 1:24,000-scale, panchromatic aerial photographs. Minimum map unit = ¼ acre.*

3. *If you are a field worker*, based on your experience, how accurate have existing wetland maps and data sources been, relative to field conditions?

Wetland data source	**Extremely accurate** ◄——►				**Extremely inaccurate**	**Don't know**
National Wetlands Inventory maps (**NWI**)						
USGS topographic maps (**TOPO**)						
Rhode Island Soil Survey (**RISS**)						
RIGIS digital wetland maps (**RIGIS-WET**)						
RIGIS digital land use coverage (**RIGIS-LU**)						
Aerial photographs (**PHOTO**)						
Digital orthophotos (**DOQ**)						
Other (please specify) _____						

4. *If you use aerial photography for wetlands work*:

a. How do you access the photos?

___ the photos are owned by my organization/agency
___ I use photos owned by the State
___ other (please specify) _____
___ don't know/not applicable

b. How important is it to your work that access to State-owned aerial photos be improved?

___ extremely important
___ very important
___ somewhat important
___ not very important
___ not at all important
___ don't know/not applicable

c. To satisfy your needs, what is the *minimum* frequency at which statewide aerial photos should be taken?

___ every year
___ every 2-3 years
___ every 5 years
___ every 10 years
___ don't know/not applicable

5. Please indicate the *primary* wetland-related activity(ies) that you perform—and the map or data sources that you *routinely* utilize for those activities—by checking the appropriate box(es).

Note: Refer to question #2 for definitions of wetland data source codes.

	Wetland data source							
Activity	**NWI**	**TOPO**	**RISS**	**RIGIS WET**	**RIGIS LU**	**PHOTO**	**DOQ**	**Other**
Statewide planning								
Municipal planning								
Watershed planning								
Site-specific construction planning								
Regulatory permitting								
Regulatory enforcement								
Environmental impact assessment								
Restoration planning								
Habitat management								
Scientific research								
Education								
Land acquisition or sales								
Other: _____								

6. Please indicate the *specific* activity(ies) for which you use wetland maps and data sources by placing a check mark in the appropriate box(es).

Note: Refer to question #2 for definitions of wetland data source codes.

	Wetland data source							
Specific activity	**NWI**	**TOPO**	**RISS**	**RIGIS WET**	**RIGIS LU**	**PHOTO**	**DOQ**	**Other**
Determining wetland presence/absence								
Determining wetland types								
Wetland boundary determinations								
Wildlife habitat assessments								
Base maps for wetland-related projects								
Alternatives analysis								
Calculating general wetland statistics								
Landscape-scale GIS analyses								
Open space/acquisition planning								
Tax assessment								
Real estate transactions								
Mitigation site selection								
Other: _____								

7. Do existing wetland maps and data sources meet your needs?

___ yes
___ no
___ don't know/not applicable

8. Do you have access to the Internet?

___ yes
___ no
___ don't know/not applicable

9. Do you have access to ArcView or other GIS software?

___ yes
___ no
___ don't know/not applicable

Your use of RIGIS digital wetland maps

Note: If you have never used RIGIS wetland map data, proceed directly to question #14.

10. How often do the RIGIS wetland map data meet your needs—in terms of *scale* (i.e., in terms of the minimum size of mapped areas)?

___ always
___ usually
___ sometimes
___ infrequently
___ never
___ don't know/not applicable

11. How often do the RIGIS wetland map data meet your needs—in terms of *wetland classification accuracy*?

___ always
___ usually
___ sometimes
___ infrequently
___ never
___ don't know/not applicable

12. How often do the RIGIS wetland map data meet your needs—in terms of *positional accuracy* (i.e., map location vs. actual location of wetland on the ground)?

___ always
___ usually
___ sometimes
___ infrequently
___ never
___ don't know/not applicable

13. How often do the RIGIS wetland map data meet your needs—in terms of *the age of the data*?

___ always
___ usually
___ sometimes
___ infrequently
___ never
___ don't know/not applicable

Your wetland map data needs

14. Which of the following wetland map scales would suffice for your needs? (Check all that apply.)

___ 1 inch = 200 feet (1:2,400)
___ 1 inch = 400 feet (1:4,800)
___ 1 inch = 1,000 feet (1:12,000)
___ 1 inch = 2,000 feet (1:24,000)
___ 1 inch = 4,000 feet (1:48,000)
___ other (please specify): _____
___ don't know/not applicable

15. How important is the correct classification of wetland types (e.g., forested swamp, shrub swamp, bog, marsh, pond) to your work?

___ extremely important
___ very important
___ somewhat important
___ not very important
___ not at all important
___ don't know/not applicable

16. What level of positional accuracy do you need? (Circle one.)

The following accuracy figures indicate the error associated with a particular map scale, according to National Map Accuracy Standards developed by the U.S. Geological Survey. Note that other sources of error (e.g., from aerial photo-interpretation) may add to the error associated with map scale.

Accuracy	***Scale***	
± 6.67 feet	1 inch = 200 feet	(1:2,400)
± 13.33 feet	1 inch = 400 feet	(1:4,800)
± 33.33 feet	1 inch = 1,000 feet	(1:12,000)
± 40.00 feet	1 inch = 2,000 feet	(1:24,000)
± 80.00 feet	1 inch = 4,000 feet	(1:48,000)

17. In what format(s) would you prefer improved wetland maps and data? (Check all that apply.)

___ hardcopy: paper maps
- *Please specify preferred scale*:_____

___ digital: raw data for use with GIS software (e.g., .e00 files)

___ digital: pre-made static maps (e.g., www.edc.uri.edu/riatlas)
- *Please specify preferred scale*:_____

___ digital: Internet Map Server (e.g., http://wetlands.fws.gov/mapper_tool.htm)

___ other (please specify): _____

18. Should the improvement of wetland map data be a priority for the State?

___ yes
___ no
___ don't know/not applicable

How improved wetland map data would assist you in your work

19. To what degree would improvements in Rhode Island's current wetland maps (in terms of scale, classification, positional accuracy, and age of data) help you in your work?

___ extensively
___ quite a bit
___ somewhat
___ very little
___ not at all
___ don't know/not applicable

20. How often would you use wetland maps that have been improved to meet your needs?

___ on a daily basis
___ on a weekly basis
___ on a monthly basis
___ occasionally throughout the year
___ every few years
___ never
___ don't know/not applicable

21. For what purpose(s) would you *like* to use wetland map data that you cannot at present due to various shortcomings?

_____

_____

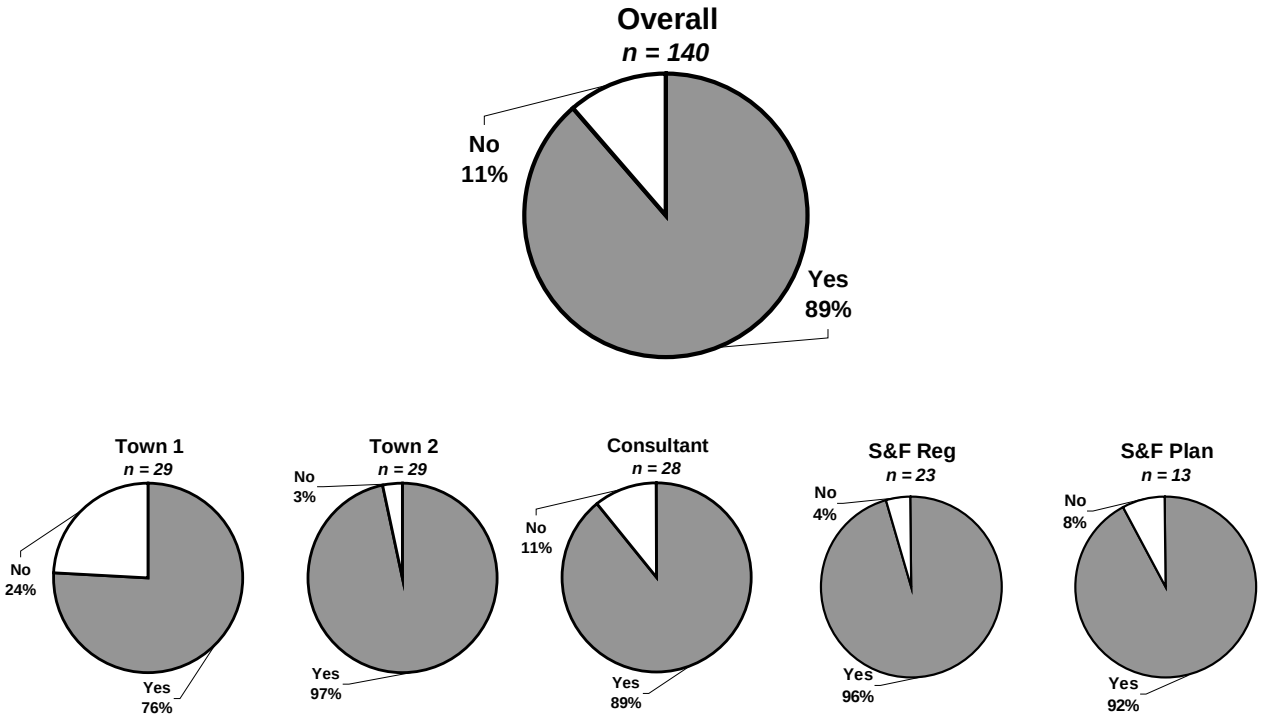
_____

_____

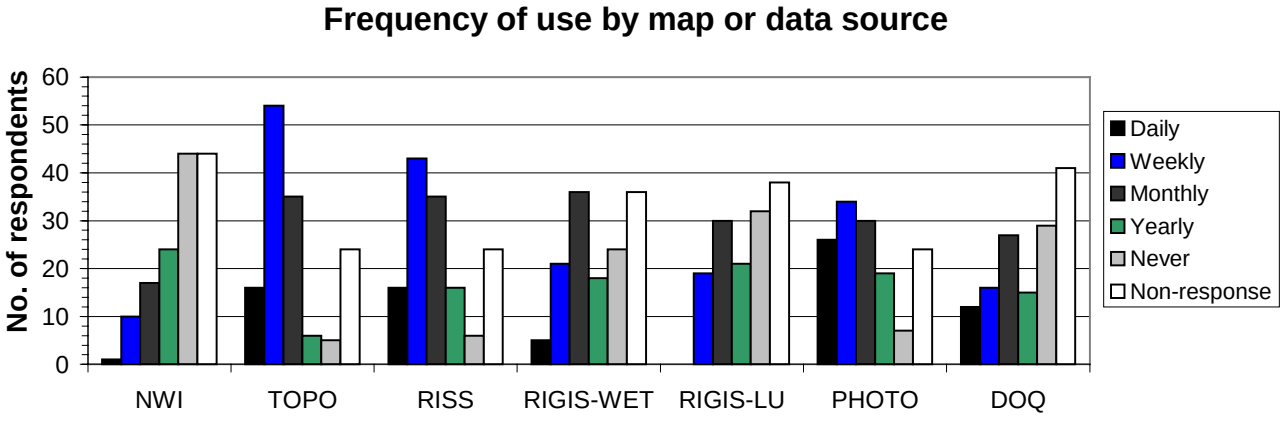
Comments

22. Please provide additional information or comments to help us assess the utility of existing wetland map data and to determine how those data could be improved to meet your needs.

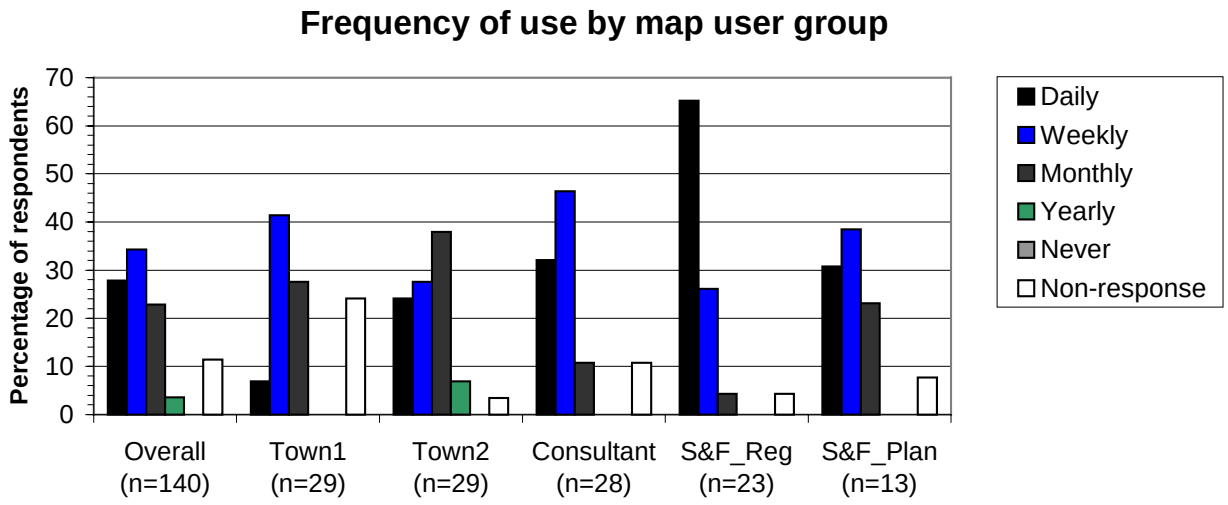
1. Do you use wetland maps or data sources in your work?



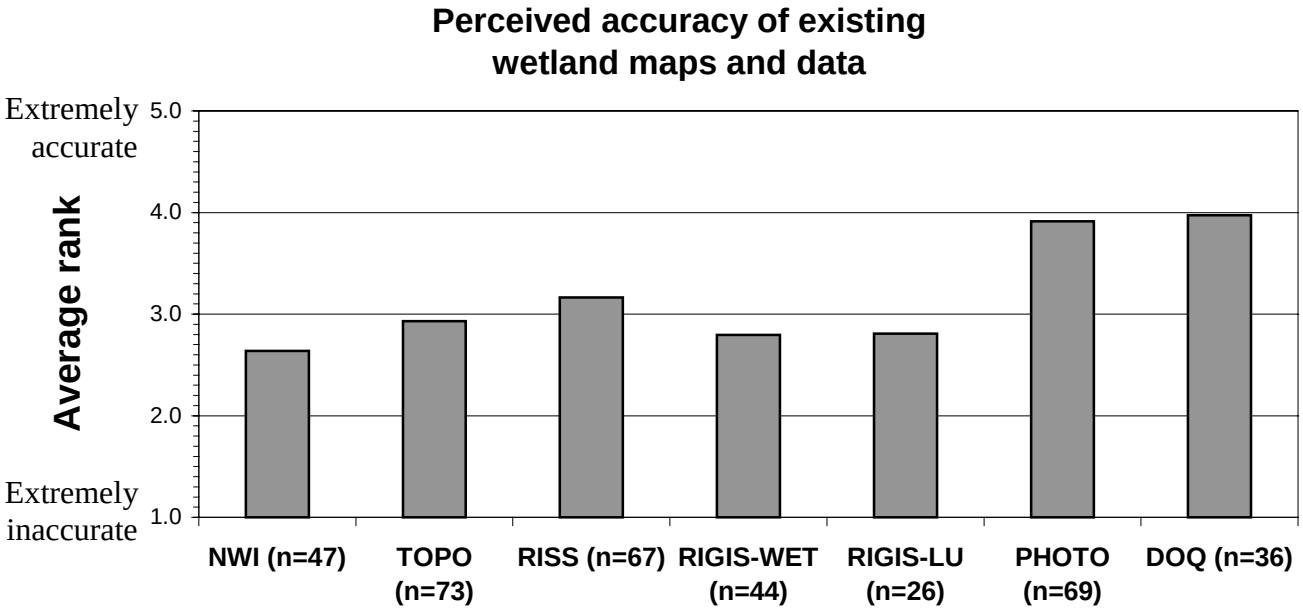
2. How often do you use wetland maps or data sources?



2. (Continued.)

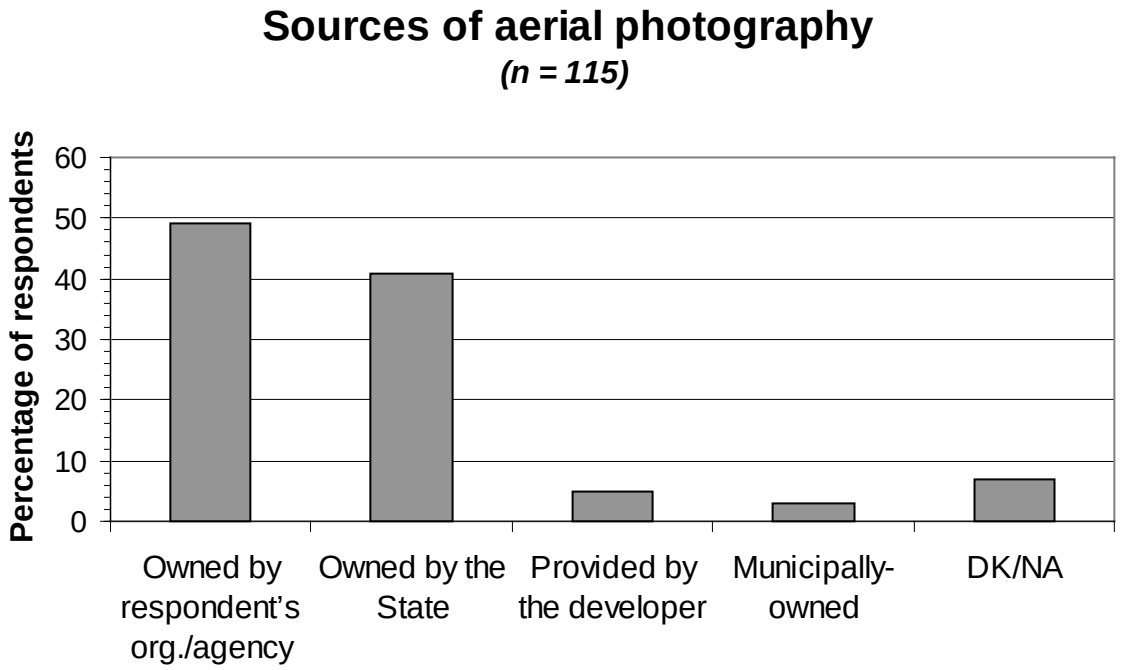


3. ***If you are a field worker,*** **based on your experience, how accurate have existing wetland maps and data sources been, relative to field conditions?**

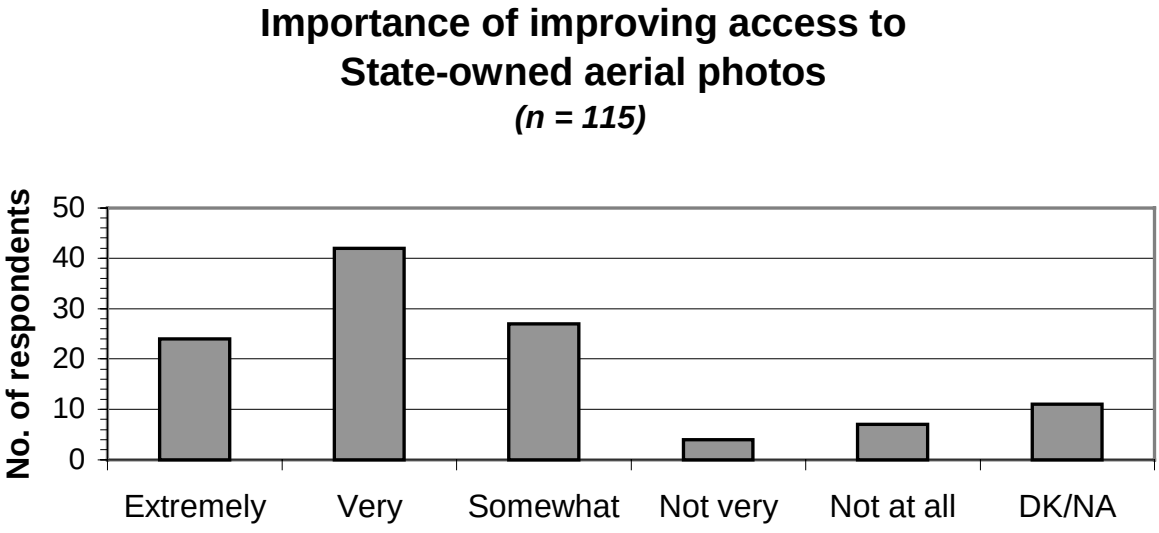


4. ***If you use aerial photography for wetlands work:***

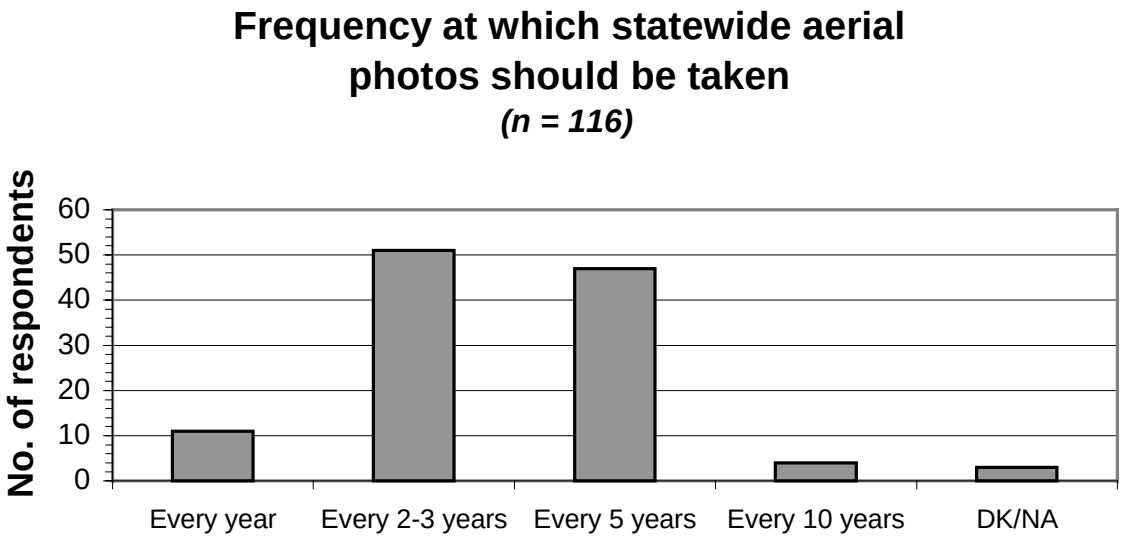
   a. How do you access the photos?



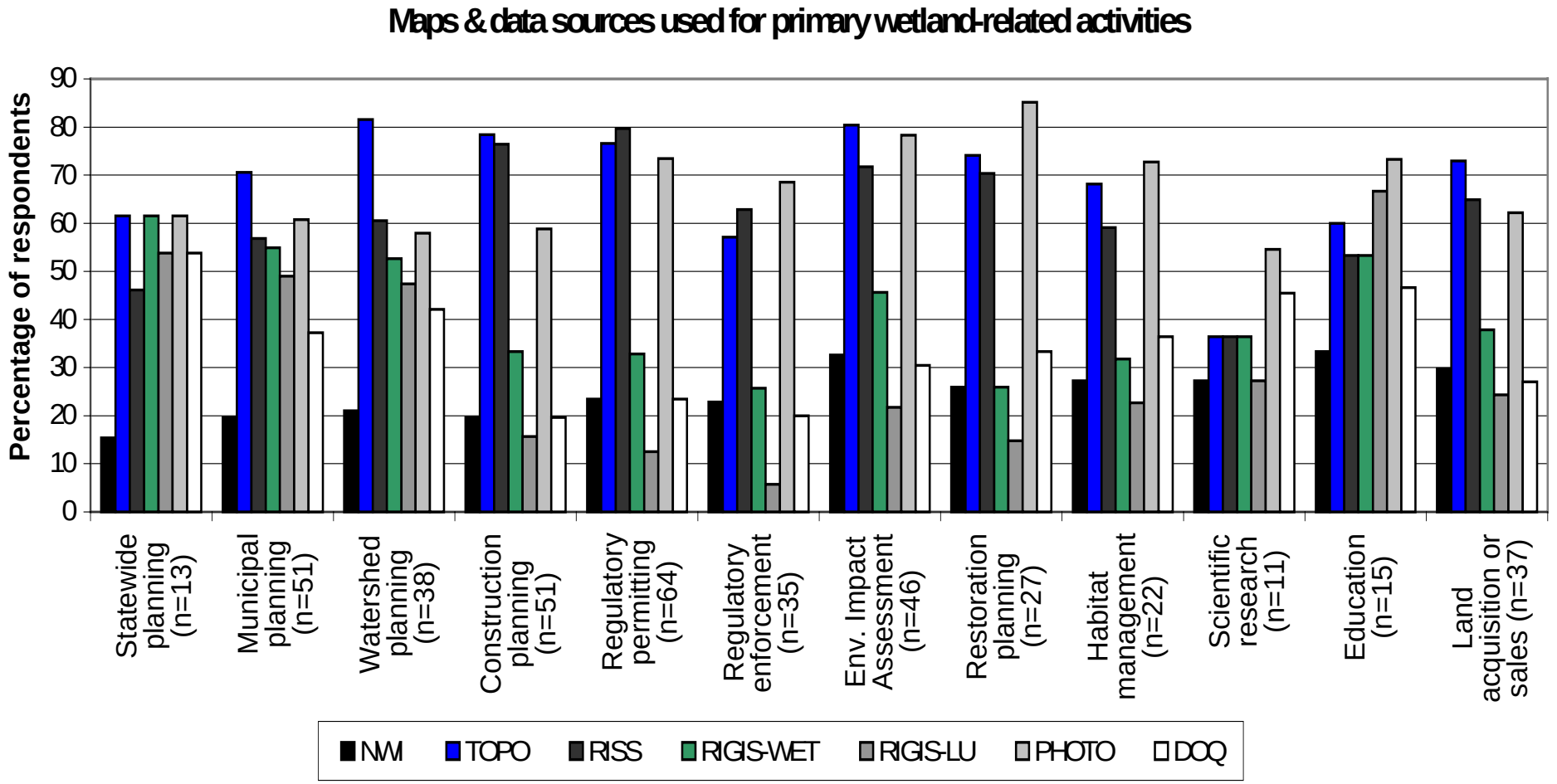
   b. How important is it to your work that access to State-owned aerial photos be improved?



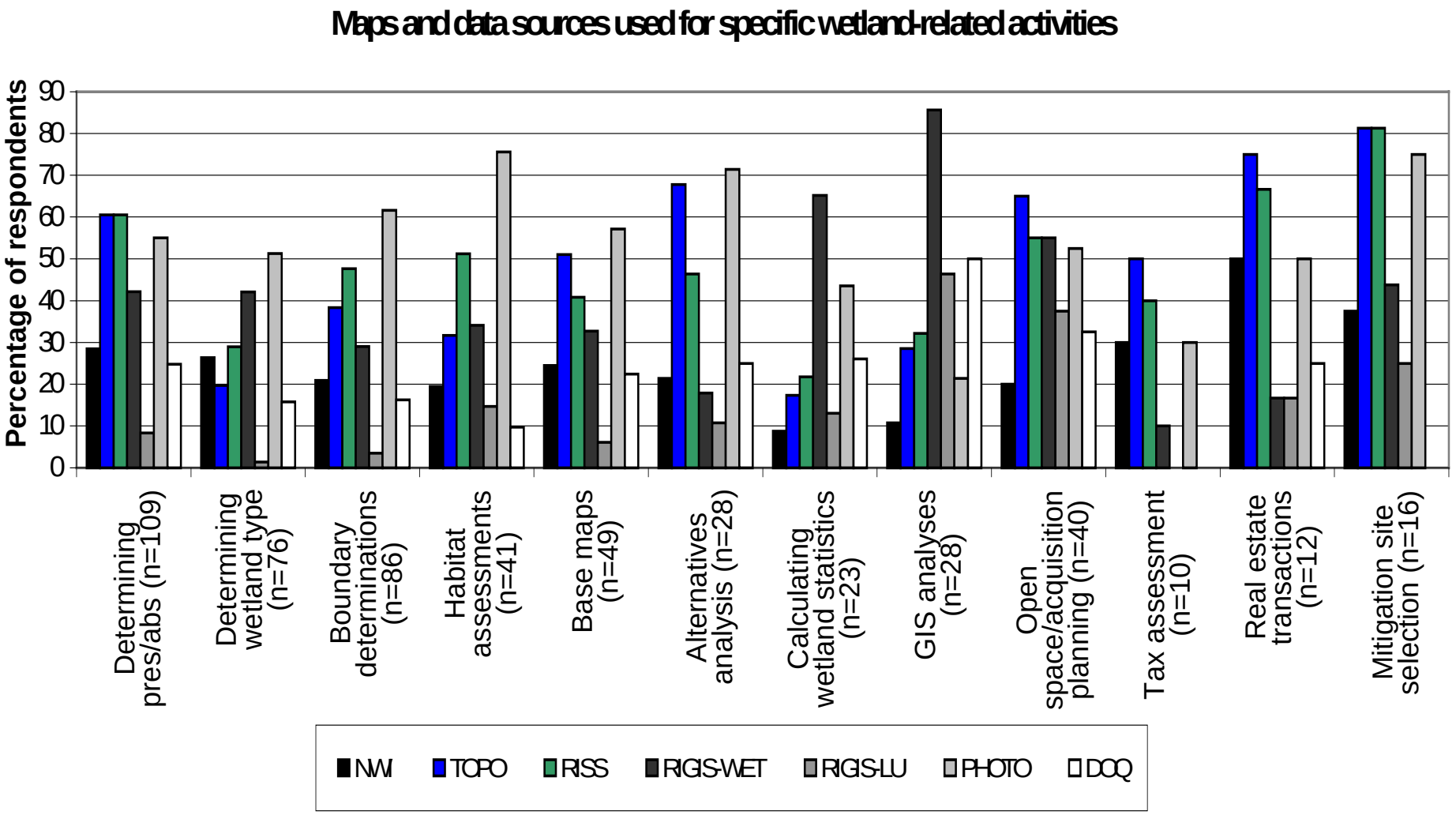
c. To satisfy your needs, what is the *minimum* frequency at which statewide aerial photos should be taken?



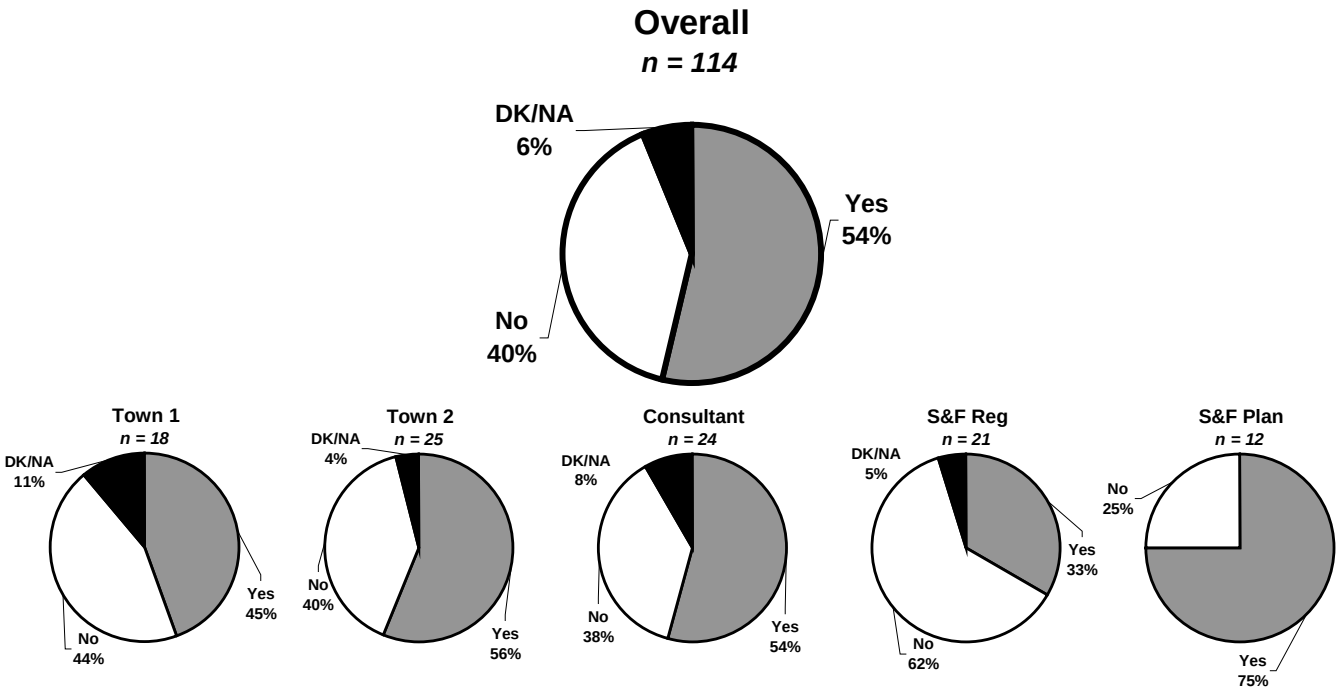
5. Please indicate the *primary* wetland-related activity(ies) that you perform—and the map or data sources that you *routinely* utilize for those activities—by checking the appropriate box(es).



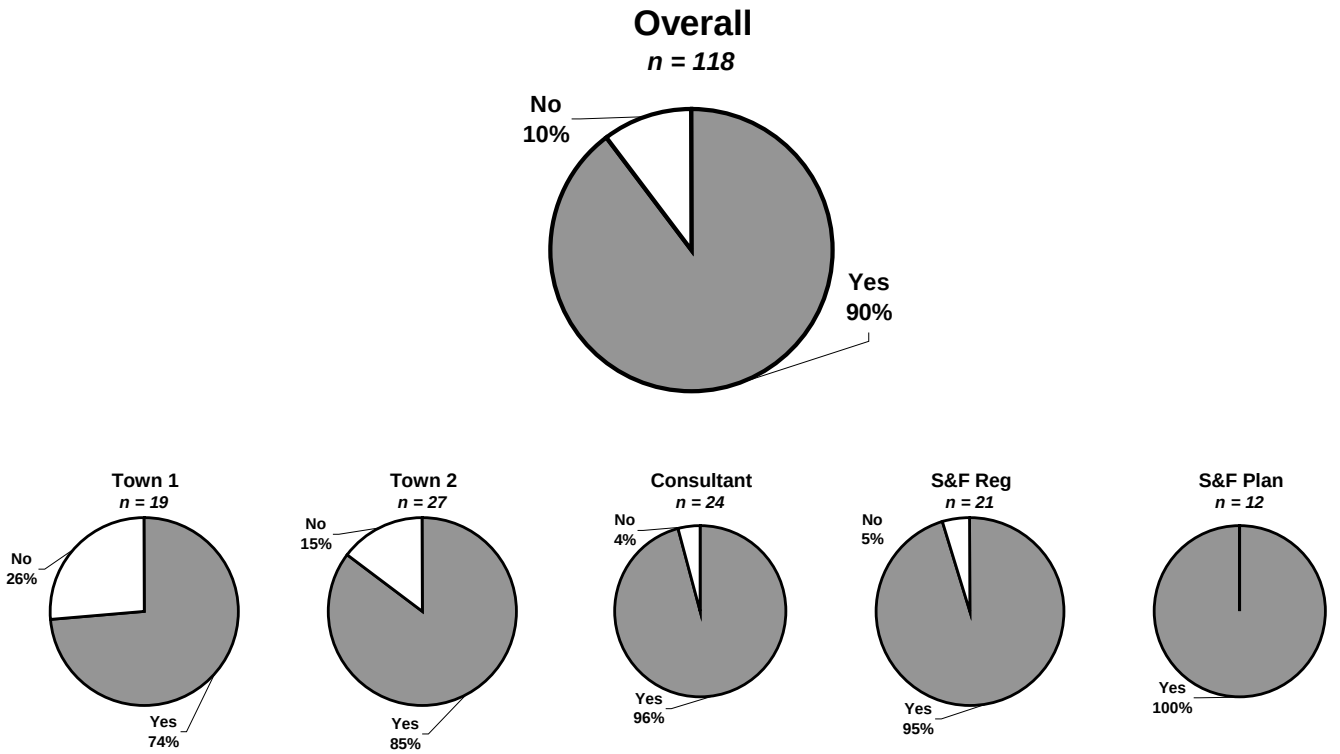
6. Please indicate the *specific* activity(ies) for which you use wetland maps and data sources by placing a check mark in the appropriate box(es).



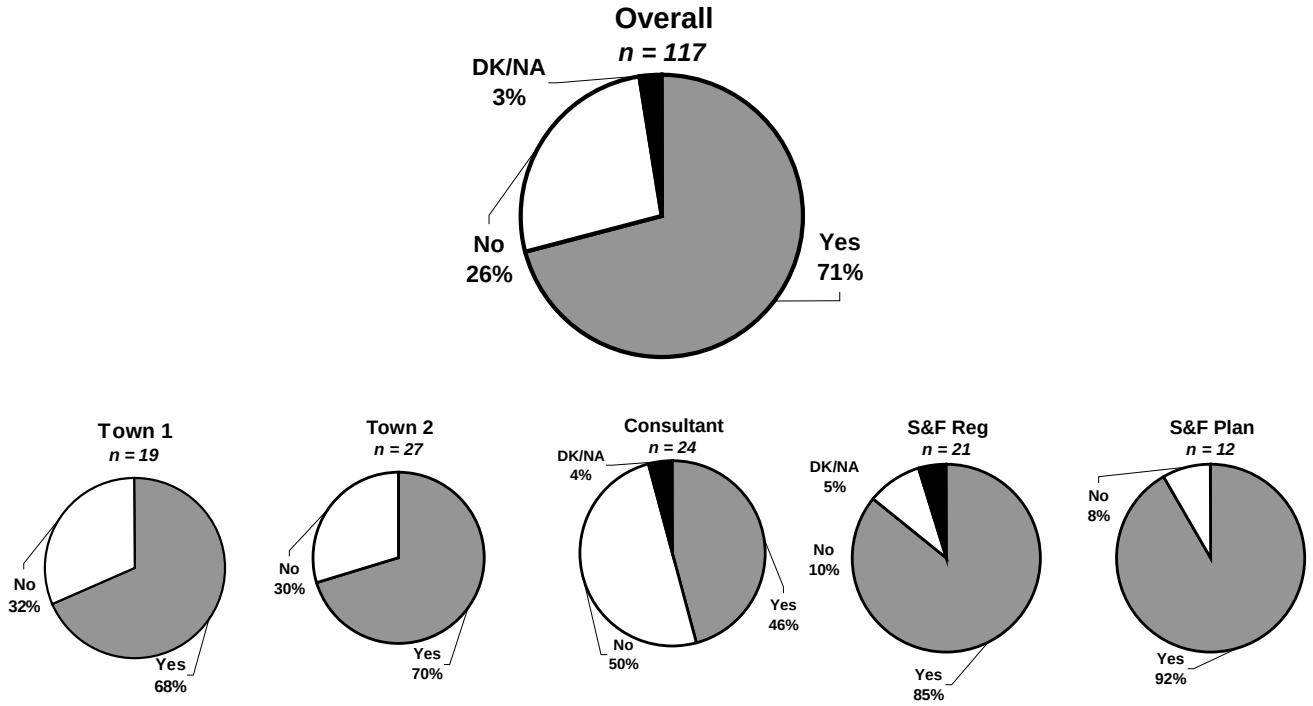
7. Do existing wetland maps and data sources meet your needs?



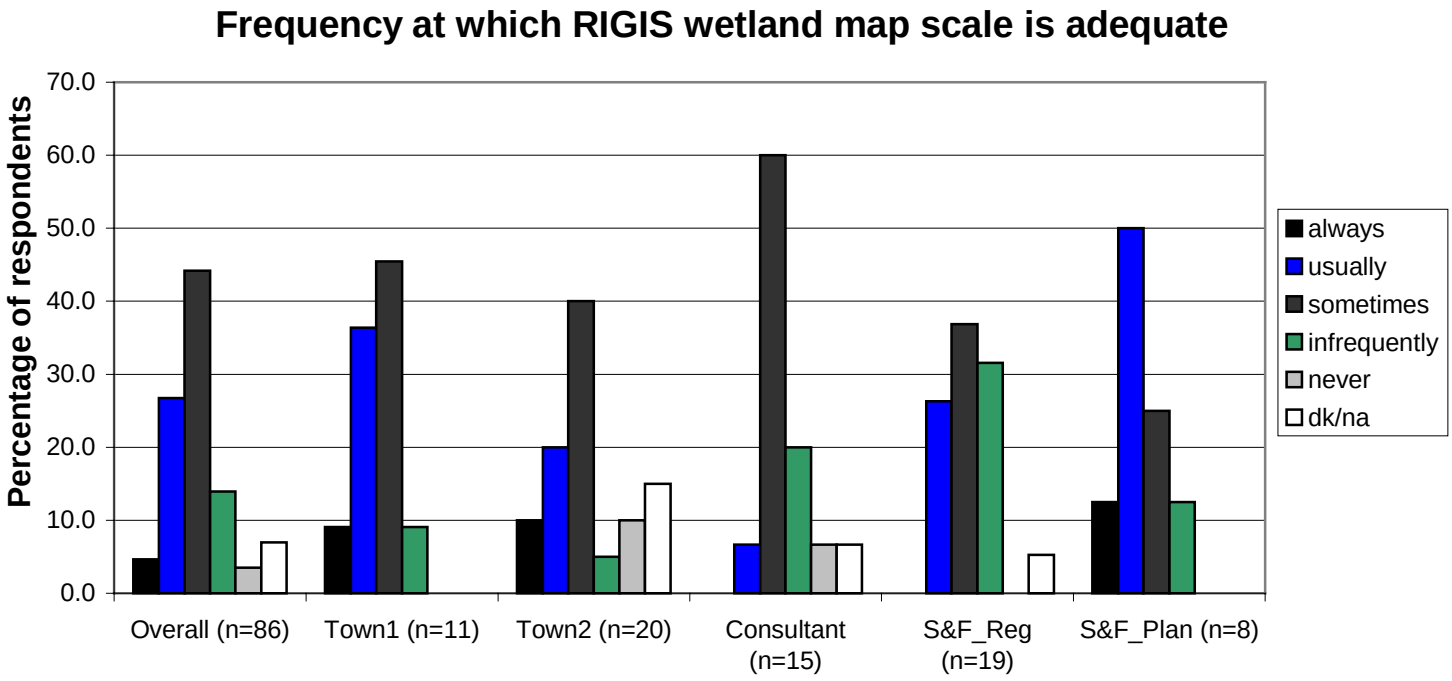
8. Do you have access to the Internet?



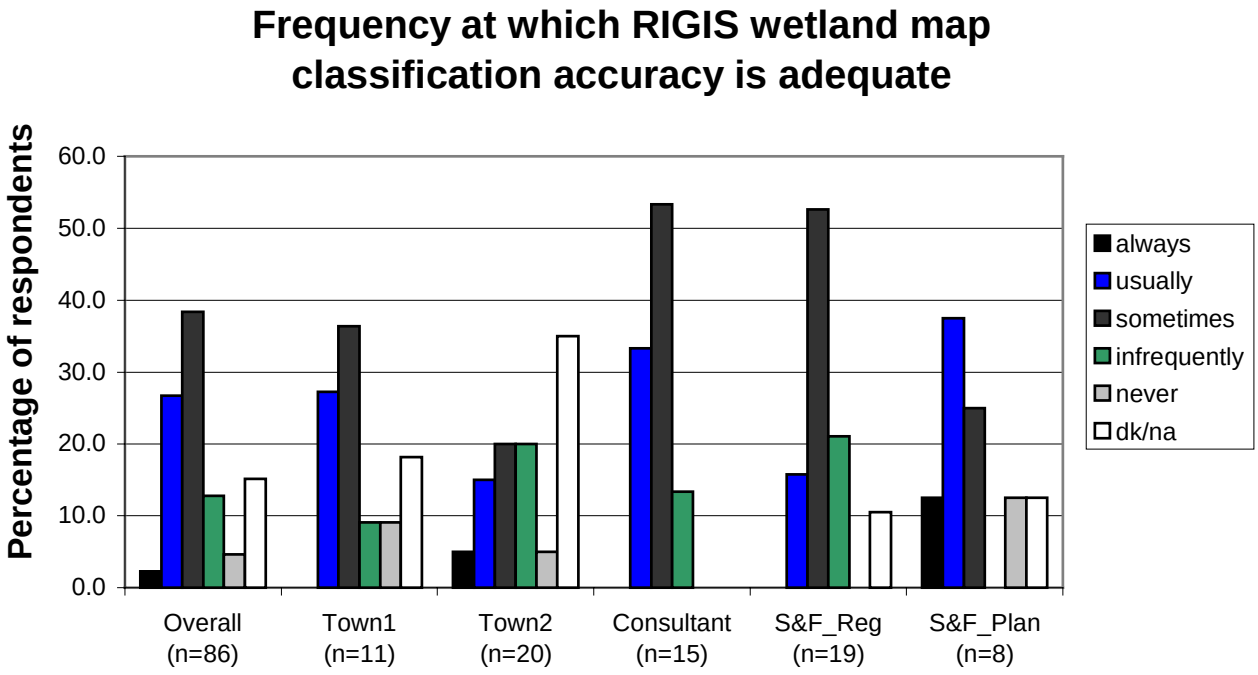
9. Do you have access to ArcView or other GIS software?



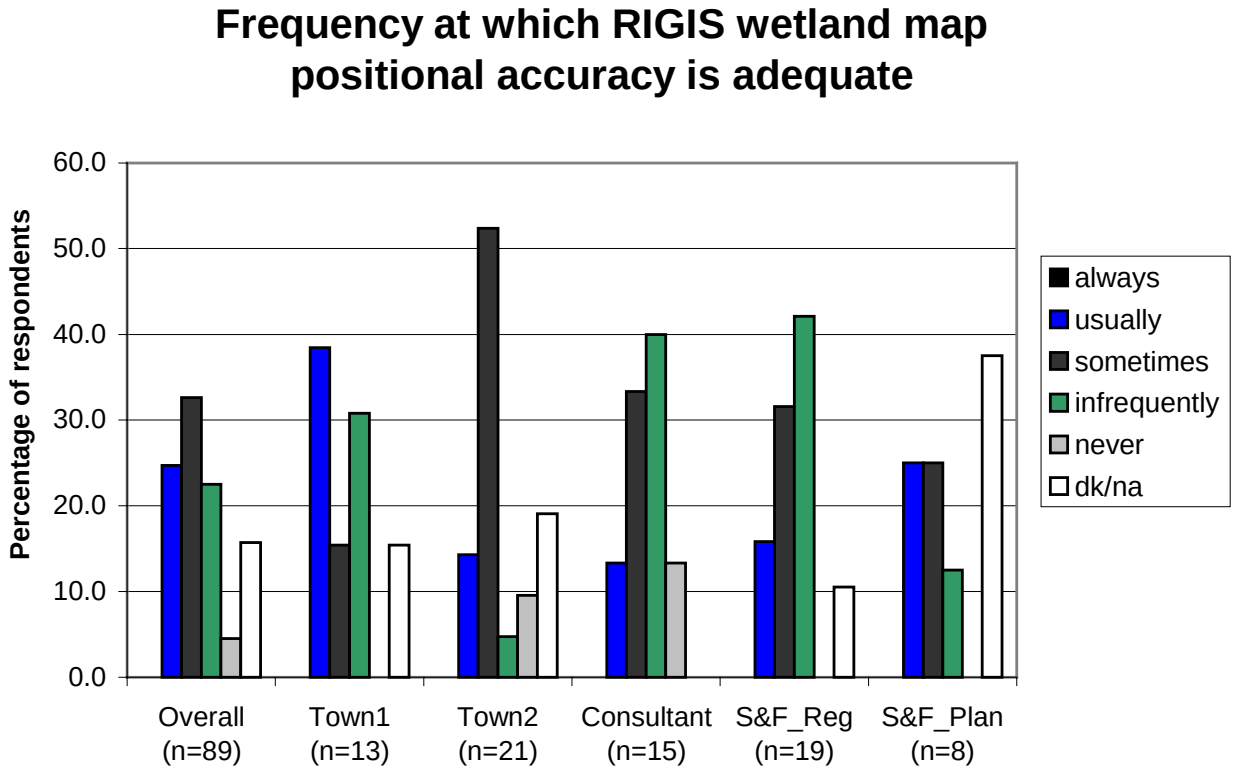
10. How often do the RIGIS wetland map data meet your needs—in terms of *scale* (i.e., in terms of the minimum size of mapped areas)?



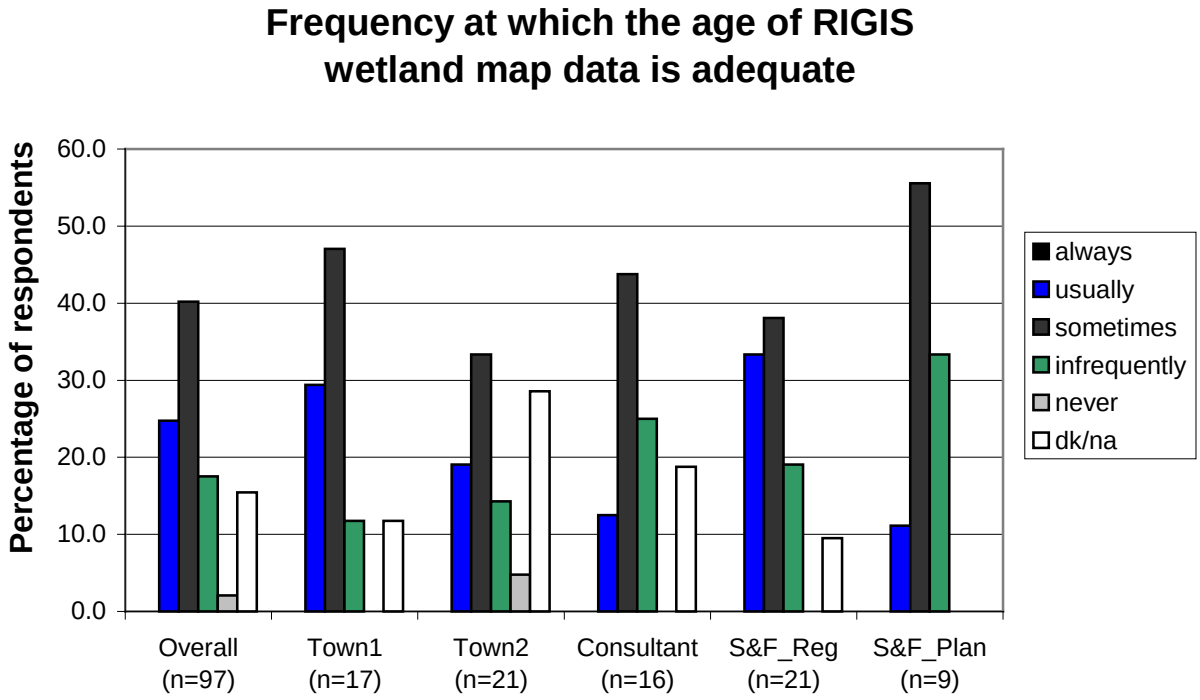
11. How often do the RIGIS wetland map data meet your needs—in terms of *wetland classification accuracy*?



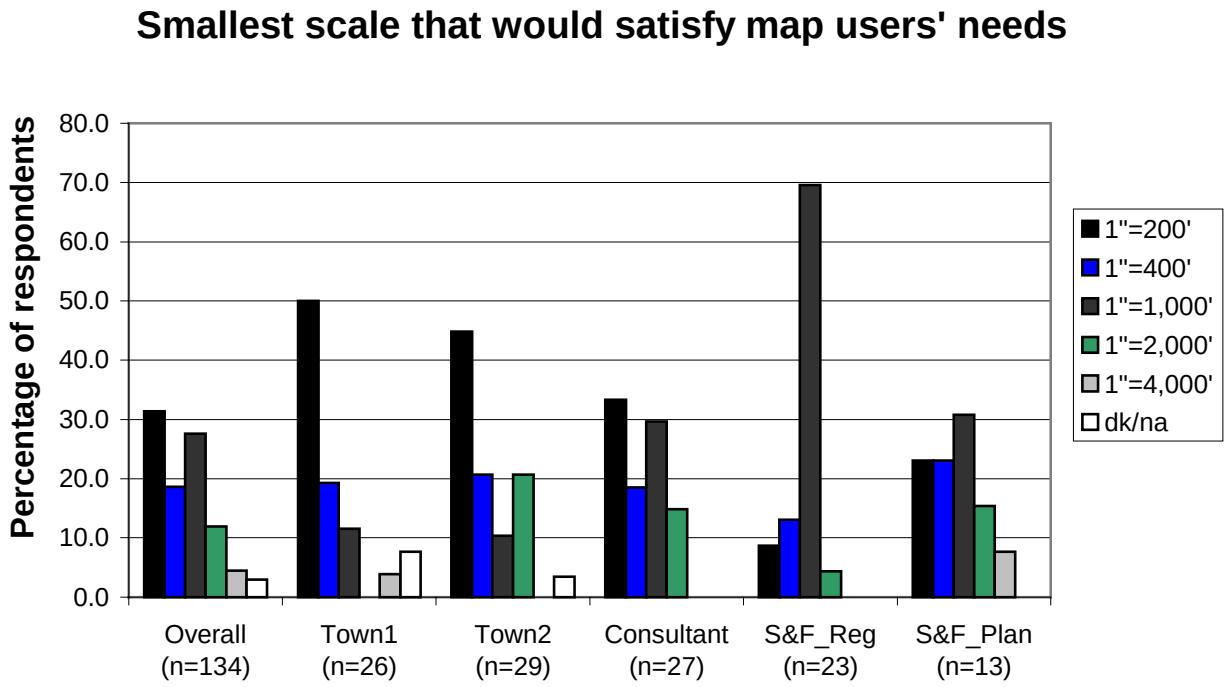
12. How often do the RIGIS wetland map data meet your needs—in terms of *positional accuracy* (i.e., map location vs. actual location of wetland on the ground)?

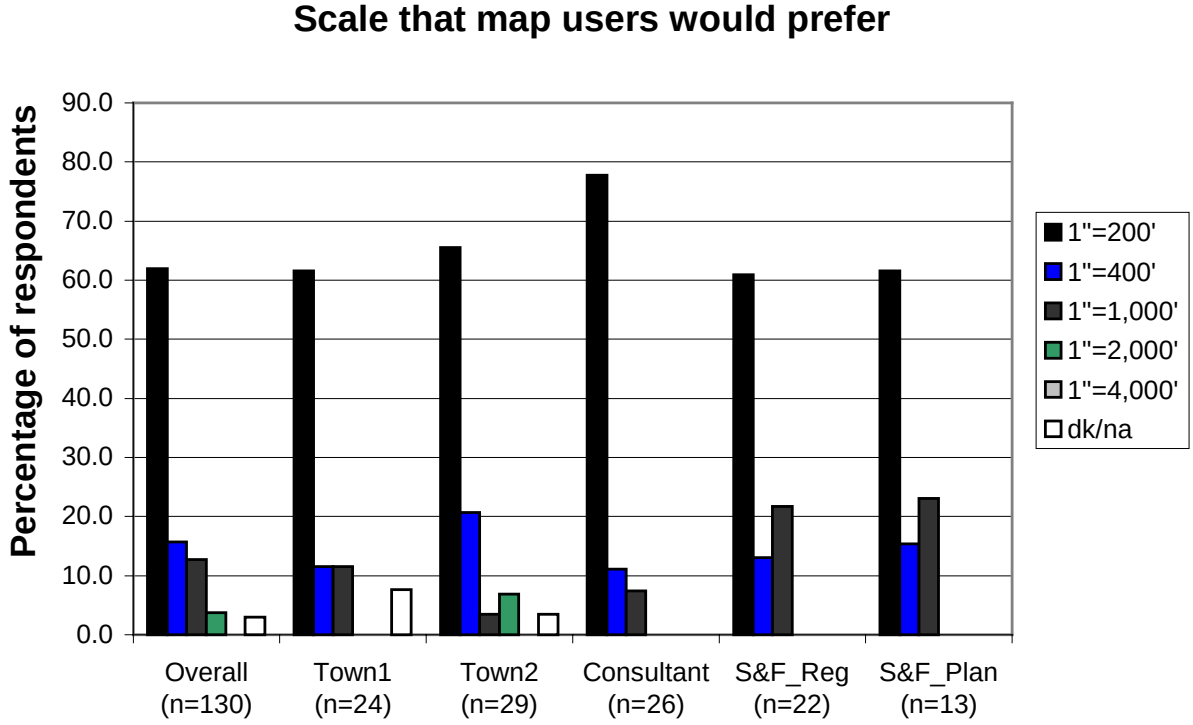


13. How often do the RIGIS wetland map data meet your needs—in terms of *the age of the data*?

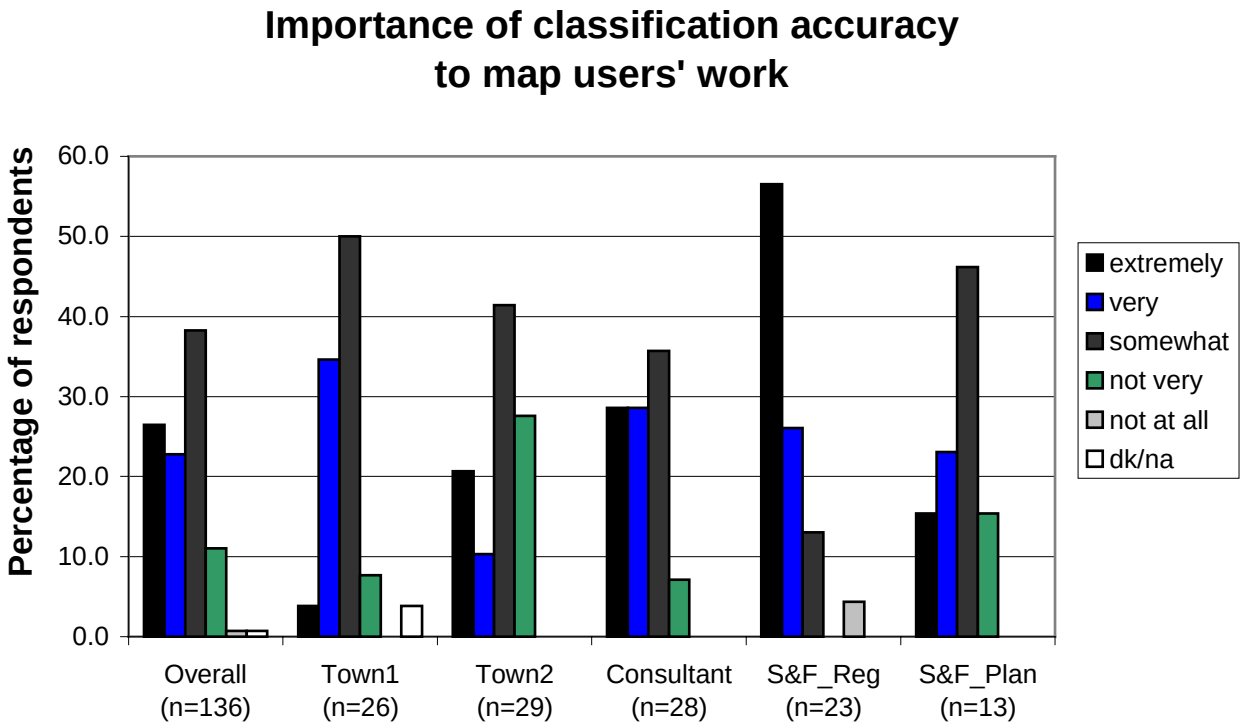


14. Which of the following wetland map scales would suffice for your needs?

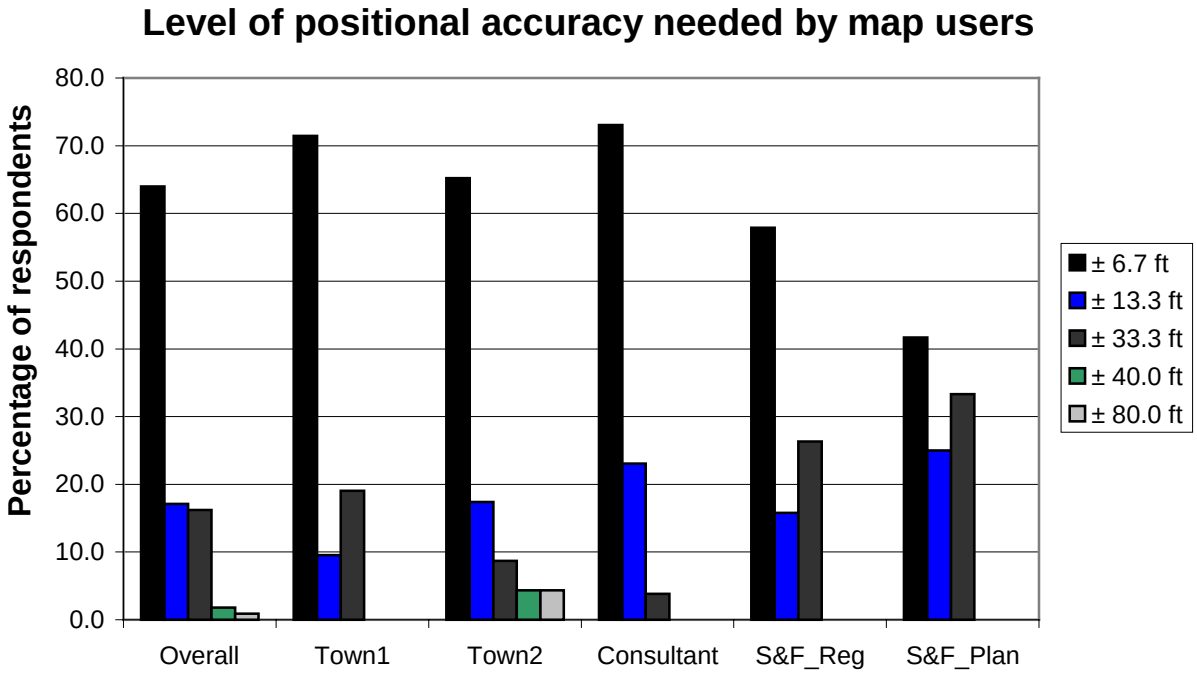




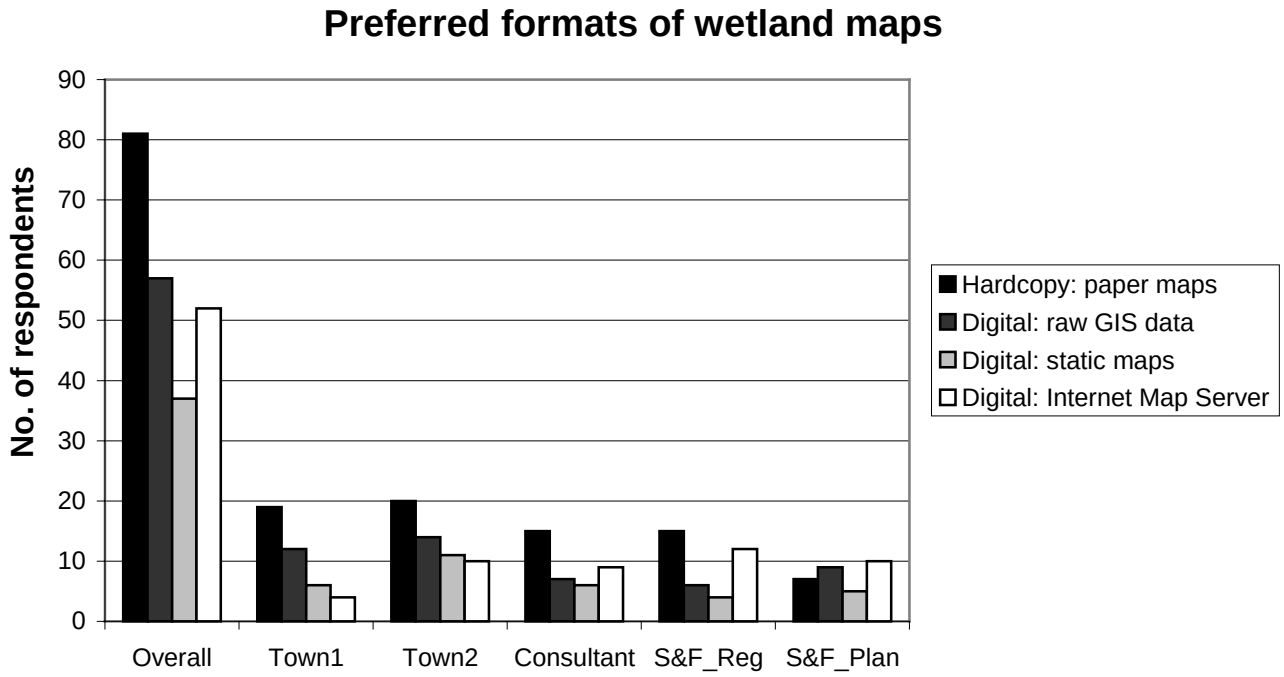
15. How important is the correct classification of wetland types (e.g., forested swamp, shrub swamp, bog, marsh, pond) to your work?



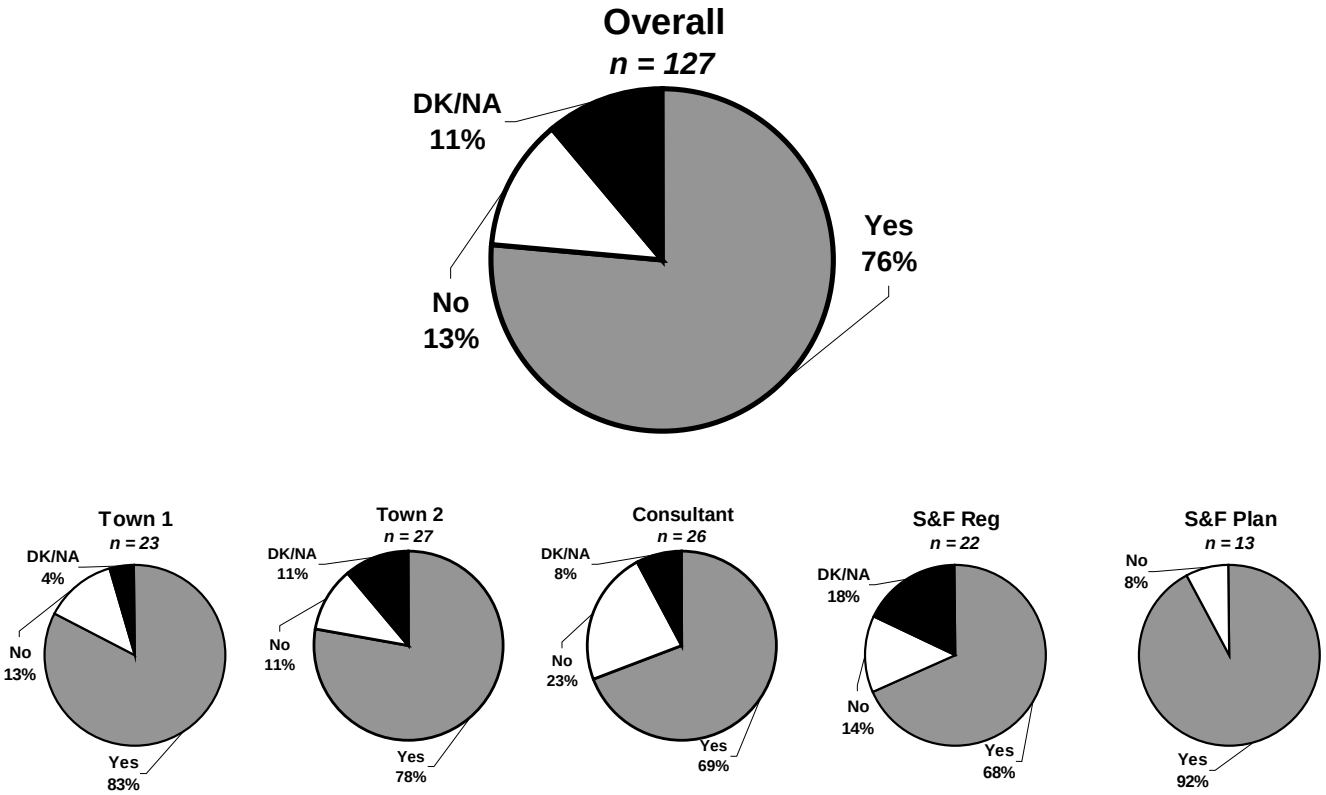
16. What level of positional accuracy do you need?



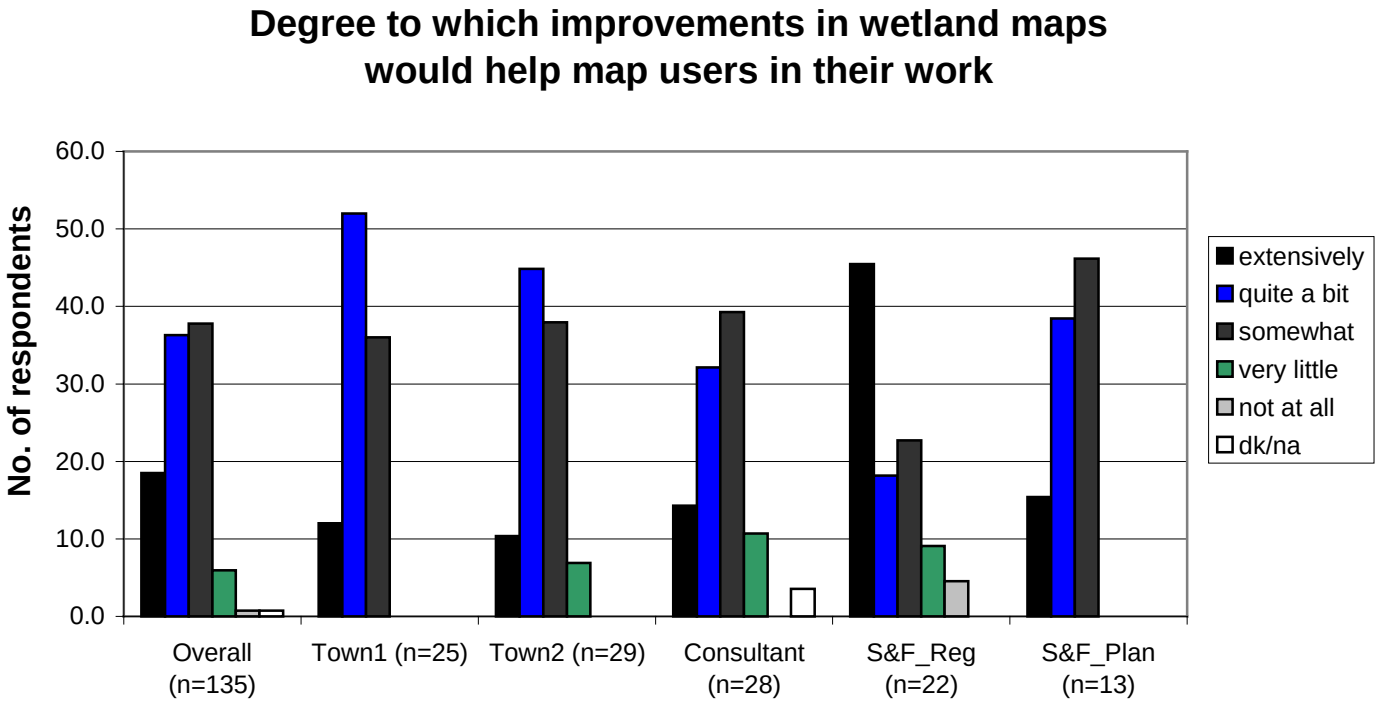
17. In what format(s) would you prefer improved wetland maps and data?



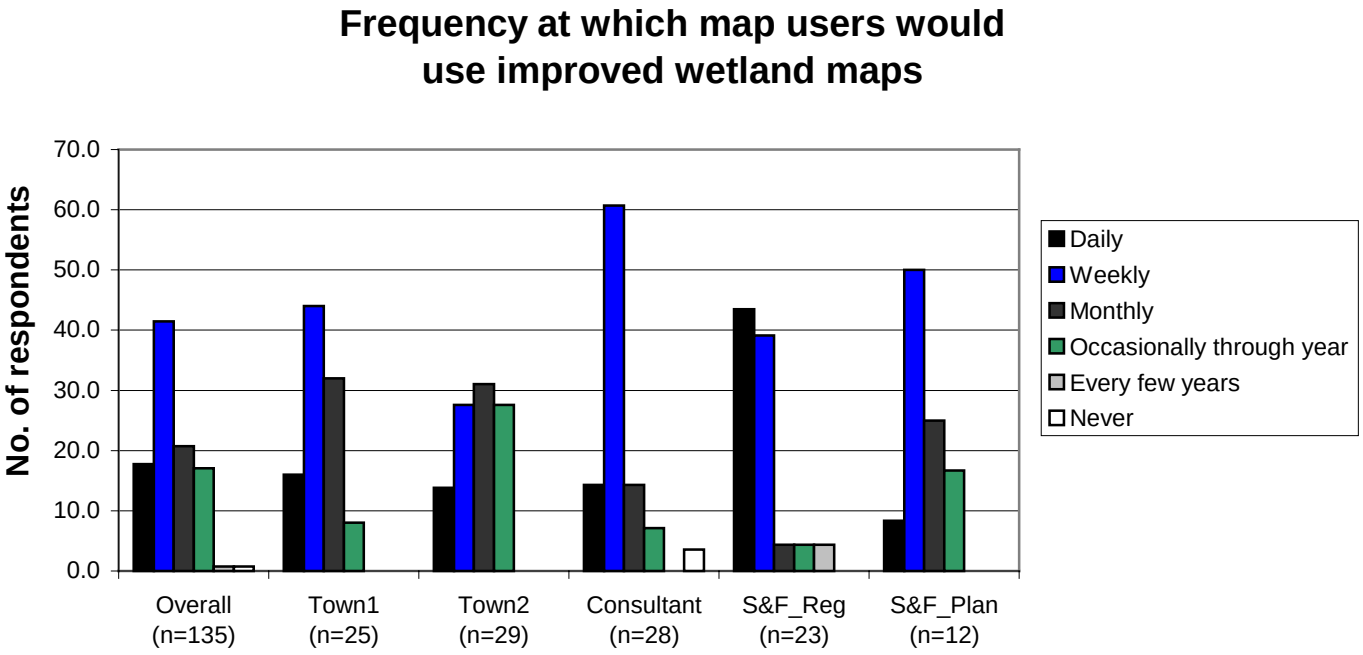
18. Should the improvement of wetland map data be a priority for the State?



19. To what degree would improvements in Rhode Island's current wetland maps (in terms of scale, classification, positional accuracy, and age of data) help you in your work?



20. How often would you use wetland maps that have been improved to meet your needs?



21. For what purpose(s) would you *like* to use wetland map data that you cannot at present due to various shortcomings?

No. of responses									Wetland map use*
	Map user group								
Overall	***Town1***	***Town2***	***S&F_Plan***	***S&F_Reg***	***Consultant***	***NGO***	***Academic***	***Assessor***	
14	2	6	1	4		1			Review of development plans and permit applications
13	4	2		6	1				Precisely determining wetland edge/boundary
11	2				9				Development planning/Feasibility studies/Applying for permits
9	2	4			1		1	1	Viewing wetland boundaries in relation to parcel boundaries
7		1	1	2	3				Determining wetland type
6		1		4	1				Determining wetland size
5		1		1	3				Determining wetland presence
5			3	2					Wetland restoration planning
5		1	1	1	1		1		Preliminary development planning
4			1		1	1	1		Regional and watershed assessments and analyses
3				2	1				Cumulative wetland impact analyses
2				1	1				Wetland functional assessments
2				1	1				Researching review history
2						1	1		Identifying very small wetland units/Fine resolution
2								2	Determining highest & best use for valuation purposes

*Many individual responses were received for this question; only those that were stated by at least two respondents are provided here.

22. Please provide additional information or comments to help us assess the utility of existing wetland map data and to determine how those data could be improved to meet your needs.

No. of responses								Comment*
Map user group								
Overall	***Town1***	***Town2***	***S&F_Plan***	***S&F_Reg***	***Consultant***	***NGO***	***Academic***	
16	3	3	3	3	1	2	1	Wetland maps should have better positional accuracy
10				1	8		1	Wetland maps cannot replace field investigations
5		1	2			1	1	Wetland maps should be updated more frequently
3				1	2			Wetland maps should only be used for broad, general purposes
3	1				2			Wetland maps should be larger-scale
3				1	1	1		We need maps that don't require GIS software
2				2				It is better to use aerial photography than maps
2				1	1			Site-specific wetland info should be obtained from field visits
2			1		1			The RI Soil Survey is more accurate than wetland maps
2					2			More accurate wetland maps would facilitate better planning
2					2			High quality digital orthophotos should be taken at frequent intervals
2			1		1			RIGIS wetland maps and the RISS should be re-registered to an orthophoto base
2					2			Maps should be ground-truthed
2				1	1			Current wetland maps are often misused

*Many individual responses were received for this question; only those that were stated by at least two respondents are provided here.

Appendix C. Mapping Experts Consulted.

Daniel Civco
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Appendix D. Overview of the Optem Digital Transfer Scope.

OPTEM
AVIMO PRECISION INSTRUMENTS
Optics for a Shrinking World

Digital Transfer Scope (DTS)

The versatile DTS™ is ideal for digital photo interpretation and change detection in land planning , forestry, agriculture, environmental conservation, and natural resource management.

Optem's new DTS™ combines the resolution of hardcopy aerial photography with the versatility of advancing GIS (Geographical Information Systems) technology.

This powerful workstation allows you to perform all functions of stereo interpretation, digitizing, editing and GIS, all on one desktop. Developed for efficiency and convenience, the DTS effectively utilizes aerial photography to update base maps. Full resolution of aerial photography is retained through all digital manipulation functions along with any digitally edited areas of interest. An internal LCD allows you to simultaneously view digital base maps superimposed with hardcopy aerial photography. Compatible with most state-of-the-art PCs, the DTS combines image interpretation and superimposition of aerial photography onto vector GIS data in a compact, portable workstation. The DTS software is an extension of ArcView™ GIS from ESRI. This software warps, stretches and rotates digital base maps to fit hardcopy aerial photographs. This software allows you to directly input new GIS data into your ArcView project files for future editing and updating.

FEATURES AND ADVANTAGES

- **Efficient and Convenient** - Save time and perform all of your photo interpretation, digitizing and editing functions all from one workstation. An internal LCD allows you to simultaneously view digital base maps superimposed with hardcopy aerial photography.

- **Powerful Software** - Utilize full functionality of Arc View with the DTS software extension.
- **Continuous Zoom Viewing** - Zoom in to take advantage of the original photography's full resolution. Zoom in and out to set your optimum fields-of-view.

- **Optimal Stereo Viewing** - Direct optical viewing of resource management. stereo and non-stereo aerial photography.
- **Mobile** - Lightweight, manageable and durable, you can securely transport DTS to remote locations and secondary facilities for easy in-field photo interpretation.

STEREOSCOPE SPECIFICATIONS	
Film	9" x 9"
Magnification (Low Power Objectives Eyepiece magnification Total Magnification	 10x Widefield 2.lX - 14.7X
Magnification (High Power Objectives): Eyepiece magnification Total Magnification	 10X Widefield 4.2X - 29.4X
Fields of View (Maximum): Low Power Objectives HighPower Objectives	 95mm 46mm
Working Distance	9"
Table-to-Eyepoint	16"
IPD (Interpupilliary Distance)	48 - 72mm
Weight .	45 lbs
Physical Dimensions: Height Width Depth	 20" 24" 23"
LIGHT TABLE ILLUMINATION SPECIFICATIONS	
Intensity	12V/20W
Stage	X-Y manual scanning
Voltage	110V, 220V automatic switchable
INTERNAL LCD MONITOR SPECIFICATIONS	
Resolution	640 x 480 lines, VGA
Type	Liquid Crystal Display (LCD)
CAMERA PORT SPECIFICATIONS	
Formats Available	1" 2/3" 1/2" 3/8"
Camera Mount Type	"C" mount
COMPUTER SYSTEM REQUIREMENTS	
Software	ArcView 3.1
Operating System	Windows"" 95/NT
Hardware	Pentium or higher 133 MHz minimum 32 Mb Ram minimum

Appendix E. Wetland Mapping Procedures of the Massachusetts Department of Environmental Protection's Wetland Conservancy Program.

~ MassGIS ~

Orthophoto Wetlands and Streams (1:5,000) - February 2001

Download these layers: Wetland polygons | Stream arcs

OVERVIEW

The Orthophoto Wetlands and Streams datalayers comprise a polygon coverage and a line coverage. They are registered to, and tiled by, the Orthophoto Quad Library. The attribute codes in the WETLANDS polygon coverage describe different types of wetland environments. The Wetlands polygon coverages are named W and compose the WETLANDS layer. The arcs in the line coverages, which are named S, represent streams and compose the STREAMS layer.

METHODOLOGY

The wetlands were interpreted from stereo, 1:12000 scale, color-infrared photography by staff at UMASS Amherst. The interpretation is field checked by Department of Environmental Protection (DEP) Wetlands Conservancy Program (WCP). Completed interpretations are then scanned at 250 dpi with a Howtek Scanmaster 3+. The resulting images are converted to ARC/INFO coverages using ARCSCAN with additional processing in ARCEDIT. The distortion from terrain and camera coordinates are removed using a combination of PHOTOGIS, a photogrammetry software program, and a digital terrain model (DTM) derived from 1:5,000 black and white ortho-rectified digital aerial photography. In ARC, the corrected coverages are then mapjoined and clipped by the boundary of a State Plane Coordinate grid cell which represents a 4 kilometer by 4 kilometer orthophoto sheet. Plots are generated at 1:5,000 scale and final quality control is performed at that scale. It should be noted that the resulting wetlands are for planning purposes only; final wetland boundary determination must accord with MA Act M.G.L. c. 131.

ATTRIBUTES

Currently all attribute information for the wetlands coverages is maintained in ARC/INFO in a PAT. The WETCODEs are incorporated as annotext (ARC/INFO feature class annotation, subclass WET) in the datalayer.

The wetland coverage **W.PAT** is populated with these items:

ITEM NAME	WDTH	OPUT	TYPE	N.DEC	DESCRIPTION
WETCODE	4	5	B	-	WETLAND CONSERVANCY CODES
ITEM_VALUE_C	12	12	C	-	WETLAND LABEL ABBREVIATIONS
ITEM_VALUE_DESC	60	60	C	-	DESCRIPTION OF WETLAND LABELS

The following types of wetlands are represented in the datalayer:

LABEL	WETCODE	DESCRIPTION
1	BA	COASTAL BANK BLUFFOR SEA CLIFF
2	BB	BARRIER BEACH SYSTEM
3	BE	COASTAL BEACH
4	BG	BOG
5	CB	CRANBERRY BOG
6	D	COASTAL DUNE
7	DM	DEEP MARSH
8	M	SHALLOW MARSH MEADOWOR FEN
9	OW	OPEN WATER
10	RS	ROCKY INTERTIDAL SHORE
11	SM	SALT MARSH
12	SS	SHRUB SWAMP
13	TF	TIDAL FLAT
14	WS1	WOODED SWAMP DECIDUOUS
15	WS2	WOODED SWAMP CONIFEROUS
16	WS3	WOODED SWAMP MIXEDTREES
17	BB-BE	BARRIER BEACH-COASTALBEACH
18	BB-BG	BARRIER BEACH-BOG
19	BB-D	BARRIER BEACH-COASTALDUNE
20	BB-DM	BARRIER BEACH-DEEPMARSH
21	BB-M	BARRIER BEACH-MARSH
22	B-OW	BARRIER BEACH-OPENWATER
23	BB-SS	BARRIER BEACH-SHRUBSWAMP
24	BB-WS1	BARRIER BEACH-WOODEDSWAMP DECIDUOUS
25	BB-WS2	BARRIER BEACH-WOODEDSWAMP CONIFEROUS
26	BB-WS3	BARRIER BEACH-WOODEDSWAMP MIXED TREES
27	BB-SM	BARRIER BEACH-SALTMARSH
88	N/A	N/A
99	U	UPLAND

An AAT exists in the Wetlands polygon coverage. The only lines coded represent the edge of a N/A, or not-interpreted area. Item W<sheet-id>-id for these arcs is coded 9999.

The **S.AAT** for each stream coverage possesses arcs with S<sheet-id>-id coded 8888 and no other attributes. All arcs represent streams.

MAINTENANCE

These datalayers are being developed by DEP GIS group. Distribution is through MassGIS. Questions may be directed to DEP GIS to 617-574-6890.

The datalayers are currently under development. Data production is complete in the Wachusett, Ware, Quabbin, Shawsheen, North Coastal, Ipswich, Merrimack, Parker, Cape Cod and Islands basins. A large part of the Metro Boston area and Buzzards Bay basin are also complete. Production of additional wetlands data is underway in the southeastern part of the state. Please consult the current project Status Map for the most up-to-date availability.