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W.P.

New Jersey Department of Environmental Protection

C-1197

THE NEW JERSEY SUBMERGED AQUATIC VEGETATION DISTRIBUTION ATLAS FINAL REPORT

DISTRIBUTION LEVEL MAPS WITH PERCENT COVER AND SPECIES ASSOCIATION INFORMATION OF SUBMERSED AQUATIC VEGETATION IN NEW JERSEY'S COASTAL ZONE

OPERATIONAL MAPPING PROGRAM

ROBERT T. MACOMBER
Director, Water Resources Division

and

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EARTH SATELLITE CORPORATION
7222 47th Street (Chevy Chase)
Washington, D.C. 20015

Prepared for New Jersey Department of Environmental Protection, Division of Coastal Resources, Bureau of Coastal Planning and Development, with the financial assistance of the U.S. Department of Commerce, National Oceanic and Atmospheric Administration, Office of Coastal Zone Management, under the provisions of the Federal Coastal Zone Management Act, P.L. 92-583, as amended.

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The dedicated efforts of Mr. Dick Allen, as Principal Biologist/ Consultant, to organize seaplane reconnaissance missions and maximize photointerpretation accuracy are reflected in the fine quality of the final SAV distribution maps.

1.0 INTRODUCTION

1.1 Background

Since the early 1960's, increased awareness of the dependence of the aquatic ecosystem on wetland vegetation has required better management and regulation of our coastal areas. As a result, New Jersey was one of the first states to enact a Wetlands Act in 1970 and a Coastal Area Facility Review Act in 1973, optimizing coastal planning and promulgating wetland species maps as a regulatory device.[1/] New Jersey and other states have utilized remote sensing during the wetland resource identification and mapping evaluation process.

With emergent wetland resource management plans now in effect, mapping interest has recently focused on the equally valuable estuarine submersed aquatic vegetation (SAV) beds dominant in our nation's littoral zone. As primary producers, submersed aquatic vegetation represents the first trophic level in the aquatic ecosystem. Most of the above-ground biomass decomposes annually to detrital food particles available to higher level herbivores. The dependence of the shellfishing and fisheries industries on the nursery and shelter functions provided by the seagrass beds is widely recognized. The value of SAV in migratory waterfowl winter forage has also been recognized through research conducted during the 1960's.

[1/] The New Jersey wetland mapping program was conducted by Earth Satellite Corporation under contract to the New Jersey Department of Environmental Protection in 1973-1974.

The need for monitoring the distribution of SAV in New Jersey back bays was expressed by the New Jersey Division of Fish, Game and Wildlife in 1974 (Mairs et al., 1974). Pursuant to the New Jersey Coastal Management Program - Bay and Ocean Shore Segment - the Office of Coastal Zone Management recognized the need for SAV distribution maps in 1977, and funded research (Good et al., 1978) that determined that SAV distribution mapping through aerial photography and surface ground truthing is feasible and cost effective. Critically-timed aerial photography and seaplane reconnaissance were proven to be the most accurate and cost effective means of SAV resource distribution mapping in the Chesapeake Bay (Macomber, 1978).

1.2 Synopsis of Approach to SAV Distribution Inventory

The first complete inventory of submersed aquatic vegetation in the Maryland portion of the Chesapeake Bay was successfully conducted by Earth Satellite Corporation (EarthSat) during the 1978 growing season. The innovative approach to ground truth and aerial photo procurement resulted in significant photointerpreter benefit, cost savings and increased accuracy. A float-equipped reconnaissance aircraft and a photo aircraft were both operated by the field biologist/photointerpreter team, thus eliminating all standby costs and facilitating proper timing of photo coverage to the phenologic growth stage of the vegetation. This proven approach (with certain tailored modifications necessitated by New Jersey's deeper water and larger SAV bed size) was used to map 27 USGS quad sheets in New Jersey's coastal area during the 1979 growing season. EarthSat's experienced biologist/photointerpreter team conducted all phases of the mapping program using available aircraft, equipment and procedures selected and proven efficient for SAV distribution mapping. The EarthSat biologists conducted preliminary seaplane reconnaissance overflights and surface sampling of all New Jersey SAV areas in May-June 1979 to determine the general distribution, phenologic development stage and species associations present in New Jersey estuarine waters. Information from these overflights was used to time aerial photo acquisition precisely. Aerial photo missions flown by the project manager (at 12,000 feet ASL using a photo aircraft and a Wild precision metric mapping camera) were timed to the maximum distribution stage of plant development. The New Jersey species association exhibited a bi-modal maximum distribution similar to the southerly, more saline regions of the Chesapeake Bay. Photo coverage of the maximum distribution of _Zostera marina_ (eelgrass) and _Zanachellia palustris_ (horned pondweed) was obtained during the May-June time frame. _Ruppia maritima_ (widgeon grass) and _Potamogeton pectinatus_ (sago pondweed) reached maximum distribution during August-September, and required a second set of aerial photos. Seaplane reconnaissance (the most accurate and efficient means of determining when maximum distribution of a particular plant species is occurring locally) was used to determine the exact timing of the aerial photo missions. Surface sampling ground truth was acquired at pre-selected locations (as mutually agreed upon by NJDEP and EarthSat) and at locations of interest encountered during the seaplane overflights. All ground truth information was annotated on the quad sheet or the aerial photograph. Species associations from surface samples and relative percent cover visual estimates from above, were recorded by the field biologist/photointerpreter team on the field print.

Photointerpretation and map production was accomplished by the field team during October 1979 as soon as photo coverage and ground truth information was complete. Delineations of SAV bed boundaries were made on Log-E-tronics field prints in the field and later in the office during the photointerpretation process. These delineations were subsequently transferred in ink to the Cronaflex photo quad basemaps. Surface ground truth, including species associations and percent cover, were annotated on the maps at all seaplane landing sites.

EarthSat utilized the capabilities of two well qualified, multi-talented professionals whose qualifications include Coastal Ecology/Remote Sensing and Biology, SAV field botanical expertise, Commercial and Seaplane Pilot's License, photointerpretation, aerial photography, and cartography. This team conducted all phases of inventory. EarthSat, through its principal subcontractor, AeroEco, utilized a Piper SuperCub STOL (short take-off and landing) seaplane on EDO oversized floats (maximum draught, six inches) for surface sampling, and a Cessna 180H STOL photo aircraft fitted with a Wild 9" x 9" precision metric mapping camera certified by USGS (calibration report in Appendix A).

2.0 MATERIALS AMD METHODS

2.1 Aerial Photography to Assess Distribution and Abundance of Submersed Aquatic Vegetation

Aerial photography has been used by several investigators to estimate distribution of submersed aquatic vegetation along shorelines. Lukens (1968) and Anderson (1971) were the first to use aerial photography for this purpose in the Chesapeake Bay, Maryland. Orth and Gordan (1975) used this technique to study eelgrass beds in the lower Chesapeake Bay. Markham (1977) mapped submersed vegetation from aerial photos in Canadarago Lake, New York.

EarthSat conducted research to determine the optimal film/filter combination for mapping eastern U.S. estuarine SAV during mid-August of 1977. EarthSat flew various scales of multispectral photography using the I^2S four lens camera in the Eastern Bay and Eastern Neck regions of the Chesapeake Bay. The results of careful analysis and controlled compositing of various band combinations indicated a superior capability of the green/red band combination to discriminate SAV from the background. The best single band was the red band. The infrared band, as per remote sensing physics theory, offered <u>no</u> water penetration and thus <u>no</u> SAV information. The blue band was severely degraded by atmospheric haze (particularly at altitudes of 8,000 feet and higher), and by water turbidity. Combinations including the blue band added nothing at the lower altitudes, and most certainly degraded the imagery at the higher altitudes, i.e., 12,000 feet.

It is for this reason that EarthSat and others recommend the use of black-and-white negative aerial film in the medium to high speed range with a minus blue filter. Aerial photography for this project was conducted using Kodak Double-X Aerographic 2405 standard film for mapping and charting in concert with a deep yellow, i.e., minus-blue filter. This film has a flat spectral sensitivity curve through the visible spectrum, and a peak sensitivity in the red where maximum haze penetration is possible and SAV information is found. The resolving power of 2405 is 100 lines/mm for a high contrast object and 50 lines/mm for a low contrast object such as SAV. Low sun angle photography demands a medium to high speed film in order to obtain a proper exposure. Double-X 2405 has an effective aerial film speed of 320 ASA, allowing proper exposure at f-5.6 and 1/300th of a second at solar altitudes down to 3° at 12,000 feet over the New Jersey coast.

Aerial photographic data was interpreted for the purpose of delineating the distribution and aerial extent of the total SAV population in New Jersey waters. The final products are photo quad sheet mylars with delineations of total SAV distribution as interpretable from 1:24,000 black-and-white special purpose aerial photography.

The aircraft used to acquire aerial photography under subcontract to EarthSat is owned and operated by AeroEco of Reston, Virginia. It is a Cessna 180H STOL.

AeroEco employed a Wild Precision Metric Mapping Camera with a 9" x 9" format and a 6" focal length lens. Full tip, tilt and crab corrections are a standard feature of this camera, as are automatic 60% stereo forward lap and integral view finder flightline tracking.

The AeroEco camera holds a recent (November 1978) certification and Calibration Report issued by the United States Geological Survey in Reston, Virginia (see Appendix A).

The nominal scale of the aerial photography was chosen to match the photo quad sheet mapping base, i.e., 1:24,000. This required a flying height of 12,000 feet ASL and provided a ground coverage of 18,000 feet on a side per photograph. With standard stereo forward lap and sidelap and a north/south flightline orientation, approximately 16 photographs were required to cover a full quad sheet.

The optimal time for early season photographic acquisition of SAV in the New Jersey coastal zone was determined to be between May 15 and June 31. The water turbidity at this time of year is low because boating traffic is not yet at a peak, and the growth stage of *Potomogeton pectinatus* and *Zostera marina* was found to be at a maximum.

All photography was acquired at tidal stage/water turbidity levels that allowed experienced interpreters maximum opportunity to accurately and consistently delineate total SAV distribution. (See Photographic Specifications, Table 1.)

Early Season Photography

Zostera marina was the target species during the June photo overflights of the middle New Jersey coast. *Potamogeton pectinatus* was in full distribution in Upper Barnegat Bay by mid-June. A gradual transition, starting below the Route 37 bridge north of

TABLE 1

AERIAL PHOTOGRAPHY SPECIFICATIONS FOR AN INVENTORY OF THE DISTRIBUTION OF SUBMERSED AQUATIC VEGETATION AND ALGAL BEDS IN NEW JERSEY COASTAL WATERS

1.0 SCALE

A scale/film type combination sufficient to resolve submersed vegetation to five metres in areal extent.

2.0 FILM TYPE

2405 or 2402

3.0 FORMAT

9" x 9"

4.0 CAMERA

Precision metric mapping camera - (Wild or Zeiss)

5.0 SOLAR ALTITUDE

Low - i.e., 20° to 40°; to minimize sun glare on the water.

6.0 TIDAL STAGE

Low tide plus or minus two hours as predicted by NOS tide tables and local knowledge for the area being photographed.

7.0 TURBIDITY

Minimal, to insure interpretation of SAV beds.

8.0 WIND

Low velocity or off-shore breeze to minimize wave action, shoreline erosion, and associated water turbidity.

9.0 WEATHER

CAVU (Ceiling and Visibility Unlimited)

10.0 TIMING/SEASON

Two sets of photography required to insure coverage of maximum distribution of all grass species. Surface sampling of the vegetation completed prior to aerial photography to insure timing coincident with maximum distribution.

Toms River, to Ruppia maritima was discovered during the seaplane reconnaissance flights in mid-June.

Flightlines were laid out on 1:250,000 scale topographic map mosaics of the New Jersey coast. Figure 1 is a reduction of the original flightline map with an overlay showing the early season aerial photo flightlines. The early season photo coverage was obtained during excellent weather conditions on June 25, 1979 (see Table 2) from an altitude of 12,000 feet during the low tidal/low sun altitude window. See the aerial photographer's log, Figure 2a and 2b, for exact flightline times. Table 3a lists the low tidal windows occurring during low sun altitude periods of the day for June. A cross reference between the photographer's log (Figure 2a and 2b) and the low sun altitude/low tidal window schedule (Table 3a) shows that the photography was timed to the appropriate tidal stages and sun altitudes.

The film was developed by Precision Photo Laboratories in Dayton, Ohio, on an Eastman Kodak Versamat continuous film processor. A test strip at the beginning of each roll was provided so that the speed of the Versamat could be adjusted to provide the proper film density.

The photo center of each frame was plotted on the flightline map to insure that the coverage was adequate. Each negative was annotated on the east edge of the frame with the date of exposure, the line number and the sequential exposure number within the flightline. The negatives were then printed on Dupont VCP resin coated paper on a Log-E-tronics electronic dodging contact printer.

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TABLE 2

Mission

NJSAV Photo #1 - Monday, June 25
#2 - Thursday and Friday, August 16 and 17

Mission

NJSAV Recon #1 - Tuesday and Thursday, June 20-21
#2 - Tuesday-Thursday, August 7-9
#3 - Tuesday-Thursday, September 25-27

Figure 2a: Early Season

FLIGHT DEPARTMENT
PHOTOGRAPHIC LOG

AeroEco
2303 Archdale Road
Reston, Va. 22091

TAKE OFF ______ TAKE OFF ______
LANDING ______ LANDING ______
TAKE OFF ______ TAKE OFF ______
LANDING ______ LANDING ______

LOCATION NJ SAV #1
PROJECT NO. 1197
DATE 6/25/79
AIRCRAFT NO. 47990
PILOT Marin
PHOTOGRAPHER Macomber
CAMERA/FILM/FILTER 15 AG 81/2405/Yellow 60% forward lap
NOTES (WEATHER, ETC.) CAVU

RUN NO.	DIR HDG	DRIFT	FRAME START	FRAME STOP	NO. EXP.	TIME START	TIME STOP	ASL ALTITUDE	EXPOS. S/SPEED	DATA F/NO.	REMARKS
25	E	4N	1	77	77	?	1:32	12,700	1/300	f 16	COFE
1	N	5E	78	96		2:10	2:27	12,300	1/300		NJ SAV #1--sun angle little high--wait two hours
9	spot shot		97	-		5:12		12,300	1/300	f 11.5	
2	N		98	106		5:15	5:20	12,300		f 11.5	
10	spot shot		107	-		5:24					
11	spot shot		108	-		5:28					
3	N	8E	109	130		5:34	5:48				
5	N		131	146		5:57	6:07			f 11	
6	W		147	150		6:10	6:12				
17	spot shot	N	151	-		6:16					
7	NE		152	156	1 extra	6:20	6:22				Traffic 747
8	NE		157	160		6:30					
(S.H.) 18				161			6:32				

PERIOD ______

TOTAL FLYING HOURS ______

Figure 2b: Early Season FLIGHT DEPARTMENT PHOTOGRAPHIC LOG

AeroEco
2303 Archdale Road
Reston, Va. 22091

TAKE OFF ____ TAKE OFF ____
LANDING ____ LANDING ____
TAKE OFF ____ TAKE OFF ____
LANDING ____ LANDING ____

LOCATION NJ SAV #1
PROJECT NO. 1197
DATE 6/25/79
AIRCRAFT NO. 47990
PILOT Marin
PHOTOGRAPHER Macomber
CAMERA/FILM/FILTER 15 AG 81/2405/Yellow 60% forward lap
NOTES (WEATHER, ETC.)

RUN NO.	DIR HDG	DRIFT	FRAME		NO. EXP.	TIME		ASL ALTITUDE	EXPOS.	DATA	REMARKS
			START	STOP		START	STOP		S/SPEED	F/NO.	
6	spot shot	S		162		6:42					
16	spot shot	S	163	164							
4	S		165	191	26	6:48	7:02				

PERIOD ____ ____

TOTAL FLYING HOURS 7.3

EARLY SEASON LOW TIDAL/LOW SOLAR ALTITUDE PHOTOGRAPHIC WINDOWS, EDST

JUNE	Cape May to Lower Great Egg Harbor Bay	Great Egg Harbor Bay to Atlantic City	Upper Atlantic City to Lower Little Egg Inlet	Little Egg Inlet	Little Egg Harbor to Lower Barnegat Inlet	Barnegat Inlet	Upper Barnegat Inlet to Tom's River	Upper Barnegat Bay to Metedeconk River	Manasquan Inlet	Shark River	Shrewsbury River	Navesink River	Sandy Hook
1	0775	0800	0825	0775		0725			0800	0725			0725
2	0875	0900		0875		0825			0900	0825			0825
3						0900				0900			0900
4								1500					
5								1575					
6							1500	1650					
7					1500		1575	1725			1500		
8					1575		1650	1800			1575	1500	
9					1650		1725	1875			1650	1575	
10	1500	1525	1550	1500	1725		1800		1525		1725	1650	
11	1600	1626	1650	1600	1825	1550	1900	0825	1625	1550	1825	1750	1550
12	1675	1700	1725	1675	1900	1625	0750	0900	1700	1625	1900	1825	1625
13	1750	1775	1800	1750	0775	1700	0850		1775	1700	0775	0700	1700
14	1850	1875	1900	1850	0850	1800			1875	1800	0850	0775	1800
15	0700	0725	0750	0700					0725			0850	
16	0800	0825	0850	0800		0750			0825	0750			0750
17	0900			0900		0850				0850			0850
18													
19								1550					
20								1625					
21					1500		1575	1725			1500		
22					1575		1650	1800			1575	1500	
23					1650		1725	1875			1650	1575	
24	1500	1525	1550	1500	1725		1800		1525		1725	1650	
25	**1575**	**1600**	**1625**	**1575**	**1800**	**1525**	**1875**	**0825**	**1600**	**1525**	**1800**	**1725**	**1525**
26	1650	1675	1700	1650	1875	1600	0750	0900	1675	1600	1875	1800	1600
27	1725	1750	1775	1725	0750	1675	0825		1750	1675	0750	1875	1675
28	1775	1800	1825	1775	0800	1725	0875		1800	1725	0800	0725	1725
29	1850	1875	0700	1850	0875	1800			1875	1800	0875	0800	1800
30	0700	0725	0750	0700		1875			0725	1875		0850	1875

COASTAL SECTORS

▬ Heavy lines indicate date of early season photography.

Table 3a. Low tides in low solar altitude periods, 0700-0900 and 1500-1900.
Note: time presented rounded to nearest 0.25 hour.

This printer scans the negative with a CRT light beam and automatically adjusts the exposure of each area within the negative to maximize detail in the shadow and highlight areas. Subtle low contrast SAV information is thus enhanced on the field print.

The early season photography was thus ready for preliminary photointerpretation and seaplane ground truth verification.

Late Season Photography

The late season photography was acquired on August 16 during a low sun altitude/low tidal window over portions of the New Jersey coast (see Figure 2, Figure 3c and Table 1). On August 17, during a high sun altitude/low tidal window, additional photography was acquired over selected areas, including Barnegat Bay, where SAV had been found (via seaplane trawls) to be growing in deeper waters. The higher sun altitude, resulting in greater light penetration into the deeper waters of upper Barnegat Bay, was employed in hopes of imaging the extent of SAV in this area. Increased sun glitter caused by the higher sun altitude was compensated for by shooting 80% forward lap. These extra measures were necessary only in deep water areas (i.e., greater than 10 feet at MLW) where SAV boundaries were difficult to discern on the low sun altitude photography.

The late season photography was developed, annotated and printed in the same manner as the early season photography.

2.2 Field Data Collection

The first seaplane reconnaissance missions were conducted on June 20-21, 1979, from Cape May to Sandy Hook, to determine the SAV

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LATE SEASON LOW TIDAL/HIGH SOLAR ALTITUDE PHOTOGRAPHIC WINDOWS, EDST

AUGUST	Cape May to Lower Great Egg Harbor Bay	Great Egg Harbor Bay to Atlantic City	Upper Atlantic City to Lower Little Egg Inlet	Little Egg Inlet	Little Egg Harbor to Lower Barnegat Inlet	Barnegat Inlet	Upper Barnegat Inlet to Tom's River	Upper Barnegat Bay to Metedeconk River	Manasquan Inlet	Shark River	Shrewsbury River	Navesink River	Sandy Hook
1					1075		1150	1300			1075	1000	
2			1000		1175		1250	1400			1175	1100	
3	1075	1100	1125	1075	1300	1025	1375		1100	1025	1300	1225	1025
4	1150	1175	1200	1150	1375	1100	1450		1175	1100	1375	1300	1100
5	1250	1275	1300	1250	1475	1200			1275	1200	1475	1400	1200
6	1350	1375	1400	1350		1300			1375	1300		1500	1300
7	1450	1475	1500	1450		1400			1475	1400			1400
8						1475				1475			1475
9													
10													
11								1000					
12								1075					
13							1025	1175					
14					1050		1125	1275			1050		
15					1125		1200	1350			1125	1050	
16	1000	1025	1050	1000	1225	▨ 0950	1300	1450	1025	▨ 0950	1225	1150	▨ 0950
17	1100	1125	1150	1100	1325	1050	1400	▨ 1550	1125	1050	1325	1250	1050
18	1200	1225	1250	1200	1425	1150	1500		1225	1150	1425	1350	1150
19	1275	1300	1325	1275	1500	1225			1300	1225	1500	1425	1225
20	1350	1375	1400	1350		1300			1375	1300		1500	1300
21	1425	1450	1475	1425		1375			1450	1375			1375
22	1500			1500		1450				1450			1450
23													
24													
25													
26													
27								1025					
28								1075					
29								1125					
30					1000		1075	1225			1000		
31					1125		1200	1350			1125	1050	

COASTAL SECTORS

▬ Heavy lines indicate date of late season photography.

▨ Indicates photography procured within one-half hour of optimal window.

Table 3b. Low tides in high solar altitude periods, 1000-1500
Note: time presented rounded to nearest 0.25 hour.

Figure 3c: Late Season

FLIGHT DEPARTMENT
PHOTOGRAPHIC LOG

AeroEco
2303 Archdale Road
Reston, Va. 22091

TAKE OFF 07:30
LANDING ______
TAKE OFF ______
LANDING ______

TAKE OFF ______
LANDING ______
TAKE OFF ______
LANDING ______

LOCATION NJ SAV #2
PROJECT NO. 1197
DATE 8/17/79 8/16/79
AIRCRAFT NO. 47990
PILOT SKOV
PHOTOGRAPHER Macomber
CAMERA/FILM/FILTER AM 81/2405/Yellow
80% forward lap
NOTES (WEATHER, ETC.) CAVU Low tide 8:47, Cape May

RUN NO.	DIR HDG	DRIFT	FRAME		NO. EXP.	TIME		ASL ALTITUDE	EXPOS. S/SPEED	DATA F/NO.	REMARKS
			START	STOP		START	STOP				
1a	N	11°	1	9	8	9:15	9:21	12,500	1/300	f 8	Test develop
1b & 1c	N	11°	10	29			9:47				Ok
spot 9	N		30	31			9:50				
2	N	11°	32	40			10:00				
spot 10	N		41				10:05				
spot 11	N		42				10:07				
8/17/79 spot 12	N/S		43 clearing shot 44-46			14:00					
4	N		47	66		14:00	14:25				
4a	N		67	74		14:	14:30				
spot 13	N		75								
5S	N		76	90		14	14:46				
spot 16	S		91								
15 14			92 93				14:53				

PERIOD ______

TOTAL FLYING HOURS ______

growth stage and species associations present in New Jersey and to establish a base of operations. The seaplane facilities in Atlantic City proved to be unsatisfactory for overnight docking due to reports of vandalism at the town pier. Refueling arrangements were confirmed with the fixed base operator and were subsequently carried out with minimal inefficiencies. Overnight docking, washing and refueling facilities were utilized at Little Ferry Seaplane Base, since no other suitable location was available. All subsequent seaplane reconnaissance missions were conducted from Little Ferry.

It was determined that full distribution of the early species associations did exist as of mid-June 1979. Also, water clarity was generally observed to be excellent. Interviews with local marina operators revealed that water turbidity would increase significantly after the 4th of July because of heavier summer boat traffic. It was therefore decided that photo coverage should be obtained at the earliest tidal/weather window (see Table 3a). (Note: Water clarity is highest in the autumn months, e.g., October and November, but federal fiscal year grant constraints and declining standing crops did not allow photography at this time.)

The first set of photography was obtained under ideal tidal/weather/sun angle conditions. The photos were studied under magnification using various combinations of bottom and overhead lighting to maximize vegetation-substrate contrast. The photo-interpreter made preliminary delineations--of those beds in which the SAV visual signature was unquestionable--directly on the photographs. In a similar manner, notations of non-optimal photo imagery, future ground truthing sites and information for future ground truthing activities were made directly on the photographs.

After a complete preliminary interpretation, a second reconnaissance mission was scheduled. Each mile of shoreline and open water was inspected from the aerial vantage point. A Piper Super Cub STOL seaplane with oversized EDO floats was used to gather field data on all the quad sheets listed in Table 2. The two-man field team, consisting of a coastal ecologist/pilot and a biologist/photointerpreter, gathered numerous sample points of information rapidly and inexpensively using the aircraft via four increasing extrapolative techniques:

(a) Via direct contact and species identification on foot.

(b) Via along-shore transect trolling and random bottom sampling with the SAV rake and a new specially designed deeper water trawl (double faced close tined rake).

(c) Via surface observations during slow speed taxi.

(d) Via 50-1,000 foot aerial reconnaissance extrapolation of prior surface sample points.

The field team had ample time to conduct ground truth spot checks and low altitude extrapolations because of the mobility and versatility of the Super Cub seaplane. This aircraft was used to navigate the shallow waters and inlets to depths of six inches under its own power, or by paddles much like a canoe. It was anchored or beached when the field team gathered samples on foot. The Super Cub was also taxied at slow speeds (1-5 knots) like a small outboard motor boat for extended surface transects and along shore runs. The Super Cub made high speed taxi runs at speeds up to 50 mph when transiting from one area to the next or when along-

TABLE 4

LIST OF USGS 7½-MINUTE QUADRANGLE MAPS INCLUDED IN THE NEW JERSEY SAV DISTRIBUTION ATLAS

This study included the estuarine water portions of the following USGS quads

Sandy Hook**
Ashbury Park
Point Pleasant
Seaside Park
Barnegat Light
Ship Bottom
New Gretna
Beach Haven
Pleasantville*
Marmora
Atlantic City
Woodbine*
Avalon
Wildwood
Long Branch
Lakewood*
Tom's River
Forked River
West Creek*
Long Beach, NE
Tuckerton
Oceanville
Brigantine Inlet
Ocean City
Sea Isle City
Stone Harbor
Cape May

* Quads with very small estuarine water areas therein

** Within Sandy Hook Bay, the mapping area was limited to waters of eight feet or less (mean low water) shore extended runs were conducted. The STOL capability of the Super Cub allowed the field team to operate in and out of small inlets (300 feet long) and to fly reconnaissance missions down to 15-20 mph at 50 foot altitudes. Rapid straightline point-to-point transit from the Little Ferry Seaplane Base to the surface sampling areas and between SAV areas allowed the field team to arrive on-site anywhere in the New Jersey coastal area within one and one-half hours.

Also, the field team wore polarized sunglasses to eliminate surface glare and to allow for maximum SAV documentation.

Complete information on species associations, distribution, percent cover, and delineations of the seaward limits of the grass beds were recorded directly on the photographs by the project biologist. In some cases, the field data reconfirmed information obtained in the preliminary photointerpretation. Areas which had been difficult to interpret in the office because of localized turbidity were visited and additional data was gathered. Relevant observations such as species growth stage, relative vigor and preference to tidal current, depth, local land, and water use variations were also noted by the field team.

Seaplane landings were made often enough to assure that bottom phenomena being interpreted as SAV were in fact submersed vegetation beds as opposed to schools of fish, clam shell bars, substrate differences (such as dark organic-rich mud) or deeper water. Each landing site location was annotated directly on the photograph. Approximate percent cover estimates were made of the standing crop at the landing site by taking off and flying back over the site and viewing it again from above.

Upon completion of the ground truthing mission, the early season photography was reinterpreted in a manner identical to the preliminary interpretation. Photo data were integrated with field data, and further delineations of SAV beds were made. Data which had been obtained in the preliminary photointerpretation and checked in the reconnaissance mission were interpreted again. This redundancy, inherent in the inventory procedures, assured the utmost in quality control. These procedures also resulted in considerable photointerpreter benefit as the photointerpreter had studied the beds from an aerial vantage point in the field.

2.3 Map Production

The photos were interpreted in light of the field data. Information from the field trips and both sets of photography were composited on individual photos covering the entire study area. This information included delineation of the SAV bed's seaward perimeters and annotations of species distribution, association percentages and percent cover. After the delineations for each quad sheet were completed, a final evaluation and quality check was carried out.

As the photography was flown at the same scale as the selected basemaps, the composite data were transferred directly from the photos to scaled Cronaflex "photo quads" formatted to the 1:24,000 USGS series. These "photo quads" were duplicated by EarthSat from a set made available by the NJDEP. Final inking of the basemaps was completed using a Faber Castell #2 technical drafting pen with permanent ink. The photos were registered to the basemaps, and the basemaps were edge matched. Figure 4 is a reduction of a typical photo quad final product map.

All species information was gathered using the ground truthing methods described herein. Therefore, all species annotations are also indicative of a landing site. Table 5 is a list of SAV species found in New Jersey and their map abbreviations. The data for the other symbols, such as the percent cover class annotations and the "SAV" annotations, were gathered by aerial observation or during the photointerpretation process and, therefore, their placement is not associated with a particular landing site.

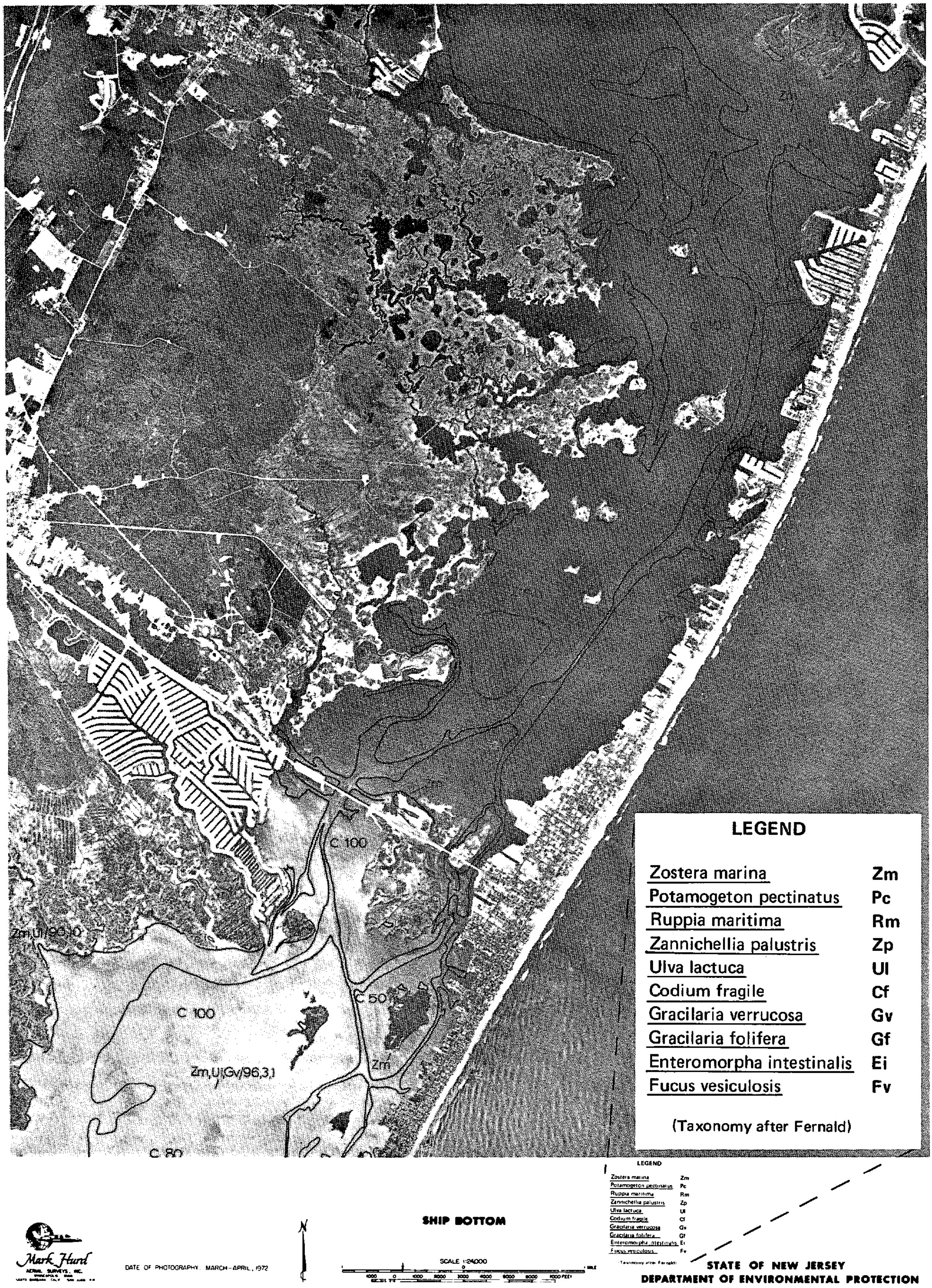
Two types of percentages are presented on the basemaps. Species association percentages follow species annotations when the data were sufficient to make an estimate, and indicate the relative percent composition of each species within a SAV bed. The percentages are related to the preceding species information respectively (i.e., sp.A, sp.B/% A, % B). Percent cover class annotations are preceded by a "C" and indicate the abundance of all species within a single bed relative to other beds within the study area. The percent cover class annotations are non-quantitative visual estimates and should not be confused with biomass or vegetative productivity measurements.

The seaward perimeter of the individual SAV beds was delineated by a single black line, except where land provided a natural boundary

This map produced by:
EARTH SATELLITE CORPORATION
7222 47th Street (Chevy Chase)
Washington, D.C.

NEW JERSEY
SUBMERSED AQUATIC VEGETATION
DISTRIBUTION - 1979

From 1" = 2000' air photos and low-altitude airplane reconnaissance flown June-Sept., 1979
by
AERDECO
Reston, Virginia



STATE OF NEW JERSEY
DEPARTMENT OF ENVIRONMENTAL PROTECTION

Figure 4.

TABLE 5

List of SAV species found in New Jersey waters and their abbreviations

Zostera marina	Zm
Potamogeton pectinatus	Pc
Ruppia maritima	Rm
Zannichellia palustris	Zp
Ulva lactuca	Ul
Codium fragile	Cf
Gracilaria verrucosa	Gv
Gracilaria folifera	Gf
Enteromorpha intestinalis	Ei
Fucus vesiculosis	Fv

to growth. In areas where the beds are large and extensively convoluted, it may be difficult for the map user to differentiate the substrate and vegetation sides of an individual line. The "SAV" annotations were placed in such vegetated areas to aid in this process.

All the beds were entirely enclosed within lines or land boundaries. These boundaries indicate the absolute limit of any submersed vegetative growth. It should be noted that in some cases, what is delineated as one complete bed may include a broad range of vegetation densities. For the purpose of this mapping effort, an SAV bed is roughly defined as connected vegetated substrate. In cases where the SAV density was consistent throughout the entire bed, a percent cover class estimate was made and annotated on the final basemap as described earlier.

It was not always possible to place the written annotations within the bounded areas. In such cases, a line was used to connect the annotations to the relevent locations within the SAV beds.

The third series of seaplane ground truthing missions was conducted during September 25-27, 1979, following the procurement of the late season aerial photography. Verification of the preliminary SAV bed delineations on the field photos continued. Less than optimal weather conditions including low ceilings, rain showers, winds, and turbulence made ground truthing difficult on the first day. Associated water turbidity and high tides in the middle of the day obscured the SAV beds. The subsequent days offered better conditions, and the accuracy of the preliminary photointerpretation was determined to be high.

These missions were carried out according to a previously planned mission profile, which specified transects to be flown and additional seaplane landing sites that were required to insure adequate and complete ground truth information. All transects were flown, and all landing site information was successfully obtained.

3.0 RESULTS AND RECOMMENDATIONS

3.1 Aerial Photography

Both the early and late season photography provided excellent imagery. Mr. Robert Macomber made day-by-day decisions on the possibility of acquiring SAV aerial photography based upon vegetation, water and weather conditions. This was possible because Mr. Macomber was conducting ground truth seaplane missions and was thus intimately familiar with SAV growth, water clarity and weather conditions throughout the SAV areas of New Jersey. The EarthSat team prepared tidal/sun angle charts (see Tables 3a and 3b) to aid in timing the photographic procurement. This carefully planned approach provided high quality aerial photo coverage of the coast of New Jersey at a very affordable cost.

3.2 Field Data Collecting

The use of the seaplane in reconnaissance missions proved itself time and again as the best available means of obtaining field data. The biologists/photointerpreters were able to view the grass beds from above and make immediate and accurate assessments of the distribution of the vegetation portrayed on the aerial photo. Surface craft navigation would have been very difficult within the beds due to plants tangling in the propellers and would have given very limited perspective of SAV distribition. All SAV areas on the 27 quads were flown in the low altitude ground truthing mode, and accurate verification of the maximum distribution of SAV beds was delineated on the field prints. This task would have been virtually impossible to accomplish from a boat. The rapid point-to-point surface sampling capability available to the field team was far beyond that of a boat and equally efficient once a surface sampling site was reached.

The timing of the seaplane reconnaissance on the day of, or within two days of the photographic overflight of a locality was not always practical. Weather and turbidity conditions did, at times, preclude seaplane observations. In addition, film development and film printing took several days. The distribution of a seagrass bed and/or its species association and percent cover are not factors which change rapidly, i.e., over a two-day period. In fact, there was more advantage to a longer term, more repetitive sampling program centered around two maximum distribution seasons and accompanying photo overflights. The ground truth was collected within a time frame that insured adequate assessment of the accuracy of the distribution information on the photographs.

3.3 Map Production

EarthSat has determined, through past research and operational SAV mapping programs, that 1:24,000 photography can be used to interpret and delineate the distribution of SAV beds over an entire region, such as the Coastal Zone of New Jersey or the Chesapeake Bay in Maryland. In 1978, EarthSat mapped distribution of SAV on 80 quad sheets in the Chesapeake Bay. This Distribution Atlas now documents the previously unknown fact that only one-half to two-thirds of the Chesapeake Bay quads have any SAV. The Chesapeake Bay

Management Atlas to be produced following the three year monitoring of distribution trends will provide species associations and percent cover for vegetated quads at a scale of 1:6,000 using color photography.

The SAV delineations for the New Jersey Division of Coastal Resources were transferred directly from the photographs to the final basemaps in ink. This combination of photointerpretation data transfer and cartographic final inking resulted in a great increase in efficiency in what are otherwise two separate and labor intensive tasks. This method is not only most efficient in terms of redundant task elimination, but is also less susceptible to error.

4.0 CONCLUSIONS

The distribution of submersed aquatic vegetation along the New Jersey coast is distinctly stratified. From Cape May north to Great Bay, where the marshes generally extend all the way to the barrier islands, only the algal species, almost exclusively *Ulva lactuca*, are found in the shallows of the myriad of bays, sounds and channels. A small amount of the various algal species as listed in Table 5 were found growing in the open bay waters from Great Bay to the Metedeconk River. North of the Metedeconk, the distribution is again comprised primarily of *Ulva lactuca*, with a small percentage of other algal species mixed in. The exception to this is a large mixed bed of *Ruppia maritima* at the mouth of the Navesink River. The beds of *Ulva lactuca* in some of the shallower rivers and sounds north of Barnegat Bay are quite expansive and dense.

The relatively open bay waters from Great Bay to the Metedeconk River are dominated by vascular species. Large and dense beds of *Zostera marina* grow on the broad shallows behind the barrier islands and along the shoreline proper. The extent of these beds is so vast that delineation of areas of bare substrate within totally vegetation back bay areas proved to be most appropriate.

With decreasing salinity, *Zostera marina* transitions to equally vast beds of *Potamogeton pectinatus*, above the Route 37 Bridge, north of Tom's River. The *Potamogeton pectinatus* is mixed with lesser amounts of *Zannichellia palustris*, *Ruppia maritima* and *Zostera marina* and is found up to the Metedeconk River. SAV distribution studies in Chesapeake Bay, Maryland have not discovered beds of *Potamogeton pectinatus* as extensive as those found in upper Barnegat Bay. The extensive protected shallows behind New Jersey's barrier beaches provide an ideal environment for vast SAV beds to thrive.

New Jersey submersed aquatic vegetation is characterized by less diversity of vascular species than that found in the less saline Maryland regions of the Chesapeake Bay.

5.0 RECOMMENDATIONS

The final basemaps provide excellent detail of the overall distribution of SAV in New Jersey's estuarine waters. The location and perimeter of every bed is precisely delineated.

The careful selection of ground truthing locations, facilitated by the aerial observation and photointerpretation processes, resulted in selected species distribution information. The final basemaps are evidence of the cost efficiency and accuracy of the data collection methods.

Seagrass distribution shown on the maps could be compared with information such as local currents, bottom topography, land use, salinity, and local nonpoint source pollution management practices. Future monitoring of the distribution of seagrasses in New Jersey as an indicator of water quality trends could lead to new land use management plans and in improved water quality.

Activities which affect water turbidity and sedimentation rate (such as dredging or certain kinds of land use) may be a controlling factor in SAV distribution.

This large area inventory is an important first step in the management of New Jersey's seagrass resources and will be an input to the Coastal Zone Management Plan. However, it does not provide adequate species information, quantified species association percentage or percent cover information at the 1:24,000 mapping and photo scale. If more detailed management level information of these types is deemed cost effective, future funds could be applied to obtain larger-scale color photography to produce larger-scale management maps in selected areas.

This year's distribution inventory would provide the basis for selecting, for instance, the high density vascular plant areas north of Great Bay for further study.

The distribution and relative density of any particular SAV species varies notably within one growing season. SAV distributions are also known to be quite dynamic from year to year. Any conclusions drawn from this year's basemaps should be prefaced with the understanding that the data is only one frame in a dynamic, changing system. These dynamic aspects ultimately lead to consideration of repeat inventories on an annual basis similar to the monitoring effort ongoing in Chesapeake Bay. Such a schedule of data collection would identify seagrass population trends which can in turn reflect water quality trends in New Jersey's back bays.

Future funds could also be directed toward more detailed ecological analyses. Ecological value assessment of SAV grass bed areas must be based on net worth or contribution to the aquatic ecosystem. Management of New Jersey's Coastal Zone will require a determination of the value of specific SAV areas as a source of forage for waterfowl, such as the Atlantic brant and other migratory waterfowl, as a source of shelter from predation for fin fish and shellfish, especially bay scallops; as a source of detrital contribution to the aquatic food chain; and for bottom and shoreline stabilization. The SAV species within a given bed, and percent cover differences between beds, will determine the relative value of each SAV area. More detailed species and cover mapping may now be desirable in New Jersey as a follow-up to the general distribution inventory.

The collection of samples of associated substrate could be an important aspect of any future inventory. The EarthSat field team is uniquely qualified to gather this kind of data via the seaplane in the ground truthing mode. Sample locations could be determined from the air and numerous surficial sediment cores of the substrata in representative grass beds could be gathered rapidly and inexpensively. Samples would be analyzed as to particle size and silt/clay/organic content to determine suitable habitat conditions.

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(rev. 8-75)

USGS Report No. RT-R/471

APPENDIX A

United States Department of the Interior

GEOLOGICAL SURVEY
RESTON, VIRGINIA 22092

REPORT OF CALIBRATION

October 31, 1978

of Aerial Mapping Camera

Camera type	Wild Heerbrugg RC5A	Camera serial no.	318
Lens type	Wild Aviogon	Lens serial no.	Ag 81
Nominal focal length	153 mm	Maximum aperture	f/5.6
		Test aperture	f/5.6

Submitted by
Aero Eco
Reston, Virginia 22091

Reference: Letter dated October 23, 1978, from Mr. Robert T. Macomber

These measurements were made on Kodak micro flat glass plates, 0.25 inch thick with spectroscopic emulsion type V-F Panchromatic, developed in D-19 at 68°F for 3 minutes with continuous agitation. These photographic plates were exposed on a multicollimator camera calibrator using a white light source rated at approximately 3500K.

I. Calibrated Focal Length: 152.154 mm

This measurement is considered accurate within 0.005 mm

II. Radial Distortion:

Field angle (degrees)	$\bar{D}_c$	D_c for azimuth angle			
		0° A-C	90° A-D	180° B-D	270° B-C
	µm	µm	µm	µm	µm
7.5	5	6	5	4	6
15	7	6	7	5	9
22.5	3	0	5	3	6
30	-1	-4	3	-5	3
35	-5	-9	-1	-10	2
40	1	-7	9	-6	6

The radial distortion is measured for each of 4 radii of the focal plane separated by 90° in azimuth. To minimize plotting error due to distortion, a full least-squares solution is used to determine the calibrated focal length. $\bar{D}_c$ is the average distortion for a given field angle. Values of distortion D_c based on the calibrated focal length referred to the calibrated principal point (point of symmetry) are listed for azimuths 0°, 90°, 180°, and 270°. The radial distortion is given in micrometres and indicates the radial displacement of the image from its ideal position for the calibrated focal length. A positive value indicates a displacement away from the center of the field. These measurements are considered accurate within 5 µm.

III. Resolving power in cycles/mm

Area-weighted average resolution 54.7

Field angle:	0°	7.5°	15°	22.5°	30°	35°	40°
Radial lines	113	113	80	40	57	67	20
Tangential lines	113	95	80	57	57	40	40

The resolving power is obtained by photographing a series of test bars and examining the resulting image with appropriate magnification to find the spatial frequency of the finest pattern in which the bars can be counted with reasonable confidence. The series of patterns has spatial frequencies from 5 to 268 cycles/mm in a geometric series having a ratio of the 4th root of 2. Radial lines are parallel to a radius from the center of the field, and tangential lines are perpendicular to a radius.

IV. Filter Parallelism

The two surfaces of the Wild 500 Pan No. 2979 filter accompanying this camera are within 10 seconds of being parallel. This filter was used for the calibration.

V. Shutter Calibration

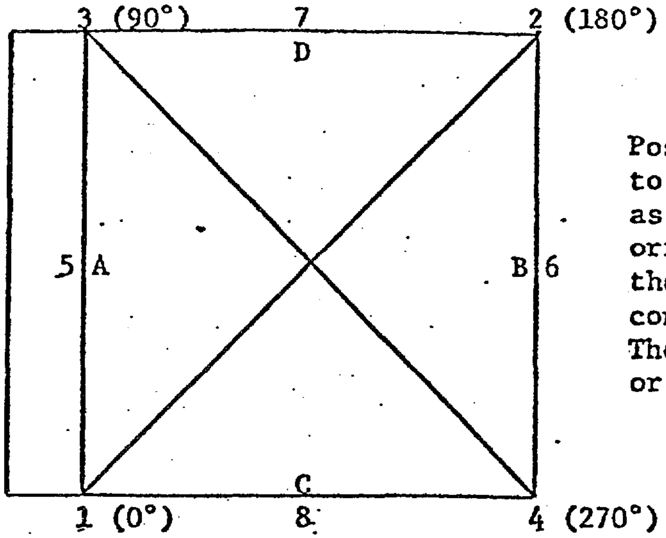
Indicated shutter speed	Effective shutter speed	Efficiency
1/200	4.1 ms = 1/240 s	72%
1/300	3.4 ms = 1/290 s	71%

The effective shutter speeds were determined with the lens at aperture f/5.6 The method is considered accurate within 3%. The technique used is Method I described in American National Standard PH3.48-1972.

VI. Magazine Platen

The platen mounted in Wild RC5 film magazine No. 209 does not depart from a true plane by more than 13 µm (0.0005 in).

VII. Principal Point and Fiducial Coordinates



Positions of all points are referenced to the principal point of autocollimation as origin. The diagram indicates the orientation of the reference points when the camera is viewed from the back, or a contact positive with the emulsion up. The direction-of-flight fiducial marker or data strip is to the left.

	X coordinate	Y coordinate
Indicated principal point, corner fiducials	0.006 mm	0.028 mm
Indicated principal point, midside fiducials	----	----
Principal point of autocollimation	0.0	0.0
Calibrated principal point (point of symmetry)	0.013	0.002

Fiducial Marks		
1	-105.990 mm	-105.971 mm
2	106.017	106.041
3	-105.992	106.031
4	105.999	-105.971
5	----	----
6	----	----
7	----	----
8	----	----

VIII. Distances Between Fiducial Marks

Corner fiducials (diagonals)

1-2 299.826 mm 3-4 299.809 mm

Lines joining these markers intersect at an angle of 89° 59' 52"

Midside fiducials Not Applicable

5-6 mm 7-8 mm

Lines joining these markers intersect at an angle of

Corner fiducials (perimeter)

1-3 212.002 mm 2-3 212.009 mm

1-4 211.989 mm 2-4 212.011 mm

The method of measuring these distances is considered accurate within 0.005 mm.

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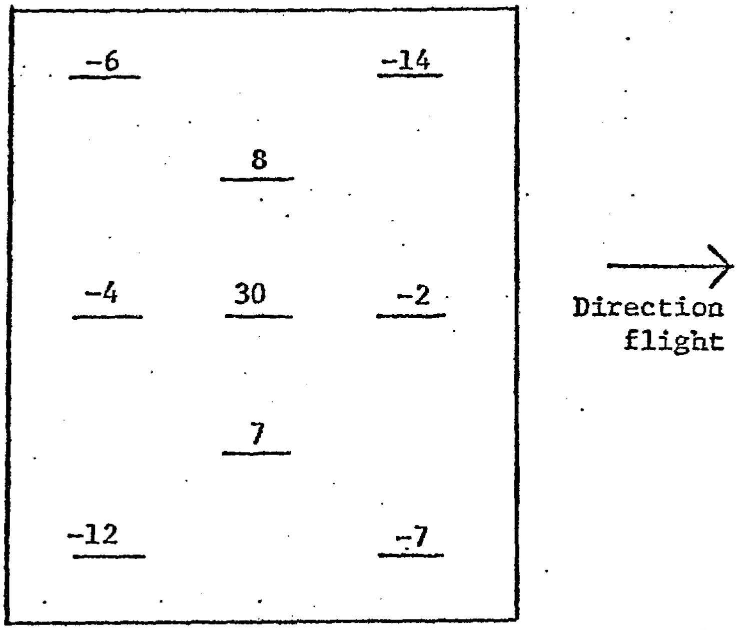
STEREOMODEL FLATNESS TEST AND FILM RESOLUTION

Camera No. 318 Lens No. Ag 81 Magazine No. 209

Focal length 152.154 mm Maximum angle of field tested 40°

Base-height ratio 0.6 Accuracy of determination 5 µm



Stereomodel
Test point array
(values in micrometres)

The values shown on the diagram are the average departures from flatness (at negative scale) for two computer-simulated stereomodels based on comparator measurements on contact glass (Kodak micro flat) diapositives made from Kodak 2405 film exposures.

Resolving Power, in cycles/mm Area-weighted average resolution 35.5
Film: Type 2405

Field angle:	0°	7.5°	15°	22.5°	30°	35°	40°
Radial lines	57	57	48	28	40	48	20
Tangential lines	57	48	40	40	34	28	24

William P. Tayman

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