*Practical Paper*

# Assessing Lakeshore Permit Compliance Using Low Altitude Oblique 35-mm Aerial Photography*

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ABSTRACT: Our affinity for water, lifestyle changes, and population growth have led to increased demands on inland lakes. These demands have led to shoreland development, modification of both shoreland and littoral zone vegetation, and modification of shoreline. Lake water quality, fisheries, and wildlife have been impacted negatively. To address such problems, the state of Wisconsin passed legislation designed to force implementation of land-use control programs over lake development. Such programs rely upon a system of permits to control development activities.

Little is known about the effectiveness of Wisconsin's lakeshore protection programs. This paper will describe the development and use of small format aerial oblique techniques to identify lakeshore modifications on shoreland, at the shoreline, and in near-shore waters. Six lakes in Oconto County, Wisconsin were studied. Results were compared to permit records to establish rates of compliance.

## INTRODUCTION

CITIZENS OF THIS COUNTRY have always had an affinity for water. Coastal locations on our ocean and inland shorelines have been considered "prime" land to develop for decades. Population growth, along with lifestyle changes and increased affluence, have led to increased residential and recreational development on inland lakes in the United States.

Cottage/second home development on lakes has been accompanied by a number of human activities which result in deleterious change of the lakeshore and lake waters. Shoreland vegetation has been cleared. Wetland areas adjacent to shoreland have been drained and filled. Shorelines have been altered physically to "improve" lots. Additionally, littoral zones of lakes, with associated plant and animal communities, have been disturbed by dredging, filling, and modification of aquatic vegetation.

Lakeshore development and associated activities may have significant detrimental effects on lake components, the shore environment, and ecosystems. Although few cause-and-effect relationships have been established, probable and potential negative effects on lake systems resulting from lakeshore development have been recognized. Important federal and state policy reflecting this recognition was established in the late 1960s and early 1970s. The Wisconsin legislature, noting that lakes serve both as an economic (tourism) and natural resource, and that serious economic loss would result if lakes were allowed to continue to degrade, passed legislation designed to protect inland lakes.

Following passage of the Wisconsin Water Resources Act of 1966 (WWRA), counties were required to enact shoreland regulations. Shoreland zoning was supported strongly in a 1972 landmark Wisconsin Supreme Court decision (Just vs. Marinette County). Under Wisconsin programs, counties were given administrative responsibilities for lakeshore zoning and shoreland protection ordinances. The Wisconsin Department of Natural Resources (WDNR) was required to establish minimum standards and to provide oversight to counties.

Although Wisconsin's lake and lakeshore protection programs have been implemented fully for 20 years, very little is known about their effectiveness.

## THE STUDY

Although Wisconsin's lake and lakeshore protection programs may have sound objectives, their effectiveness is not known nor does there appear to be a coordinated approach to assess program effectiveness. State administered water regulation includes control over alteration of the bank, shoreline, and bed of navigable bodies of water. Activities regulated include dredging, bulkhead line development, sand blanketing, and riprapping. All of the above activities require approval via permit. Passage of WWRA led to county adoption of programs to protect shoreland resources. Oconto County, located in northeastern Wisconsin (Figure 1), developed ordinances addressing standards of land division, building setbacks from lakeshore, lot size, cutting of vegetation, grading, filling, construction, and sanitation. These activities, as well, require approval.

Much has been written of the potential of lakeshore protection programs (Dresen and Vollbrecht, 1986; Yanggen, 1983; WDNR, 1982). However, studies have not been conducted to determine if lakeshore zoning (locally administered) or state administered water regulations are having an effect on lakeshore conditions.

While lakeshore protection programs commonly depend upon a system of permits to control compliance with program goals, such programs appear problematic. To test the hypothesis that permit compliance for regulated lakeshore activities is marginal within Oconto County, Wisconsin, six lakes were selected for analysis. Study objectives were (1) to develop methodology using 35-mm aerial photography to assess permit compliance of regulated lakeshore activities; (2) to assess the utility of these aerial photographic techniques to analyze regulated lakeshore activities; (3) to establish rates of permit compliance for each regu-

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lated activity on the study lakes; and (4) to estimate project cost-effectiveness.

### Description of Study Areas

Wisconsin is a state blessed with over 15,000 fresh water lakes. Six lakes in Oconto County were selected for study (Figure 1). Oconto County is located in northeastern Wisconsin, approximately one hour from Green Bay. Study lakes range in area from 8.7 hectares (Sunrise Lake) to 396 hectares (White Potato Lake). A short description of each lake is provided below (Carlson *et al.*, 1977).

| | |
|---|---|
| Archibald Lake | – Surface hectares 174.0<br>Shoreland: Predominantly upland, consisting of mixed hardwoods and conifers. Limited areas of shrub-meadow wetland<br>Development: 113 dwellings and 1 resort |
| Boot Lake | – Surface hectares 106.4<br>Shoreland: Upland of mixed hardwoods and conifers<br>Development: 40 dwellings, 1 resort, 1 U.S. Forest Service Campground |
| Paya Lake | – Surface hectares 49.1<br>Shoreland: Upland of mixed hardwoods and conifers<br>Development: 39 dwellings |
| Sunrise Lake | – Surface hectares 8.7<br>Shoreland: Upland of mixed hardwoods and conifers<br>Development: 1 dwelling |
| Wheeler Lake | – Surface hectares 118.6<br>Shoreland: Upland of mixed hardwoods and conifers<br>Development: 120 dwellings and 2 resorts |
| White Potato | – Surface hectares 596.0<br>Shoreland: 75% upland of mixed conifers and hardwoods; 25% coniferous swamp wetland<br>Development: 139 dwellings, 1 resort, 1 motel, and 1 campground. |

## RESEARCH METHODS

To establish permit compliance of regulated lakeshore activities, comparison between historical records and current 35-mm oblique slides was required. Historical records used were 1971-72 USGS vertical aerial photographs (panchromatic, 1:20,000 scale), public land survey maps, and Oconto County tax rolls. All lakes were flown for aerial photographic coverage in the fall or spring of 1987-88 to test the efficacy of hand-held oblique 35-mm color slides to aid in the identification of regulated lakeshore activities.

Given the concerns expressed regarding demise of shoreland areas and the large number of Wisconsin lakes, it was recognized that aerial photography might offer an efficient means to monitor lakeshore development for program enforcement and evaluation. Aerial and field methods were designed and implemented to establish (a) rates of permit compliance for regulated activities and (b) accuracy of the 35-mm aerial interpretation.

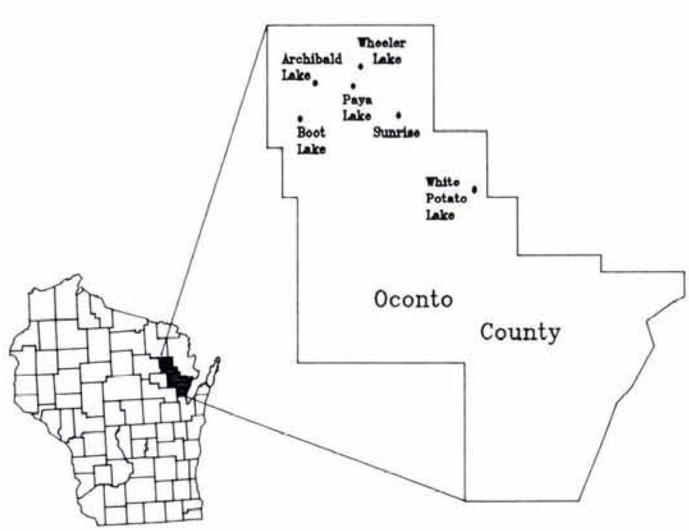


Fig. 1. Name and location of study lakes in Oconto County, Wisconsin.

The use of both vertical and oblique aerial photography for a wide variety of natural resource and urban-based problems is well documented. Lillesand and Kiefer (1979) describe applications including land-use/land-cover mapping, forest tree species identification and timber volume assessment, and water pollution detection. Successful habitat analysis and classification has been reported by Befort and Ulliman (1985) and Norton *et al.* (1985). MacConnell and Niedzwiedz (1979) applied vertical aerial photography to assess stream and stream bank conditions after channelization on Vermont's White River. Historical air photos have been used to establish coastal wetland change (Niedzwiedz and Batie, 1984) and urban residential change (Niedzwiedz, 1990). In the latter study, interpreted results from the historical air photos served as a "baseline" for 35-mm photography taken as part of that study. Extremely low altitude aerial photography (180 to 275m/600 to 900 ft) was used by Welch *et al.* (1985) to assess ephemeral gully erosion.

Small format aerial photography has been applied to numerous problems. A thorough discussion of small format equipment and procedures is presented by Woodcock (1976). Small format aerial photography has been applied in most instances to natural resource problems. Shafer and Degler (1986) presented 35-mm hand-held aerial photography as a relatively inexpensive and flexible way to obtain qualitative information on environmental change associated with oil and gas exploration in northern Alaska. Paine and McCadden (1988) applied 70-mm large-scale aerial photography to inventory forest vegetation. Hagen and Smith (1986) used crown measurements made on 35-mm photographs to predict tree groundline diameters. Heer and Smith (1986), using 35-mm aerial photographs, estimated the density of young pine plantations while McCarthy *et al.* (1982) assessed characteristics of spruce-fir forests in an attempt to predict stand hazard and potential losses to spruce budworm. Walker (1985), in an innovative low altitude application, utilized ultra-light reconnaissance and small format camera systems (35 and 70 mm) to record archaeologic sites.

While wetland and water quality applications of aerial photography are many, attempts made to assess lakeshore development and compliance with protection programs have not been made, or have not been published widely. Hill *et al.* (1985) do report, however, successful development of a permit geographic information system for coastal zone management in Louisiana. Their system utilizes Landsat MSS data and various types of mapped and textual data.

The use of oblique photographs and oblique 35-mm aerial photography is documented elsewhere and is not within the scope of this paper (Eastman-Kodak, 1974; Fleming and Dixon, 1981; Niedzwiedz, 1986; Niedzwiedz, 1990; Roberts and Griswold, 1986; Shafer and Degler, 1986). Evans and Mata (1984) cite efforts to control interpreted results from oblique 35-mm photos.

Photographic equipment for this study consisted of two 35-mm SLR cameras equipped with 50-mm lenses, No. 1A skylight filters, and auto-advance motor drives. These compact, lightweight cameras facilitated operation and viewing during photographic work. Film used was standard Kodak Ektachrome and Kodachrome (ASA 64).

A Cessna 172 aircraft was used for this study. This aircraft has characteristics required for low-altitude oblique photography of lakeshore areas: large enough to accommodate a photo team consisting of a photographer, spotter/equipment person, and pilot; has a moveable passenger window hinged at the top; aircraft wings are attached at the top to allow unobstructed photography; and the aircraft is highly maneuverable.

Flight planning is critical to efficient and effective lakeshore photography on small inland lakes. Flight lines were established offshore parallel to, and approximately 92 metres (300 feet) from, lake shorelines (Figure 2). Flying altitude was 152 metres (500 feet). As the aircraft traveled counter-clockwise and parallel to the shoreline, oblique slides were taken in sequence from the open window. An oblique angle of approximately 45 degrees and slide coverage endlap of about 50 percent were maintained.

To identify regulated lakeshore modifications on the study lakes, current 35-mm slides of lakeshore properties were interpreted to identify instances of development or modification. Lakeshore regulations divide lakeshore into three zones: shoreland, shoreline, and wetland-littoral (Figure 3). Within these zones, slides were interpreted using the classification scheme described in Table 1. Slide derived interpretive results were tabulated and compared against field documentation to establish interpretive accuracies per lakeshore modification type. Chi-square analysis of interpretive results/field documentation also was conducted.

All aerial documentation was conducted lot-by-lot while viewing projections of aerial slides (Figure 4). Aerial interpretive results were coordinated with public land survey maps, recorded in a ledger, and later transferred to a LOTUS 123 spreadsheet. Because program implementation began in 1972, a historical record of lakeshore development was required. USGS air photos (1971/72 black-and-white, panchromatic, 1:20,000 scale) were compared to 1987/88 slides to determine on which lots and the type of development that had occurred since 1971/72. Public land survey maps and tax rolls were used to identify the specific year of development for each lot and development activity recorded. Tax rolls also were used to link lot identification numbers from public land survey maps to lot owner name. All lakeshore lots identified as having one or more types of development requiring a permit were checked against state and county records to establish compliance. If aerial interpretive results were verified (located) on original building records, or represented by an appropriate permit(s), the development activity(ies) was judged as in compliance.

Results of the analysis are presented in Table 2. To enhance aerial slide interpretive accuracy, lakeshore conditions of all study lakes were recorded on 35-mm slides and documented with detailed field notes. Both slides and field notes were taken from a boat as it traveled slowly just off shore, parallel to the shoreline.

## RESULTS AND DISCUSSION

Interpretive analysis of aerial slides and historical records indicate that, since 1971/72, 146 lots had at least one regulated lakeshore development modification requiring a permit. Official WDNR and Oconto County records show that 160 permits should have been on file. A total of 55 permits were issued for lakeshore development which yielded an overall compliance rate of 34.4 percent. Compliance for specific lakeshore development activities is reported in Table 2.

This research represented a pilot study, a primary goal of which was to assess the utility of 35-mm oblique photography to aid in the identification of regulated lakeshore development.

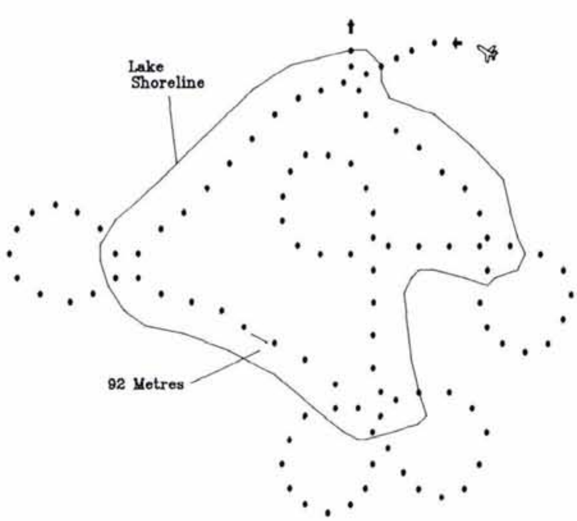


FIG. 2. The relationship of shoreline configuration and flight-line paths necessary to photograph lake shoreland. Flightlines are located parallel to, and approximately 92 meters from, each shoreline.

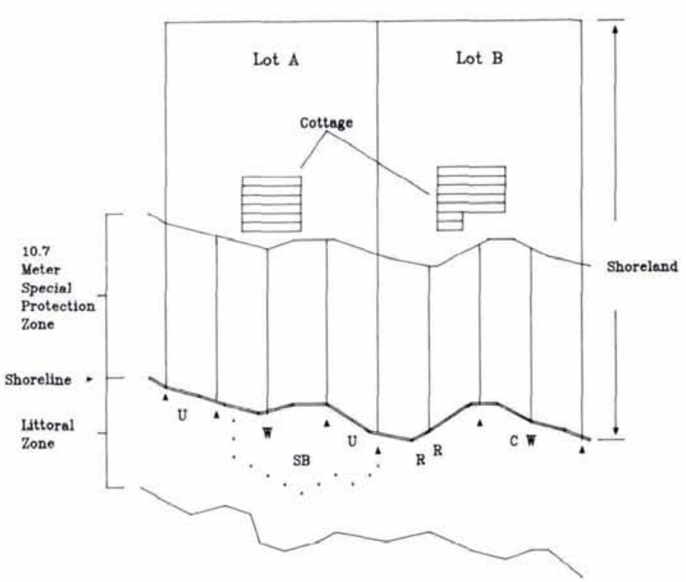


FIG. 3. Line drawing of inland lake shoreland as defined by Wisconsin Department of Natural Resources. Shoreland zones, e.g., shoreland, shoreline, and littoral, were defined for the purposes of use control and zoning. The special protection zone adjacent to the shoreline also is shown. An example of shoreline and littoral zone interpretation is provided. Delineation Key: (▲) - start/end of shoreline type; (U) - undisturbed; (W) - wood wall; (RR) - riprap wall; (CW) - concrete wall; (SB) - sandblanket (dots indicate boundary). Vertical lines running perpendicular to the shoreline represent lot quarter sections used to interpret shoreland vegetation.

TABLE 1. LAKESHORE MODIFICATION CLASSIFICATION SCHEME. MODIFICATIONS BY TYPE WHERE IDENTIFIED PER LOT USING 35-MM AERIAL SLIDES. MODIFICATIONS WERE RECORDED AND FILES REFERENCED USING LOTUS 1-2-3. COMPARISON WITH HISTORICAL RECORDS (E.G., 1972 USGS AERIAL PHOTOS AND COUNTY TAX ROLLS) WAS MADE TO ASSESS PERMIT COMPLIANCE.

I. *Shoreland*
- A. Structure*
  - 1. Home/Cottage
  - 2. House Trailer
  - 3. Garage
  - 4. Outbuilding/Shed
  - 5. Paved Patio/Deck
  - 6. Boathouse
- B. Structure Setback*
- C. Grading*
- D. Paving*
- E. Exposed Soil
- F. Slope (mean slope from shoreline to structure)
- G. Vegetation Modification
  - 1. Overstory — Near Shore (within 11 metres of shoreline)*
    - a. Clearcut
    - b. Clearcut to 33% crown closure
    - c. 34 to 66% Crown Closure
    - d. 67% to Undisturbed
    - e. Undisturbed
  - 2. Overstory — Inland (Beyond 11-metre protective zone. Classes same as above.
  - 3. Understory — Near shore*
    - a. Exposed Soil
    - b. Lawn
    - c. Less than 50% undisturbed (thinned or removed)
    - d. Greater than 50% undisturbed
    - e. Undisturbed
  - 4. Understory — Inland. Classes same as above.

II. *Shoreline*
- A. Undisturbed/natural
- B. Riprap — boulders or broken concrete*
- C. Wood wall — log or lumber*
- D. Concrete Wall*

III. *Wetland — Littoral*
- A. Dredging*
- B. Ditching*
- C. Sandblanket*

*Approval/Permit required
For vegetation and shoreline interpretation, each lot was partitioned into 1/4 units, along lot frontage.

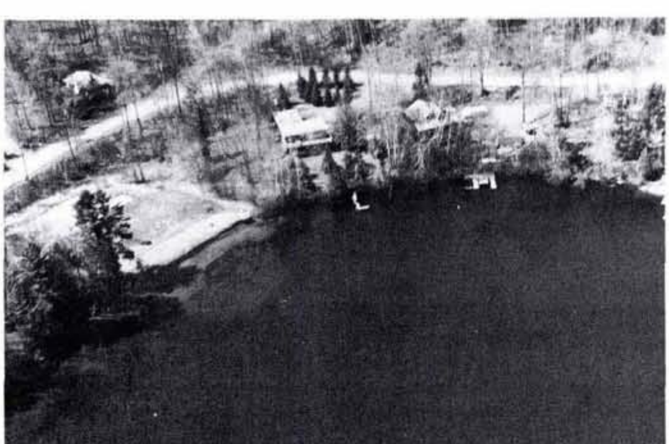

FIG. 4. Example of slide coverage of a segment of lake shoreland. Example shows from left to right: undisturbed shoreland and littoral zone; clearcut lot with graded surface, lawn, wall, and sandblanket; and two lots with different degrees of vegetation modification but no shoreline or littoral zone modification.

Results showed that the methods implemented can be utilized to identify shoreland development and associated activities, and to check permit compliance. The methods used were efficient, inexpensive, and effective.

## INTERPRETIVE ACCURACY

Aerial interpretive results were checked against field observations to determine relative aerial interpretive accuracy and to identify areas for methodologic improvement. An examination of the error matrix for discrete variables (Table 3) reveals an overall interpretation accuracy of 64 percent for lakeshore modifications of the types dredging/filling, shoreline buffering (riprap, walls, etc.), soil disturbance, and grading/paving. To obtain interpretive accuracy for specific lakeshore modifications of the discrete type, the number of correctly interpreted observations in a specific type was divided by the total number of observations that were assigned to that specific type (i.e., the row total). Lakeshore modifications interpreted most accurately include undisturbed littoral zone (100 percent); absence of paving (85 percent); terracing (81 percent); concrete, stone, or wood retaining walls (80 percent); and undisturbed shoreline (78 percent). All of these areas exhibit distinctive interpretive characteristics which made them more readily identifiable.

Other shoreland modification types were identified with moderate accuracy – undisturbed inland areas (69 percent) and inland exposed soil (67 percent). It appears that near-shore vegetation, both under and overstory vegetation, masks inland conditions enough to reduce interpretive accuracy. Some shoreline modifications proved difficult to interpret. Erosion at the shoreline was interpreted correctly only 32 percent of the time. Loose logs/rubble and riprap were interpreted (correctly) 25 and 22 percent of the time, respectively. The data indicate that loose logs/rubble and riprap often were misclassified as undisturbed (50 and 44 percent of the time, respectively). Such misclassification is likely the result of similar image elements between the types. Undisturbed shoreline is highly diverse which would yield mixtures of tones, textures, sizes, shapes, and shadows. Shoreline modifications that incorporate loose logs and/or rubble, or modifications that use small riprap materials, could produce mixed image elements as described above.

Obtaining accurate interpretation of lakeshore modification types requiring the interpreter to decide among a range of classification options (e.g., overstory crown-closure at 0 percent, 1 to 33 percent, 34 to 66 percent, 67 to 99 percent, or 100 percent) proved to be difficult. Examination of the error matrix for such lakeshore modifications reveals an overall interpretation accuracy of just 27.7 percent (Table 4). By general category, the most accurate interpretation was achieved with inland understory (67 percent), followed by slope conditions (53 percent) and inland overstory (38 percent). Initially, these results seem confounding. How can interpretation of foreground areas (near shoreline) be more difficult than background areas inland? An explanation is based on the fact that lakeshore modifications more likely are located between lake cottages and the shoreline. As a result, interpreters are faced with greater diversity of vegetative conditions in both the under and overstory.

High levels of accuracy were attained in specific classes from each of the above general classification categories. Steep slope conditions were identified correctly 100 percent of the time, followed by inland understory (lawn – 96 percent), inland overstory (undisturbed – 75 percent), near-shore overstory (undisturbed – 72 percent) and near-shore understory (exposed soil – 71 percent). An attribute common to all of the above examples is that they lie at the extremes of their categories. Relative to disturbance of vegetation, both under and overstory, the image elements associated with lawn, exposed soil, and undisturbed vegetative areas would be quite distinct.

When one considers the number of interpretive observations

TABLE 2. LAKESHORE MODIFICATION AND PERMIT COMPLIANCE. OBSERVATIONS PER TYPE OF MODIFICATION WERE MADE USING COLOR SLIDES AND FIELD DOCUMENTATION. PERMITS ISSUED PER TYPE OF MODIFICATION WERE IDENTIFIED BY STUDYING OCONTO COUNTY AND WDNR FILES.

| Lakeshore Modifications | Observations | Permits Expected* | Permits Issued | Percent Compliance |
|---|---|---|---|---|
| Structure | 70 | Z-70 | 42 | 60.0 |
| Insufficient Setback | 12 | V-6 | V-1 | 16.7 |
| Substandard Lot Size | 2 | V-2 | V-0 | 0 |
| Grading | 9 | Z-9 | Z-0 | 0 |
| | | SE-2 | SE-2 | 100 |
| Paving | 6 | Z-6 | Z-0 | 0 |
| Excessive Clearing | 14 | SE-6 | SE-0 | 0 |
| Riprap | 9 | DNR-6 | DNR-0 | 0 |
| | | Z-9 | Z-9 | 0 |
| Sea Wall | 23 | DNR-19 | DNR-6 | 31.6 |
| | | Z-23 | Z-4 | 17.4 |
| Dredging | 1 | DNR-1 | DNR-0 | 0 |
| | | Z-1 | Z-0 | 0 |
| TOTALS | 146 | 160 | 55 | Overall 34.4% Compliance |

Permit Key: Z-Zoning; DNR-Department of Natural Resources;
V-Variance; SE-Special Exemption

*Expected permits do not always match observation because of grandfathering of preexisting conditions.

TABLE 3. ERROR MATRIX FOR DISCRETE LAKESHORE MODIFICATIONS FROM 35-MM AERIAL SLIDE INTERPRETATION VERSUS FIELD VERIFIED INFORMATION. FIELD VERIFICATION WAS MADE FROM A BOAT LOCATED 6 TO 15 METRES OFF SHORE. WHERE APPROPRIATE, CHI-SQUARE STATISTICS WERE CALCULATED. SYMBOL KEY: DREDGING/FILLING – (0) NONE, (1) WALL BELOW OHWM, (2) SAND BLANKET, (3) OTHER FILL, (4) DREDGING; SHORELINE CHANGE - (0) UNDISTURBED, (1) RIPRAP, (2) CONCRETE/STONE/WOOD, (3) LOOSE LOGS/RUBBLE, (4) SOIL EROSION; INLAND EXPOSED SOIL- (0) UNDISTURBED, (1) EXPOSED SOIL; GRADING/PAVING - (0) NONE, (1) TERRACING, (2) FOR STRUCTURE/PAVEMENT, (3) GRADING UNPAVED SURFACE, (4) PAVED/NOT GRADED.

| | | Aerial Slide Derived Interpretation | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Field Verified | | Dredging/Filling of Littoral Zone | | | | | Shoreline Change* | | | | | Inland Exposed Soil** | | Grading Paving | | | | | Row Total | Percent Correct |
| | | 0 | 1 | 2 | 3 | 4 | 0 | 1 | 2 | 3 | 4 | 0 | 1 | 0 | 1 | 2 | 3 | 4 | | |
| Dredging Filling | | | | | | | | | | | | | | | | | | | | |
| | 0 | 90 | | | | | | | | | | | | | | | | | 90 | 100 |
| | 1 | | 2 | | | | | | | | | | | | | | | | 2 | 100 |
| | 2 | 7 | | 0 | | | | | | | | | | | | | | | 7 | 0 |
| | 3 | | | | 1 | | | | | | | | | | | | | | 1 | 100 |
| | 4 | 3 | | | | 0 | | | | | | | | | | | | | 3 | 0 |
| | | | | | | | | | | | | | | | | | | | 93/103 | 90 |
| Shoreline Change | | | | | | | | | | | | | | | | | | | | |
| | 0 | | | | | | 377 | 9 | 39 | 26 | 30 | | | | | | | | 481 | 78 |
| | 1 | | | | | | 104 | 53 | 34 | 45 | 1 | | | | | | | | 237 | 22 |
| | 2 | | | | | | 70 | 13 | 570 | 43 | 20 | | | | | | | | 716 | 80 |
| | 3 | | | | | | 50 | | 9 | 21 | 5 | | | | | | | | 85 | 25 |
| | 4 | | | | | | 153 | 11 | 19 | 8 | 90 | | | | | | | | 281 | 32 |
| | | | | | | | | | | | | | | | | | | | 1111/1800 | 62 |
| Inland Exposed Soil | | | | | | | | | | | | | | | | | | | | |
| | 0 | | | | | | | | | | | 27 | 12 | | | | | | 39 | 69 |
| | 1 | | | | | | | | | | | 8 | 16 | | | | | | 24 | 67 |
| | | | | | | | | | | | | | | | | | | | 43/63 | 68 |
| Grading Paving | | | | | | | | | | | | | | | | | | | | |
| | 0 | | | | | | | | | | | | | 67 | 11 | | | 1 | 79 | 85 |
| | 1 | | | | | | | | | | | | | 3 | 13 | | | | 16 | 81 |
| | 2 | | | | | | | | | | | | | | | 0 | | | | |
| | 3 | | | | | | | | | | | | | 1 | | | 1 | | 2 | 50 |
| | 4 | | | | | | | | | | | | | | 1 | | | 1 | 2 | 50 |
| | | | | | | | | | | | | | | | | | | | 82/99 | 83 |
| | | | | | | | | | | | | | | OVERALL ACCURACY | | | | | 1329/2065 | 64 |

*Significant at .001; **SIGNIFICANT AT .01

TABLE 4. ERROR MATRIX FOR CONTINUOUS CLASS LAKESHORE MODIFICATIONS FROM 35-MM AERIAL SLIDE INTERPRETATION VERSUS FIELD VERIFIED INFORMATION. FIELD VERIFICATION WAS MADE FROM A BOAT LOCATED 6 TO 15 METRES OFF SHORE. CHI-SQUARE STATISTICS WERE CALCULATED. SYMBOL KEY: NEAR-SHORELINE UNDERSTORY — (1) EXPOSED SOIL, (2) LAWN, (3) < 1/2 UNDISTURBED, (4) > 1/2 UNDISTURBED, (5) UNDISTURBED; NEAR-SHORELINE OVERSTORY — (1) CLEARCUT, (2) CLEARCUT TO 1/3 CROWNCLOSURE, (3) 1/3 TO 2/3 CROWNCLOSURE, (4) — 2/3 TO UNDISTURBED, (5) UNDISTURBED; INLAND UNDERSTORY — (1) LAWN/SOIL, (2) < 1/2 UNDISTURBED, (3) > 1/2 UNDISTURBED, (4) UNDISTURBED; INLAND OVERSTORY — (1) CLEARCUT, (2) CLEARCUT TO 1/3 CROWNCLOSURE, (3) 1/3 TO 2/3 CROWNCLOSURE, (4) 2/3 CROWNCLOSURE TO UNDISTURBED, (5) UNDISTURBED; SLOPE — (1) FLAT, (2) MODERATE, (3) STEEP.

| | | Aerial Slide Derived Interpretation | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Field Verified | | Near-shore* Understory | | | | | Near-shore* Overstory | | | | | Inland* Understory | | | | Inland** Overstory | | | | | Slope*** | | | Row Total | Percent Correct | | Percent Within One Class |
| | | 1 | 2 | 3 | 4 | 5 | 1 | 2 | 3 | 4 | 5 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | 5 | 1 | 2 | 3 | | | | |
| Near Shoreline Understory | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | 1 | 80 | 16 | 4 | 8 | 5 | | | | | | | | | | | | | | | | | | 113 | 71 | | 85 |
| | 2 | 751 | 30 | 14 | 6 | 13 | | | | | | | | | | | | | | | | | | 814 | 4 | | 98 |
| | 3 | 151 | 71 | 25 | 43 | 30 | | | | | | | | | | | | | | | | | | 320 | 8 | | 43 |
| | 4 | 92 | 82 | 20 | 46 | 83 | | | | | | | | | | | | | | | | | | 323 | 14 | | 46 |
| | 5 | 26 | 17 | 11 | 10 | 66 | | | | | | | | | | | | | | | | | | 130 | 51 | | 59 |
| | | | | | | | | | | | | | | | | | | | | | | | | 247/1700 | 15 | 1235/1700 | 73 |
| Near Shoreline Overstory | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | 1 | | | | | | 151 | 63 | 27 | 62 | 27 | | | | | | | | | | | | | 330 | 46 | | 65 |
| | 2 | | | | | | 81 | 119 | 130 | 150 | 70 | | | | | | | | | | | | | 550 | 22 | | 60 |
| | 3 | | | | | | 12 | 54 | 80 | 268 | 113 | | | | | | | | | | | | | 527 | 15 | | 76 |
| | 4 | | | | | | 9 | 18 | 36 | 145 | 215 | | | | | | | | | | | | | 423 | 34 | | 94 |
| | 5 | | | | | | 7 | 1 | 5 | 25 | 96 | | | | | | | | | | | | | 134 | 72 | | 90 |
| | | | | | | | | | | | | | | | | | | | | | | | | 591/1964 | 30 | 1463/1964 | 75 |
| Inland Understory | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | 1 | | | | | | | | | | | 184 | 1 | 3 | 4 | | | | | | | | | 192 | 96 | | 96 |
| | 2 | | | | | | | | | | | 30 | 9 | 2 | 5 | | | | | | | | | 46 | 20 | | 89 |
| | 3 | | | | | | | | | | | 31 | 3 | 11 | 22 | | | | | | | | | 67 | 16 | | 54 |
| | 4 | | | | | | | | | | | 3 | 0 | 0 | 5 | | | | | | | | | 8 | 63 | | 63 |
| | | | | | | | | | | | | | | | | | | | | | | | | 209/313 | 67 | 239/313 | 76 |
| Inland Overstory | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | 1 | | | | | | | | | | | | | | | 13 | 5 | 1 | | | | | | 19 | 68 | | 95 |
| | 2 | | | | | | | | | | | | | | | 36 | 51 | 32 | 19 | 5 | | | | 143 | 36 | | 83 |
| | 3 | | | | | | | | | | | | | | | 2 | 14 | 30 | 35 | 16 | | | | 97 | 31 | | 81 |
| | 4 | | | | | | | | | | | | | | | | 3 | 9 | 37 | 51 | | | | 100 | 37 | | 97 |
| | 5 | | | | | | | | | | | | | | | | | | 3 | 9 | | | | 12 | 75 | | 100 |
| | | | | | | | | | | | | | | | | | | | | | | | | 140/371 | 38 | 325/371 | 88 |
| Slope | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | 1 | | | | | | | | | | | | | | | | | | | | 13 | 8 | 4 | 25 | 52 | | |
| | 2 | | | | | | | | | | | | | | | | | | | | 20 | 13 | 32 | 32 | 20 | | |
| | 3 | | | | | | | | | | | | | | | | | | | | | | 9 | 9 | 100 | | |
| | | | | | | | | | | | | | | | | | | | | | | | | 35/66 | 53 | | |
| | | | | | | | | | | | | | | | | | | | | | | | Overall Accuracy | 1222/4414 | 27.7 | 3262/4348 | 75 |

*Significant at .001; **significant at .001 when table collapsed to 3 by 5; ***Significant at .001 when table collapsed to 2 by 3.

within one class of correct classification, interpretive accuracies for continuous variable types appear quite good. For example, while overall accuracy is 27.7 percent, interpretive observations within one class of correct observations constitute 75 percent of total interpretive observations. In fact, Table 4 shows that 12 of 19 individual interpretive classes have 76 to 100 percent of their interpretive observations within one class of correct interpretation. These figures indicate that marked improvement in interpretive accuracies is attainable by utilizing more careful interpretation of slides and improvement in slide image quality (discussed below).

The amount of data on lakeshore conditions available from a given slide varied greatly. Although an attempt was made by the pilot to maintain constant altitude and distance from the shoreline, these two factors and lot size varied enough that individual slides might show from two to as many as ten lots. In some cases, observations on all variables for all lots on a slide were possible. In other cases, observations were possible for only a few variables on only some of the lots, or parts of lots, shown on a slide.

Blurriness of aerial slides was cited as the most common reason observations of lakeshore modifications could not be made. Blurriness appears to have resulted from plane engine vibration as the photographer braced himself with arms against the plane window frame to steady the camera. It is suggested that simply using elbow/forearm pads to cushion contact with the plane's window frame will eliminate slide blurriness.

Of slides interpreted, the variable inland shrub-ground vegetation was the most problematic. Such understory vegetation was difficult to view because of overstory masking, especially if all or part of the overstory was coniferous. Aerial oblique perspectives of the shoreland did aid classification of near-shoreline shrub-ground vegetation.

The quality of slides varied somewhat from lake to lake. Much of this variability may be attributable to differences in lake size and shape, vegetation, and slope of the surrounding shoreland. Irrespective of conditions on the ground, photography was easiest along relatively straight or gently curved sections of lakeshore at least a few hundred metres long. Along more jagged shoreline, the pilot was forced to bank in an attempt to maintain a constant distance from the shoreline. In many instances, it was not possible to remain parallel to the shoreline without banking to an angle that precluded photography. The pilot would then circle and approach from a different heading. Despite these maneuvers, slides taken along jagged shoreline showed substantial variability in distance from the shoreline and angle to the shoreline. A few of these slides were nearly vertical. Slides taken with the camera aimed perpendicular to the shoreline and pointed down 45 degrees from horizontal generally were most revealing.

In addition to problems photographing jagged stretches of shoreline, the required circling mentioned above consumed flying time. In future studies, were it is not necessary to cover the entire shore of a lake or where lakeshore could be sampled, circling could be eliminated by selecting only longer, straighter stretches of shoreline.

Slide quality often was related to light conditions, with underexposure and shading reducing the interpretability of slides. While camera adjustments might result in some improvement, so might paying closer attention to changing light conditions along the lakeshore. In order to obtain acceptable lighting beneath near-shoreline tree canopy, the best location for the sun would be fairly low in the sky and behind the camera. At best, under these conditions, one might only be able to obtain well lit slides of less than half of a lake's shoreland. The limited flying time available for this research resulted in flying being done with the sun overhead to light as much of the lakeshore as possible. All of the lakeshore areas could be photographed in one flight under these conditions. If feasible, separate morning and afternoon flights of specific stretches of lakeshore might produce the highest number of good quality slides. As mentioned above, however, it may not always be critical that the entire shore of a given lake be photographed.

Seasonal weather conditions need to be taken into consideration when photographing lakeshores. Archibald Lake was photographed in the fall, other study lakes in the spring. While vegetation sometimes obstructed the view of a feature, or created shadows, these problems would have been much worse with foliage on deciduous trees and shrubs. The fall photography of Archibald was conducted inadvertently with a dusting of snow on the shoreland (there was no snow on the ground at the airport in Green Bay). This light snow cover made it difficult to interpret shoreline type, ground vegetation, and exposed soil.

Despite the mediocre interpretive accuracy of some types of lakeshore modifications, considerable potential exists for improved interpretation of lakeshore vegetation and modifications. The greatest potential for marked improvement appears to lie with changes in flight planning, plane, and camera stability. Aerial analysis of lakeshores for development activities offers numerous advantages over other alternatives. Aerial analysis is more cost effective and saves time. Less than two hours of flight time was required to photograph the lakeshore of six study lakes. To identify "problem" lakes relative to permit compliance, perhaps lakeshore "sampling" would be appropriate. Such sampling would require preflight planning to identify which segment of lakeshore to fly. Such an approach would allow flying of the straightest segments of lakeshore, thereby eliminating difficult segments to fly and one of the important sources of low quality slide images. This approach would allow better coordination of flying time during the day, which, relative to the orientation of lakeshore to be flown, should produce better lighting conditions. Lakeshore "sampling" also would allow more lakes to be assessed.

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