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Defense Mapping Agency (DMA) raster-to-vector benchmark testing

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Battelle's Columbus Laboratories (BCL) conducted raster-to-vector benchmark testing on two cartographic data capture systems at the Defense Mapping Agency Hydrographic/Topographic Center (DMAHTC). A cartographic benchmark testing package and testing methodology, developed during an earlier project, were validated during the testing on DMA production systems. This final report consists of six topical areas: 1) benchmark testing materials and testing methods; (2) benchmark testing results; 3) benchmark testing materials and testing methodology validation; 4) recommendations for benchmark testing of non-DMA cartographic data capture systems; 5) recommendations for future research and development; and 6) observations about in-house system characteristics and operating procedures.

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EXECUTIVE SUMMARY

Battelle's Columbus Laboratories (BCL) has completed raster-to-vector benchmark testing on the Scitex and Broomall cartographic data capture systems at the Defense Mapping Agency Hydrographic/Topographic Center (DMAHTC). A cartographic benchmark testing package and testing methodology, developed during the "DMA Raster-to-Vector Analysis" project, were validated during the testing on DMA production systems. This final report consists of six topical areas: 1) Benchmark testing materials and testing methods 2) Benchmark testing results 3) Benchmark materials and testing methodology validation 4) Recommendations for benchmark testing of non-DMA cartographic data capture systems 5) Recommendations for future research and development and 6) Observations about in-house system characteristics and operating procedures.

1) Benchmark testing materials and testing methods were developed during a previous DMA research effort entitled "A Defense Mapping Agency (DMA) Raster-to-Vector Analysis". The benchmark materials consist of two basic types:

- o Three sets of unique cartographic geometries (i.e., simulated contours - concentric circles, drainage, and grids) each reproduced four times in increasing levels of density

- o Sample DMA products including a Digital Terrain Elevation Data (DTED) contour and drain/ridge overlays, a DFAD color pencil compilation and a Hydrographic chart compilation

The benchmark testing procedures included:

- o Scanning, thinning, vectorizing, and plotting of the sixteen input manuscripts. Times were kept for the first three procedures.

- o Evaluation criteria were based on timings, CRT image quality assessment, digital plot/analog input "overlay" analysis, system integration/user friendliness evaluation, and numerical analysis.

2) Benchmark testing revealed the following results:

- o The Broomall AGDS scanner was affected by the amount of data being processed while the Scitex was not affected.

- o Data density adversely affected vectorization times for the AGDS particularly for the synthetic contour and grid data. Increasing data density does not appear to affect the Scitex raster-to-vector conversion rates to an equal degree. In fact, conversion rates for the synthetic drainage data actually improve with increasing data density.

- o The AGDS appeared to process the synthetic contour data faster than either the synthetic drainage or grid data, although not significantly better. The Scitex processed the synthetic contour data at a significantly faster rate than the other two data types, however.

- o Overall the Scitex performed more effectively than the Broomall AGDS, performing three to four times faster.

- o A number of error types were identified in the visual inspection of digital plots. These included: gaps, spikes, slivers, offsets, and wandering centerlines.

3) Generally, the benchmark testing materials and methodologies were effective in evaluating A/V system performance. A few recommendations for improvements were made:

- o Maintain separate statistics for all manual or interactive editing required during the benchmark testing.

- o Replace the hydrographic sheet in the benchmark package because it does not represent a typical hydrographic compilation. For example, the bathymetric soundings are the same color as other pertinent information on the sheet.

- o Develop an objectives oriented test for at least one of the DMA sample inputs. Require data capture systems to produce a specified DMA product in the most efficient manner possible. For example, this might entail the production of press-ready color separations for a hydrographic chart derived from a color compilation manuscript. Timings for individual procedures, descriptions of the types of work required and an assessment of the quality of the output would be required.

4) Battelle recommends that DMA run benchmark tests on the following commercially available cartographic data capture systems:

- o Scitex Response-280 - Given DMA's current utilization of Scitex technology it is critical that ongoing assessments of product improvements be performed.

- o Intergraph Scan Data Capture System - Reports of new raster-to-vector conversion algorithms and hardware processors make this newly introduced system an ideal candidate for benchmark testing.

- o SYSSCAN Kartoscan - In depth discussions with scientists and users of this system have revealed a state-of-the-art data capture system. Continual system development and improvement in European and U.S. based laboratories make this an attractive system for benchmark testing. Their applications development with DTED/DFAD type data in Europe is another good reason for benchmark testing.

- o Laserscan Lasertrak - This system is recommended because it represents a unique approach to cartographic data capture via laser line-following technology. It may be particularly effective in the capture of DTED and DFAD data at DMA. Its recent acquisition at USGS is another incentive for benchmark testing.

5) Battelle recommends three areas for future research and development at DMA:

- DMA should support the completion of the qualitative/editing assessment component of the basic benchmark testing package. This component consists of a single sheet of cartographic geometries in varying degrees of geometric degradation. The tests for this input focus on system generated errors and the automatic functions for correction of geometric errors on input data. Battelle recommends the completion of this test material and the validation of it on the DMAHTC Scitex and AGDS data capture systems

- Evaluation of state-of-the-art cartographic data capture systems indicates that important progress is being made (by commercial vendors) in the areas of pattern recognition, feature extraction, automatic feature tagging and spatial/topological encoding.

  DMA should support the creation of an enhanced benchmark testing capability, based upon the recently developed DMA benchmark package, which addresses these forthcoming advances.

- DMA should initiate an ongoing program of in-house commercial cartographic data capture system evaluation and upgrade. Specifically, all existing software routines on the Scitex Response - 250 should be catalogued and defined in terms of cartographic applications. Additionally, batch processing and programming functions on the system should be seriously investigated. An assessment should also be performed of the most effective utilization of "manual" interactive, computer-assisted and automatic functions on the Scitex.

6) During the benchmark testing of the Scitex cartographic data capture system a number of observations were made of the basic system characteristics and current operating procedures. Discussions of these observations are integrated throughout the report.

PREFACE

This research was supported by the U. S. Army Engineer Topographic Laboratories, Mapping Developments Division, Fort Belvoir, Virginia, and was monitored by the U. S. Army Missile Command, Redstone Arsenal, Alabama, under Contract No. DAAH01-83-D-A008, which is sponsored by the Defense Advanced Research Projects Agency.

The use of trade names in this report does not constitute an official endorsement or approval of the use of such commercial hardware or software.

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DISCLAIMER

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1.0 INTRODUCTION

Battelle's Columbus Laboratories (BCL) has recently completed the benchmark testing of two automated cartographic data capture systems at the Defense Mapping Agency Hydrographic/Topographic Center (DMAHTC) under Contract No. DAAH01-83-D-A008, Delivery Order No. 0030. A standard package of benchmark testing materials, developed during a previous DMA sponsored research project*, was used to evaluate analog-to-vector conversion performance of the Automated Graphic Digitizing System (Broomall-AGDS) and Scitex Response-250. This report summarizes the results of the testing, evaluates the utility of the benchmark materials and testing methodologies, makes observations about system characteristics and current operating procedures, recommends other commercial systems for benchmark testing, and points out areas in need of future research and development.

A number of observations are important to make at this time. First, neither the Scitex Response -250 nor the Broomall AGDS in use at DMAHTC represents the most current state-of-the-art cartographic data capture systems in today's marketplace. Scitex no longer markets or sells the Response - 250.** It has been replaced by the Response - 280 (DMAAC has recently acquired this version of the system). The Broomall is one of the original systems of its kind and many technological advances have occurred since its acquisition. These particular systems were benchmark tested due to their accessibility at DMAHTC. In addition, the primary focus of the testing was to validate the benchmark testing materials and testing methodologies.

A second comment refers to the utilization of benchmark testing materials developed during the Defense Mapping Agency (DMA) Raster-to-Vector Analysis project. All materials were used in the benchmark testing at DMAHTC except the synthetically generated quality

* Defense Mapping Agency (DMA) Raster-to-Vector Analysis.

** The Scitex Response -250 in use at DMAHTC was running version 280 software at the time of benchmark tests.

assessment sheet (Synthetic Test Sheet #1; refer to the DMA Raster-to-Vector Analysis project final technical report* for a full description of its contents). Time restraints and a longer than anticipated development (of the synthetic test material) period prevented the utilization of this input to the benchmark test.

Thirdly, the benchmark test as applied to the cartographic data capture systems at DMAHTC, addresses only Digitization and Raster-to-Vector Conversion as defined in the DMA Analog-to-Vector Conversion Model (see DMA Raster-to-Vector Analysis Final Technical Report for definitions). This resulted from time limitations on access to production equipment at DMAHTC. Additionally, the benchmark testing of more subjective A/V processing functions (e.g., manuscript preparation, interactive data editing and feature tagging) will require the development of more sophisticated human factors testing methodologies.

Sections two (2.0) and three (3.0) review the general characteristics of the benchmark testing materials and the testing methodologies. (More detailed descriptions are presented in the final technical report of a Defense Mapping Agency (DMA) 'Raster-To-Vector Analysis' project.) Sections four (4.0) and five (5.0) detail the benchmark test results for the AGDS and Scitex systems, respectively. Section six (6.0) briefly summarizes a comparison of benchmark test results between the AGDS and Scitex systems. Section seven (7.0) discusses the validity of the benchmark testing materials and testing methodologies and makes recommendations for improvements. Section eight (8.0) makes specific recommendations for non-DMA cartographic data capture system benchmark testing. Finally, section nine (9.0) outlines recommendations for future research and development.

2.0 CONCISE REVIEW OF BENCHMARK TESTING MATERIALS

There are two basic types of benchmark testing materials: Sample DMA Products and Synthetic Test Sheets.

Sample DMA Products consist of 1) a drain/ridge overlay and 2) contour sheet (film positives), 3) a color pencil compilation of a

*Selden, David D., Went, Burton H., Jr., and Kleszczelski, Stan E., "Defense Mapping Agency (DMA) Raster-to-Vector Analysis", Report No. ETL 4, prepared by Battelle's Columbus Laboratories, Tactical Technology Center, Columbus, Ohio, for U. S. Army Engineer Topographic Laboratories, Mapping Developments Division, Contract No. DAAH01-83-D-A008, MIPR No. 3.13179 (November 30, 1984).

hydrographic chart, and 4) a color pencil compilation of a Digital Feature Analysis Data (DFAD) sheet. The latter two samples are drafted on plastic Mylar. All products were chosen to represent the range of typical DMA data types, data densities and materials.

The twelve Synthetic Test Sheets consist of three types of cartographic geometries (concentric* - highly abstract contours, simulated drainage,** and orthogonal grids)*** each reproduced four times with increasing numbers of linear inches. This second set of testing materials, generated at the U.S. Army Engineer Topographic Laboratories, was created to focus on geometric patterns typically found on DMA products to determine the impact of geometry and increasing data density on raster-to-vector conversion times. Table 1A on page four (4) indicates the predetermined length in linear inches of each of the twelve synthetic input sheets. Although an attempt was made to generate equal numbers of linear inches per density level of input, algorithm complexity prevented complete attainment of this goal. Rough comparability was achieved between all four density levels for synthetic contours and synthetic grids. Levels three and four of synthetic drainage are roughly equivalent to density levels one and two of the other input types.

3.0 CONCISE REVIEW OF BENCHMARK TESTING METHODOLOGIES

Testing methods were applied equally to both the AGDS and Scitex systems with deviations resulting from unique system characteristics or limitations. The major procedures included: raster scanning, raster-to-vector conversion, and film plotting of the vector data. Automatic and "manual" interactive raster editing was performed where facilities were available and a specific need identified. The intent of the processing was to time the individual steps without editing, however.

* Referred to as SYNCON1 thru SYNCON4 for the remainder of the report.

** Referred to as SYNDRN1 thru SYNDRN4 for the remainder of the report.

*** Referred to as SYNGRID1 thru SYNGRID4 for the remainder of the report.

Table 1A

TWELVE SYNTHETIC TEST MANUSCRIPTS
LENGTH IN LINEAR INCHES

	Density Level 1	Density Level 2	Density Level 3	Density Level 4
SYNTHETIC DRAINAGE (SYNDRN)	540	785	1167	1760
SYNTHETIC CONTOURS (SYNCON)	1267	1647	3729	7717
SYNTHETIC GRIDS (SYNGRID)	1280	1632	3920	7704

Evaluation criteria are based on process timing (individual steps and combined), virtual image quality assessment, digital plot/analog input "overlay" analysis, system integration/user friendliness evaluation, and numerical analysis of timing results. A complete definition and rationalization of this set of criteria is presented in the final report of the Defense Mapping Agency (DMA) 'Raster-to-Vector Analysis' project.

4.0 AGDS BENCHMARK TESTING

The Broomall AGDS cartographic data capture system basically consists of a large format flatbed raster scanner ("black" & white), a vectorization subsystem and edit/tag subsystem. The benchmark test evaluated those functions running on the first two components while not addressing the interactive edit/tag subsystem routines. This limitation was imposed due to time restraints in addition to removing from the test the subjective nature of interactive edit functions performed by human operators.

Raw data for raster scanning and vectorization times is presented in Table 2A (page 7). Of particular note is the apparent impact of data density on scanning time. For example, SYNCON1 contains 1267 lineal inches and required one hour and fifty-one minutes to scan. In comparison, SYNCON4 (of equal format dimensions) contains 7717 lineal inches and required three hours and forty-one minutes to scan. This one hour and fifty minute discrepancy may be attributable in part to the way in which data is stored in a scanning buffer and written to disk storage when the buffer is filled. The process of writing (and reportedly reformatting, as well) slows, if not stops, the forward scanning motion of the scanning head. The more often this filling of the scanning buffer and writing to disk storage occurs (obviously increasing with greater data density) the slower the scanning appears to be. Although this appears to be the case with the synthetic contour and grid sheets, the data for synthetic drainage does not support this observation. There are two possible explanations. The specific geometric pattern may somewhat influence this process, where some tend to slow the scanning progress more than others. The other reason may reflect the setting of the scanning limits. Even though an effort was made to set the scanning size limits and scanning parameters equally for all twelve synthetic test sheets, some unintended variability may have diminished the effect for the synthetic drainage sheets.

4.1 AGDS Benchmark Testing Results

Another important trend worthy of note is the steady increase in times for vectorization as the number of linear inches increases. This was fully anticipated, logic dictating an increased processing time for greater amounts of data. Of greater interest is the raster-to-vector linear inches per minute conversion rates. Table 3A (page 8) presents the linear inch per minute conversion rates for all twelve synthetic test sheets. Please note the precipitous drop in rates for synthetic contour and grid data conversion as data densities increase. Conversely, there is a slight overall improvement in the conversion rate for the four synthetic drain inputs. This points to the increased inefficiencies of the current vectorization algorithms with increasing amounts of data, particularly for simulated contour and grid geometries. The apparent steady rate for synthetic drainage conversion may be somewhat misleading. The range in linear inches for this data type is only 1220* inches. The range for the other two data types is 6450** inches. Table 4A (page 8.1) gives a better view of how the conversion rates compare for all three data types for comparable data densities. It appears that the AGDS converts the simulated contour data slightly more efficiently than the other data types. This may reflect the system's original design for processing contour data. On the other hand, the heaviest data level indicates little difference between the gridded and non-intersecting concentric data input conversion rates.

* This number derives from subtracting 540 (number of linear inches for SYNDRN1) from 1760 (number of linear inches for SYNDRN4).

** This number derives from subtracting either 1267 or 1280 (number of linear inches for SYNCON1 and SNYGRID1) from 7717 or 7704 (number of linear inches for SYNCON4 and SYNGRID4), respectively.

Table 2A

AGDS BENCHMARK TESTING
RAW DATA RESULTS

INPUT	# LINEAL INCHES	SCAN TIME HR/MIN	VECTORIZATION TIME HR/MIN
SYNDRN1	540	01:54	00:28
SYNDRN2	785	01:41	00:42
SYNDRN3	1167	01:50	00:52
SYNDRN4	1760	01:41	01:25
SYNCON1	1267	01:51	00:59
SYNCON2	1647	02:00	01:11
SYNCON3	3929	02:09	03:48
SYNCON4	7717	03:41	12:54
SYNGRID1	1280	-	01:04
SYNGRID2	1632	02:00	01:04
SYNGRID3	3920	02:05	05:29
SYNGRID4	7704	03:01	13:05
CONTOUR (DMA)		01:55	06:01
DRN/RDG (DMA)		01:35	01:12
HYDRO (DMA)*		01:52	03:49
DFAD (DMA)		01:16	02:52

* 1/2 Compilation sheet was processed.

Table 3A

AGDS - VECTORIZATION RATES

INPUT	# LINEAL INCHES	INCHES/MINUTE
SYNDRN1	540	19.29
SYNDRN2	785	18.69
SYNDRN3	1167	22.44
SYNDRN4	1760	20.71
SYNCON1	1267	21.47
SYNCON2	1647	23.20
SYNCON3	3929	17.23
SYNCON4	7717	9.97
SYNGRID1	1280	20.00
SYNGRID2	1632	17.36
SYNGRID3	3920	11.91
SYNGRID4	7704	9.81

Table 4A

AGDS - COMPARISON OF DATA CONVERSION
RATES FOR SYNTHETIC GEOMETRIES OF COMPARABLE DENSITIES

	SYNDRN3	SYNCON1	SYNGRID1
# INCHES	1167	1267	1280
INCHES/MIN.	22.44	21.47	20.00
	SYNDRN4	SYNCON2	SYNGRID2
# INCHES	1760	1647	1632
INCHES/MIN.	20.71	23.20	17.36
		SYNCON3	SYNGRID3
# INCHES		3929	3920
INCHES/MIN.		17.23	11.91
		SYNCON4	SYNGRID4
# INCHES		7717	7704
INCHES/MIN.		9.97	9.81

4.2 Qualitative Assessment of AGDS Benchmark Test Results

This qualitative assessment is based primarily on observations made of digital plots of vector data overlaid on the original input manuscript. Although each input was individually processed and plotted, for the sake of clarity and conciseness this discussion will summarize the results of each group of synthetic input. Examples of errors and anomalies are presented in Figures 1A and 1B (pages 11-12). (Please note that all AGDS data was automatically passed through a point filter and spike removal routine prior to plotting.)

Although there are few options or parameters to set on the Broomall raster scanner or vectorization subsystems, one observation can be made about their current utilization. It appears that a fixed group of parameter settings has been developed and they are generally applied without concern for the unique characteristics of input data. In fact, little is known about the impact of changing these settings. This rigid application of parameters may result in greater numbers of errors (e.g., scanner induced) and conversely, in the diminished success of the [THN, INODES, THN] routines on the vectorizer. (THN removes data stubs and fills in holes in data. INODES reduces the number of points defining lines.)

4.2.1 Synthetic Drainage Evaluation (AGDS)

All four synthetic drainage plots were accurately scaled although limited linear misalignments were noted on SYNDRN3 and SYNDRN4. The only obvious errors were found in the form of minor line breaks on SYNDRN2. It is possible these were caused by plotter skipping and not missing data. (This points to the advantages of film plotting for quality assurance tests). Generally, the synthetic drainage plots were of very high quality.

4.2.2 Synthetic Contour Evaluation (AGDS)

All four synthetic contour plots were accurately scaled although some linear misalignments were found on SYNCON2 and SYNCON4.

These consist of one to two lineweight offsets from the center of the analog input or a general wavy appearance. Only a minimum number of line gaps were in evidence and a single errant line was noted on SYNCON4. SYNCON3 and SYNCON4 also exhibited straight edge perimeters for their center "circles." On the whole, all four synthetic contour plots exhibited a good quality.

4.2.3 Synthetic Grid Evaluation (AGDS)

All four synthetic grid plots were accurately scaled. However, linear misalignments and intersection offsets were visible on every plot. Some breaks in lines were noticed on SYNGRID4. This sheet also exhibited the most significant intersection offsets. Again, this may reflect a plotter difficulty, particularly for short line segments on the densest input sheet. Overall plotted data quality was good.

4.2.4 Digital Feature Analysis Data (DFAD) Evaluation - (AGDS)

The digital plot was accurately scaled to the analog input. Lines appeared to be smooth although some "unnecessary" squiggles, offsets and misalignments were noted. Occasional line breaks were also found. These appeared to be more than plotter generated and may reflect scanner incapability to capture "weak" input lines. General quality was considered good.

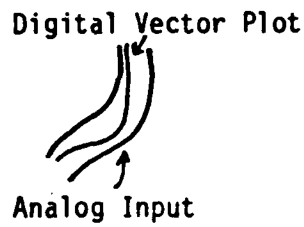
4.2.5 Contour and Drain/Ridge Overlay Evaluation - (AGDS)

Both the contour and drain/ridge digital plots exhibited a slight scaling problem. Despite this, good linear alignment, even in dense areas was noted. Few or no errors or other anomalies were noticed. Some coalescence of contours in dense areas was found. Overall quality was considered good.

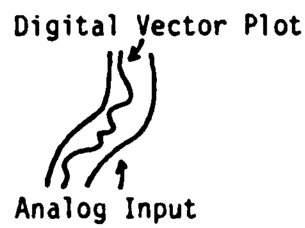
Figure 1A

ERRORS AND ANOMALIES EXHIBITED ON
DIGITAL PLOTS OF BENCHMARK TESTING
MATERIALS - (AGDS)*

LINEAR MISALIGNMENT (SIMULATED BLOWUP)

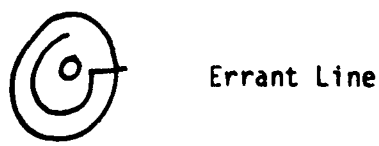


WANDERING CENTERLINE (SIMULATED BLOWUP)



OFFSET LINES

ERRANT LINE

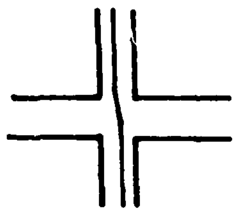


* Digital plots were plotted on a XYNETICS ballpoint vector plotter. Misalignments measured on the average .003"-.004". Occasional gaps were somewhat larger, in the range of .01".

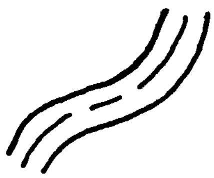
Figure 1B

ERRORS AND ANOMALIES EXHIBITED ON
DIGITAL PLOTS OF BENCHMARK TESTING
MATERIALS - (AGDS)

MISALIGNED INTERSECTIONS

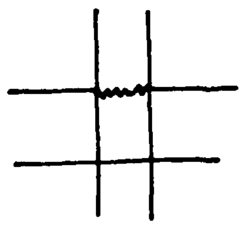


"DIGITAL GAPS"



UNNECESSARY "SQUIGGLES" ON GRIDLINES

(SIMULATED BLOWUP)



4.2.6 Hydrographic Chart Overlay Evaluation - (AGDS)

A definite scaling problem was evidenced. All red lines on the input sheet were also dropped (due to a red light scanning laser). This obviously represents a problem with scanning color coded manuscripts on the AGDS. All bathymetric soundings were also vectorized. The AGDS does not provide any raster editing tools which could be applied for selected data removal (including the numbers). All colors but red were captured, vectorized, and plotted. Thus, it is not quite correct to refer to the scanner on the AGDS as a "black and white" scanner, at least not strictly speaking. On the other hand it does not provide color separation scanning capabilities either.

5.0 SCITEX BENCHMARK TESTING

The Scitex Response-250 cartographic data capture system consists of a large format drum color raster scanner, a raster colorediting station and a large format laser film plotter. The benchmark tests utilized all three components of the system, concentrating on scanning, thinning, vectorization times, data anomalies and overall system performance. The benchmarks were run over a period of several months and utilized all available system components when available.

5.1 Scitex Benchmark Testing Results

Raw data for raster scanning and vectorization times is presented in Table 5A (page 16). The raw data sheet for the Scitex provides an extra column of information, thin time (as compared to the AGDS) which is indicative of the two step raster-to-vector conversion procedure implemented on this system. Please note the fairly consistent scanning times irrespective of data density. Overall, thin times appear to be unaffected by increasing data density for both the synthetic drainage (SYNDRN) and synthetic grid (SYNGRID) inputs. This is not the case for the synthetic contour data (SYNCON), where increasing data density results in longer thin times. In comparison, we see a marked increase in vectorization times paralleling increasing data densities. This applies equally for all three synthetic inputs.

Table 6A (page 17) presents thinning, vectorizing, and combined thin/vectorization linear inches conversion rates for the Scitex. Thin conversion rates improve with increasing data density for synthetic drainage and synthetic grid input data. The synthetic contour data thin-conversion rates do not perform in exactly the same manner. Although SYNCON3 and SYNCON4 demonstrate improving rates, they are not attaining efficiencies higher than SYNCON1 which is the case with the synthetic drainage and grid data thin-conversion rates. It should be noted that the thin conversion rates for the synthetic contours and grids are significantly better than those attained for drainage data.

Combined thin and vectorization times provide some interesting contrasts. The synthetic drainage data conversion rates steadily improve with increasing data density. Synthetic contour data demonstrates a more constant conversion rate performance although large data input does slow the processs somewhat. The synthetic grid data conversion rates overall are better than the synthetic drainage rates and curiously the fourth level of data shows the greatest success. The synthetic contour combined conversion rates are significantly better than either of the other two data types.

Table 7A (page 18) presents a more realistic view of how the combined conversion rates compare for all three data types for comparable data densities. It appears that for all four levels of data density, the Scitex converts the synthetic contour data most efficiently. This appears to reflect on the relative difficulties of converting intersecting and merging (or intersecting and crossing) data as compared to non-intersecting data.

5.2 Qualitative Assessment of Scitex Benchmark Test Results

This qualitative assessment is based primarily on observations made of digital raster/vector data and digital plots of raster* data overlaid on the original input manuscript. Even though each input was individually processed, only select samples of each of the synthetic input data types were actually plotted. The observations in the following sections will address each group of synthetic input data types in summary fashion. Examples of errors and anomalies observed on CRT screens or digital plots are presented in Figures 2A and 2B (pages 21-22). Please note that all Scitex data were processed with minimal editing performed. Such editing was performed only where continued processing required limited data modification (e.g., removal of tape marks from raster data prior to thinning). In addition, all digital raster plots evidenced a scaling offset. This was traced to a lack of precise calibration on the Scitex raster scanner. Another issue worthy of note is the apparent sensitivity of the Scitex conversion (R/V) algorithms. For example, on numerous occasions, a vectorization failed apparently due to the existence of a limited number of unthinned vectors in the file. The existence of fat lines or tape marks in a raster data file often greatly extended thinning times with often less than satisfactory results (i.e., unthinned lines remained).

* The plotting of digital raster data was not originally anticipated for proof plotting during the benchmark testing. Attempts were made to take into account the unique characteristics of raster data in making quality assessments.

Table 5A

SCITEX RAW DATA RESULTS

INPUT	# LINEAL INCHES	SCANTIME HR/MIN	THINTIME HR/MIN	VECTORIZATION TIME HR/MIN	TOTAL VEC./THIN TIME HR/MIN
SYNDRN1	540	01:42	00:22	00:12	00:34
SYNDRN2	785	01:41	00:25	00:14	00:39
SYNDRN3	1167	01:42	00:22	00:20	00:42
SYNDRN4	1760	01:43	00:25	00:36	01:01
SYNCON1	1267	01:43	00:06	00:16	00:22
SYNCON2	1647	01:42	00:13	00:20	00:33
SYNCON3	3929	01:38	00:29	00:49	01:18
SYNCON4	7717	01:44	00:37	01:51	02:28
SYNGRID1	1280	01:52	00:14	00:24	00:38
SYNGRID2	1632	02:00	00:21	00:20	00:41
SYNGRID3	3920	01:50	01:20	01:10	01:30
SYNGRID4	7704	01:58	00:20	03:20	03:40
CONTOUR(DMA)		01:05	00:40	01:50	02:30
DRN/RDG(DMA)		01:20	00:14	00:23	00:37
HYDRO(DMA)*		03:30	00:41	00:26	00:67
DFAD(DMA)		01:40	00:18	00:23	00:41

* HYDRO(DMA) has soundings and other pertinent information in the same color (black). All black data were deleted prior to thin/vectorization to prevent vectorization of bathymetric soundings.

Table 6A

SCITEX RASTER-TO-VECTOR CONVERSION RATES
THINNING, VECTORIZING, COMBINED TIMINGS

INPUT	# LINEAL INCHES	INCHES THINNED/MIN.	INCHES VEC./MIN.	THIN-VECT. INCHES/MIN.
SYNDRN1	540	24.55	45.00	15.88
SYNDRN2	785	31.40	56.07	20.13
SYNDRN3	1167	53.05	58.35	27.79
SYNDRN4	1760	70.40	48.89	28.85
SYNCON1	1267	211.17	79.19	57.59
SYNCON2	1647	126.69	82.35	49.91
SYNCON3	3929	135.48	80.18	50.37
SYNCON4	7717	208.57	69.52	52.50
SYNGRID1	1280	91.43	53.33	33.68
SYNGRID2	1632	77.71	81.60	39.80
SYNGRID3	3920	196.00	56.00	43.56
SYNGRID4	7704	385.20	38.52	35.02

Table 7A

SCITEX - COMPARISON OF COMBINED DATA
CONVERSION RATES FOR SYNTHETIC GEOMETRIES
OF COMPARABLE DENSITIES

	SYNDRN3	SYNCON1	SYNGRID1
#INCHES	1167	1267	1280
INCHES/MIN.	27.79	57.59	33.68
	SYNDRN4	SYNCON2	SYNGRID2
# INCHES	1760	1647	1632
INCHES/MIN.	28.85	49.91	39.80
		SYNCON3	SYNGRID3
# INCHES		3929	3920
INCHES/MIN		50.37	43.56
		SYNCON4	SYNGRID4
# INCHES		7717	7704
INCHES/MIN.		52.50	35.02

5.2.1 Synthetic Drainage Evaluation (Scitex)

The densest level synthetic drainage data (SYNDRN4) was plotted on the Scitex raster plotter. Other than the overall scaling problem, an anomaly was identified at all the intersections of the drainage segments. A rounding or squaring of the intersection of three line segments was prevalent throughout the plotted manuscript. Line alignment was generally good in all other instances.

5.2.2 Synthetic Contour Evaluation (Scitex)

Line quality appeared to be smooth and representative of the analog input. No errors or anomalies were observed. The center-most circle was smooth and exhibited no squaring of the circumference similar to the AGDS synthetic contour plots. This was considered a high quality ouput.

5.2.3 Synthetic Grid Evaluation (Scitex)

Synthetic grid level's two (SYNGRID2) and three (SYNGRID3) were plotted on the Scitex raster plotter. In addition to the overall sheet scaling (approximately .06" in one axis), offsetting "linear" lines were observed throughout the plotted sheets. More than likely this reflects the vagaries of the thinning process where the algorithm appears to be only accurate to plus or minus one unit of resolution on either side of a centerline. The inconsistency of the offset results in unsmooth lines. A second problem encountered on the digital plot was unthinned lines. Although rare, occasional instances of multi-pixel-wide lines were identified. This may have resulted from variations in the width of input analog lines. In these cases thinning failed to reduce the lines to one unit of resolution. A third problem was identified on SYNGRID3. Instances of slivers were noted: double lines resulting from single line input. In this case the slivers may be a result of scanner or thinning difficulties.

5.2.4 Digital Feature Analysis Data (DFAD) Evaluation - (Scitex)

Visual observation of the digital plot revealed a series of errors and anomalies. These included stubs, donuts, unthinned lines, and some evidence of wandering centerlines. Much of this is attributable to the color pencil Mylar input and the thinning process. It is conceivable that further adjustments to the scanning calibration might eliminate some of these anomalies.

5.2.5 Contour and Drain/Ridge Overlay Evaluation - (Scitex)

Digital plots were not available soon enough for Battelle to perform an overlay analysis. However, according to DMAHTC staff, visual observation of these plots revealed a "good quality" output.

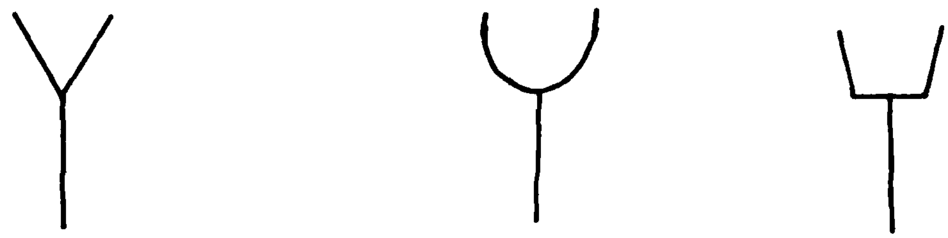
5.2.6 Hydrographic Chart Overlay Evaluation - (Scitex)

Smooth, high quality lines were observed on the digital plot. Occasional stubs were identified. It should be noted that the particular plot reviewed had been interactively edited frame by frame on the Scitex raster editing station prior to plotting.

Figure 2A

ERRORS AND ANOMALIES EXHIBITED ON
DIGITAL PLOTS OR CRT IMAGES OF
BENCHMARK TESTING DATA - (SCITEX)*

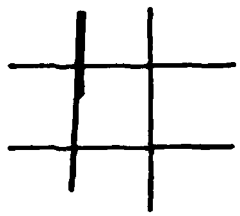
THREE SEGMENT INTERSECTION ANOMALY



Correct Representation | Rounded Anomaly | Squared Anomaly

OFFSETTING LINEAR LINES (.003 - .004")

UNTHINNED LINES



* Digital plots were produced on the Scitex laser plotter.

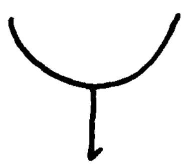
Figure 2B

ERRORS AND ANOMALIES EXHIBITED ON
DIGITAL PLOTS OR CRT IMAGES OF
BENCHMARK TESTING DATA - (SCITEX)

SLIVERS

STUBS (Post Thinning Results)
(Average stub length -
3 to 6 pixels at 20 points/mm)

HOOK STUB

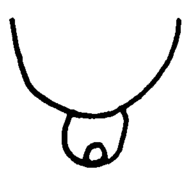


V STUB

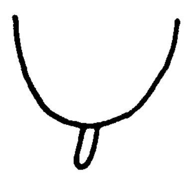
STRAIGHT STUB

CIRCULAR STUB

DONUT STUB



TUBE STUB



6.0 COMPARISON OF BENCHMARK TESTING RESULTS SCITEX RESPONSE-250 AND BROOMALL AGDS

Several charts on the following pages list the various test results for the two systems side by side. Tables 8A and 9A (pages 24-25) compare first, the raw scanning times, and second, the combined raster-to-vector conversion times for the Scitex and AGDS. Figures 3A and 4A (pages 26-27) present graphs of these data. It appears that the Scitex scan times are more constant and less subject to influence by increasing data density. The Scitex appears to be somewhat faster overall. For example, the average scan time for the twelve synthetic test sheets was two hours and ten minutes (2:10) for the Scitex as compared to two hours and thirty-three minutes (2:33) for the AGDS. Comparison of total raster-to-vector conversion times demonstrates a dramatic advantage by the Scitex. In some cases, this advantage approaches almost four to one (e.g. note 12:54 hour AGDS vectorization time for SYNCON4 as compared with 2:28 hours combined thin and vectorization time on the Scitex). Average vectorization time on the AGDS for the twelve synthetic inputs was three hours and fifty-eight minutes (3:58) as compared to one hour and eighteen minutes (1:18) on the Scitex. This advantage clearly extends to the DMA sample data as well. The Scitex conversion times for the contour, drain/ridge and DFAD data are on the order of three and four to one improved over the AGDS.

Table 10A (page 28) presents a comparison of raster-to-vector conversion rates. Figure 5A (page 29) presents a graph of the compared vectorization rates. Both serve to re-emphasize the relative effectiveness of the Scitex compared to the AGDS. Rates are significantly higher for the Scitex, particularly for the synthetic contour and grid data. The average conversion rate for the twelve synthetic inputs on the Scitex is 37.92 inches/minute compared to 17.67 inches/minute for the AGDS.

In general, it appears that the Scitex Response-250 at DMAHTC performed significantly better than the Broomall AGDS when tested using equal data input. Overall conversion times and rates re-emphasized this

Table 8A

COMPARISON OF SCAN TIME
SCITEX AND AGDS

INPUT	# LINEAL INCHES HR/MIN	AGDS SCAN TIME HR/MIN	SCITEX SCAN TIME HR/MIN
SYNDRN1	540	01:54	01:42
SYNDRN2	785	01:41	01:41
SYNDRN3	1167	01:50	01:42
SYNDRN4	1760	01:41	01:43
SYNCON1	1267	01:51	01:43
SYNCON2	1647	02:00	01:42
SYNCON3	3929	02:09	01:38
SYNCON4	7717	03:41	01:44
SYNGRID1	1280	-	01:52
SYNGRID2	1632	02:00	02:00
SYNGRID3	3920	02:05	01:50
SYNGRID4	7704	03:01	01:58
CONTOUR (DMA)		01:55	01:05
DRN/RDG (DMA)		01:35	01:20
HYDRO (DMA)		01:52	03:30
DFAD (DMA)		01:16	01:40

Table 9A

COMPARISON OF COMBINED RASTER-TO-VECTOR
CONVERSION TIMES - SCITEX AND AGDS

INPUT TIME	# LINEAL INCHES	AGDS VECTOR TIME HR/MIN	SCITEX THIN/VECT. HR/MIN
SYNDRN1	540	00:28	00:34
SYNDRN2	785	00:42	00:39
SYNDRN3	1167	00:52	00:42
SYNDRN4	1760	01:25	01:01
SYNCON1	1267	01:59	00:22
SYNCON2	1647	01:11	00.33
SYNCON3	3929	03:48	01:18
SYNCON4	7717	12:54	02:28
SYNGRID1	1280	01:04	00:38
SYNGRID2	1632	01:34	00:41
SYNGRID3	3920	05:29	01:30
SYNGRID4	7704	13:05	03:40
CONTOUR (DMA)		06:01	02:30
DRN/RDG (DMA		01:12	00:37
HYDRO (DMA)		03:49	00:67
DFAD (DMA)		02:53	00:41

Figure 3A

Scan Time
Synthetic Geometries

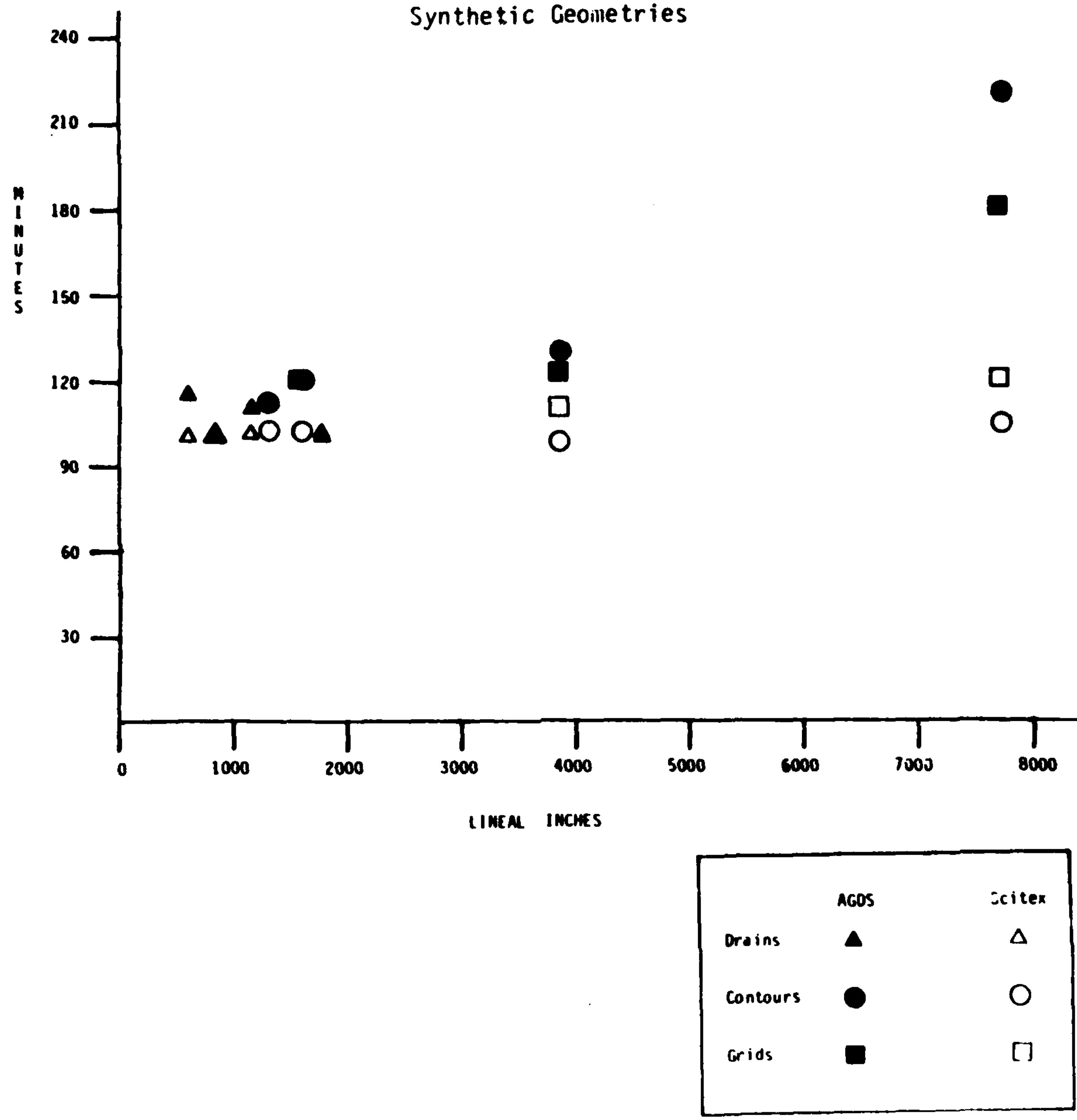


Figure 4A

Raster-to-Vector Conversion Times
Synthetic Geometries

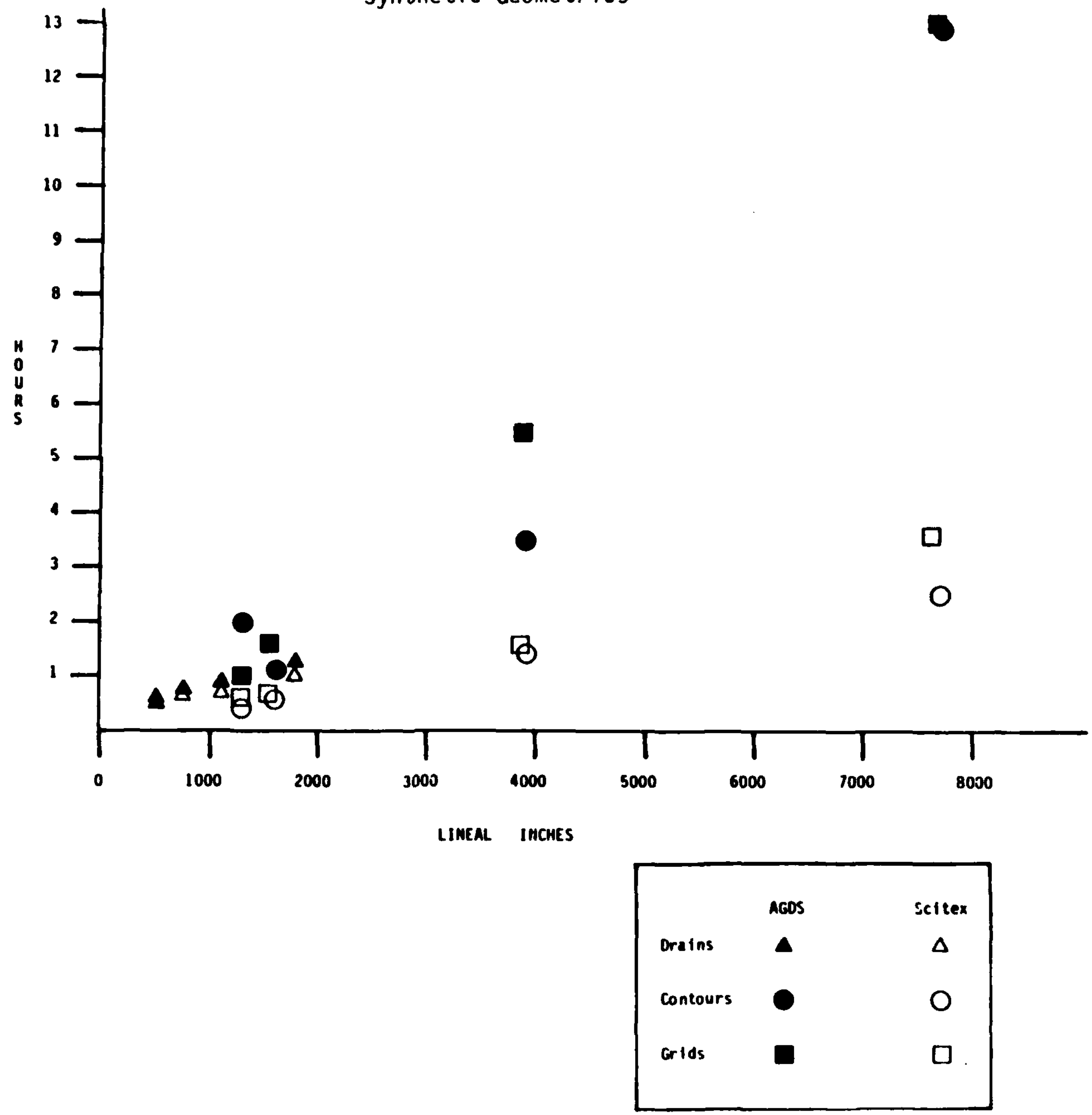


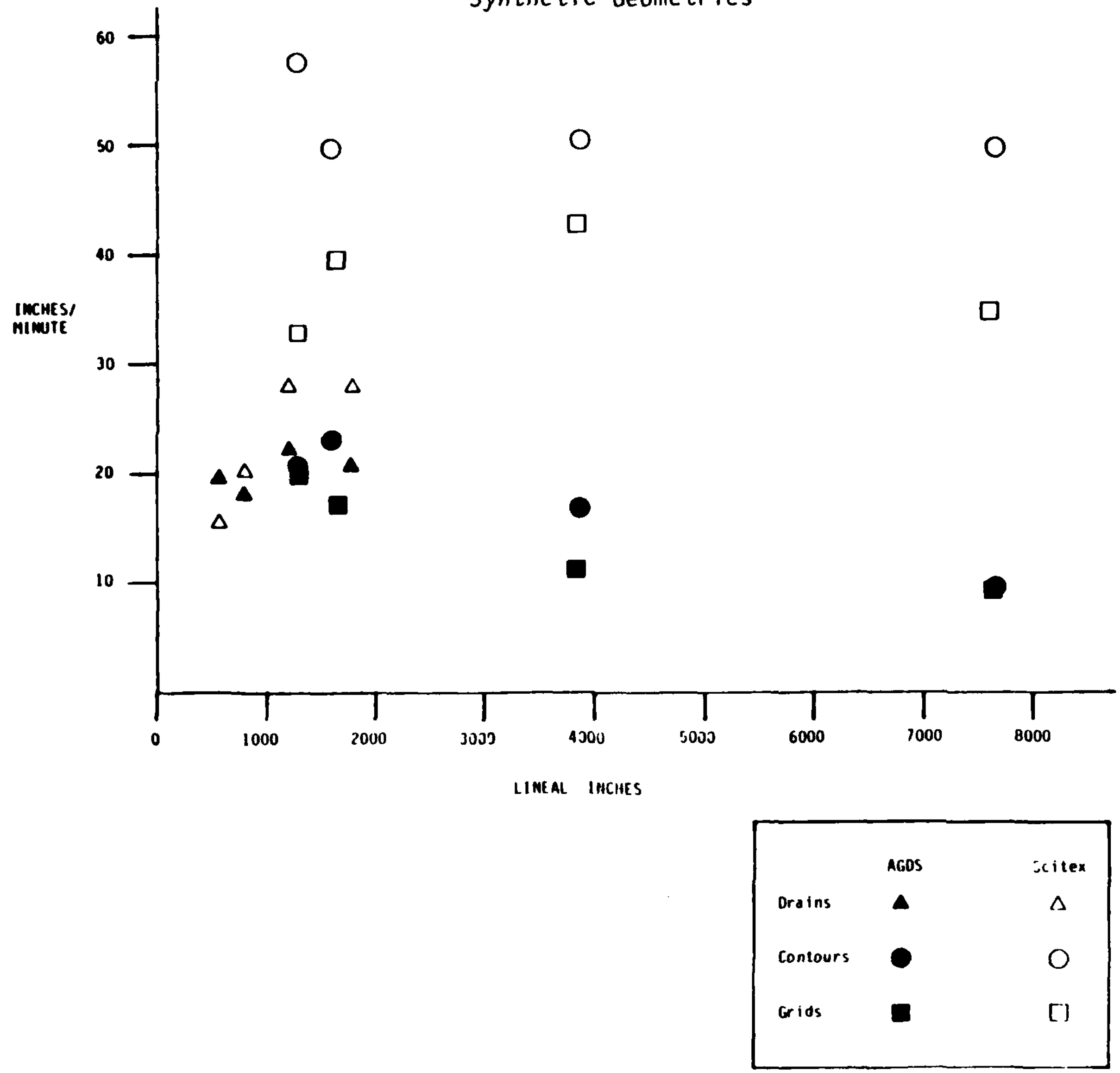
Table 10A

COMPARISON OF COMBINED RASTER-TO-VECTOR
CONVERSION RATES - SCITEX AND AGDS

INPUT	# LINEAL INCHES	AGDS INCHES/MINUTE	SCITEX INCHES/MINUTE
SYNDRN1	540	19.29	15.88
SYNDRN2	785	18.69	20.13
SYNDRN3	1167	22.44	27.79
SYNDRN4	1760	20.71	28.85
SYNCON1	1267	21.47	57.59
SYNCON2	1647	23.20	49.91
SYNCON3	3929	17.23	50.37
SYNCON4	7717	9.97	52.50
SYNGRID1	1280	20.00	33.68
SYNGRID2	1632	17.36	39.80
SYNGRID3	3920	11.91	43.56
SYNGRID4	7704	9.81	35.02

Figure 5A

Raster-to-Vector Conversion Rates
Synthetic Geometries



consistently for both the synthetic and DMA sample benchmark testing data. It should be noted that the digital plots revealed some qualitative advantage demonstrated by the Broomall AGDS. However, this is mitigated by the fact that all data in this system passed through digital filters and spike/stub removal routines (INODES and THN) prior to plotting as a standard operating procedure. This was not the case on the Scitex system.

7.0 ASSESSMENT OF BENCHMARK TESTING MATERIALS AND TESTING METHODS

One of the objectives of running benchmark tests on the DMAHTC Scitex and AGDS was to validate the benchmark materials and testing methodologies. Much was learned about the utility of the specific tests and the materials used resulting in an overall assessment of the benchmark testing package including a few recommendations for improvements.

7.1 Benchmark Testing Materials

Generally, the current set of benchmark materials is satisfactory for evaluating cartographic data capture systems. The twelve synthetic test sheets provide important information about a system's raster-to-vector conversion strengths and weaknesses vis-a-vis different cartographic geometries and increasing data densities. It provides a basic gauge for assessing performance levels and assists DMA in predicting productivity. The DMA sample materials provide an opportunity to assess a system's capability for assimilating typical analog input. The DFAD sheet appears to represent a typical sheet as do the contour and drain/ridge sheets. A problem is perceived with the current DMA Hydrographic Chart compilation example in the benchmark package. It is Battelle's understanding that most chart compilations maintain bathymetric soundings in a unique color. This particular sheet has the soundings and other pertinent information in the same color (black). This requires either the vectorization of the soundings (non-standard procedure) or the elimination of all "black data" prior to vectorization, or the step by step manual elimination of soundings (very time consuming). It is Battelle's understanding that such a compilation would be rejected by the Digital Hydrography Section under normal production operations. These facts should be taken into consideration by DMA prior to using the Hydrographic sheet in further benchmark testing. Replacement of this sheet with a more representative example is one possible option.

7.2 Benchmark Testing Methods

Battelle feels that the timing statistics (raw numbers and derived rates) are useful and valid indicators of system performance capabilities. The scanning, thinning and/or vectorizing, and plotting of data is a basic procedure for benchmark testing. It should continue to be viewed as such. These procedures as applied to the twelve synthetic testing materials during the benchmarking at DMA are sound. However, one recommendation is that separate statistics be maintained for all manual and interactive editing of synthetic input data. (Please remember that editing is not a prescribed procedure for the synthetic benchmark testing).

Timing statistics for processing of DMA sample products are considered useful and valid as indicators of system performance. More thought needs to be given to the purpose of using standard DMA materials. One recommendation is that an objectives oriented test be developed for at least one of the sample inputs. This means that DMA should establish a specified output requirement for a particular testing material. A cartographic data capture system should be applied towards achieving the specified standard in the most efficient manner. Individual process and combined processing timings should be kept. Each process should be categorized as a) human manual b) computer interactive c) computer-assisted and d) automatic. This will provide DMA with an understanding of the personnel, task type and time requirements to produce a typical DMA output which meets acceptable quality standards. An example of one objective oriented benchmark test would be to require a vendor to produce press ready color separations of a Hydrographic Chart derived from a standard compilation manuscript. Time, quality and activity types would comprise the basic evaluation criteria. Another example would be a requirement for a vendor to produce an elevation matrix suitable for DTED cell generation. Again, time, quality and activity types would be used to assess system performance levels.

Another issue has been raised concerning the number of benchmark testing materials (sixteen) currently in the DMA testing package. The concern has been expressed that perhaps too many inputs will overburden prospective vendors of cartographic data capture systems. Battelle does not believe this to be the case. First, any new state-of-the-art system to be benchmarked should match and probably surpass the performance levels of the Scitex Response-250. Thus time required on these systems should diminish. It is interesting to note that total actual processing time on the Broomall AGDS was approximately eighty-eight hours and only forty-eight hours on the Scitex. (This does not include plotting and represents a summation of final successful runs, and thus no re-runs.) It does not seem unreasonable to expect a vendor to dedicate his system for up to eighty hours to demonstrate its capabilities. This is particularly valid given the high system acquisition costs DMA must accept from such vendors. The other side of this "problem" is that a vendor has the right to refuse all or portions of the benchmark package. DMA will judge a system not only on benchmark testing but many other factors as well.

Overall, Battelle feels that the benchmark testing materials and procedures implemented at DMAHTC on the Scitex Response-250 and Broomall AGDS were effective. Consideration should be given to the suggested improvements. However, DMA now possesses a capability to assess the performance levels of state-of-the-art cartographic data capture systems. Additionally, a benchmark for performance level has been established for the Scitex (and AGDS) at DMAHTC. Benchmark test results of new ("and improved") Scitex and other commercial systems can be compared to this standard.

8.0 RECOMMENDATIONS FOR BENCHMARK TESTING OF STATE-OF-THE- ART CARTOGRAPHIC DATA CAPTURE SYSTEMS

There exists in today's marketplace a number of cartographic data capture systems which claim state-of-the-art capabilities. The DMA Raster-to-Vector Analysis final technical report provides an overview of these systems. It describes their basic system facilities, strengths and weaknesses based on commercial literature and conversations with "knowledgeable" people (both vendors and users alike). These observations are not based on empirical facts.

Battelle believes that certain commercially available systems are worthy candidates for benchmark testing. These include: Scitex Response-280, Intergraph Scan Data Capture System, SYSSCAN Kartoscan and Laserscan Lasertrak. The Scitex Response-280 series deserves benchmarking to ascertain if performance enhancements have been built into this upgrade. DMA's current investment in Scitex is high and growing (DMAAC acquisition of a Scitex Response 280 is a recent example). Decisions to continue and grow with Scitex technology should be based on some empirical data, derivable from the DMA benchmark. Conversations with key Intergraph system development engineers and past experience with Intergraph products makes a strong case for a benchmark testing recommendation. Intergraph's purported use of new raster-to-vector algorithms and hardware processors makes this newly introduced system appear quite competitive. SYSSCAN Kartoscan represents another commercial vendor who apparently is investing in an on-going program of system development and improvement. Of particular interest is their work in Europe with both DTED and DFAD data types. They have developed a number of processing capabilities specifically designed for these data types, which are obviously relevant to DMA requirements. The final system recommended for benchmark testing is the Laserscan Lasertrak. This represents the only line following system to be recommended. Its processing of contour and DFAD data should be tested for possible application at DMA. Applications development at USGS on their newly acquired Lasertrak systems should be observed for indications of future DMA applicability.

9.0 RECOMMENDATIONS FOR FUTURE RESEARCH AND DEVELOPMENT

Battelle recommends three projects for future research and development. The first recommendation is to support the completion of the quality/editing assessment component of the basic raster-to-vector conversion benchmark testing package. The second recommendation is to support the development of an advanced raster-to-vector conversion benchmark testing package. The third recommendation is to establish a program of in-house commercial system evaluation and optimization.

9.1 Completion of the Qualitative/Editing Assessment Component of the DMA Raster-to-Vector Conversion Benchmark Testing Package

The qualitative/editing assessment component is a unique and pertinent contribution to the DMA raster-to-vector conversion benchmark testing capability. This individual test sheet, consisting of a series of geometric patterns of "perfect" and degraded form, provides a mechanism for testing the automated editing functions of state-of-the-art cartographic data capture systems. It also provides a means to focus on the qualitative aspects of converting analog cartographic features into digital vector data.

Battelle recommends that this synthetic cartographic geometry test sheet which is currently partially created, be completed and validated on the Scitex and AGDS systems at DMAHTC. Together with the existing set of sixteen benchmark materials, the synthetic cartographic geometry test sheet will provide DMA with a comprehensive benchmark testing capability.

9.2 Advanced Raster-to-Vector Conversion Benchmark Testing Package Development*

The benchmark testing package developed by Battelle (including the proposed synthetic cartographic geometry sheet) represents a comprehensive testing capability for basic cartographic input possessing limited symbology or geometric complexity. The full range of analog cartographic geometries and symbolization (e.g., cased roads, depression contours, point symbols, dash-dot patterns for political boundaries, swamp symbols, railroad ticks and tint screens) have yet to be addressed. Benchmark materials and tests will be required to evaluate the performance levels of automatic feature recognition and tagging capabilities in addition to spatial/topological encoding routines being touted by state-of-the art cartographic data capture system.

Battelle recommends that DMA support the development of an advanced cartographic benchmark testing capability integrated with the basic package already provided to the mapping agency. The significant technological advances being made by cartographic state-of-the-art data capture systems warrant these new testing mechanisms.

9.3 Vendor System Evaluation and Optimization**

Battelle recommends an on-going program of DMA cartographic data capture system (i.e., Scitex and AGDS) evaluation with the goal of fully optimizing existing facilities and specifying areas in need of further development. The clear definition of the cartographic utility of all available software routines (in particular on the Scitex) is of primary concern. A systematic program of software analysis, cataloguing and use optimization is recommended. A closer look at the optimal roles

* This is a restatement of a recommended future research and development option presented in Section 8.1 of the DMA Raster-to-Vector Analysis' final technical report.

** This is a restatement of a recommended future research and development option presented in section 8.3 of the DMA Raster-to-Vector Analysis' final technical report.

of interactive, computer-assisted and automatic functions is recommended. The effective use of batch programming and heretofore unused processing functions also requires further investigation. The generalized functions of all commercial data capture systems (such as the Scitex) require continued tailoring to the specific DMA analog-to-vector conversion requirements.