The Detroit Edison Company
One Energy Plaza, Detroit, MI 48226-1279

10 CFR 51.45
10 CFR 52.77

January 29, 2010
NRC3-10-0004

U. S. Nuclear Regulatory Commission
Attention: Document Control Desk
Washington, DC 20555-0001

References:
1) Fermi 3
   Docket No.: 52-033
2) Letter from Bruce Olson (USNRC) to Peter W. Smith (Detroit Edison), "Requests for Additional Information Letter No. 2 Related to the Environmental Review for the Combined License Application for Fermi Nuclear Power Plant, Unit 3," dated November 6, 2009
3) Letter from Peter W. Smith (Detroit Edison) to USNRC, "Detroit Edison Company Response to NRC Requests for Additional Information Related to the Environmental Review," NRC3-09-0014 dated September 30, 2009
4) Letter from Peter W. Smith (Detroit Edison) to USNRC, "Detroit Edison Company Response to NRC Requests for Additional Information Related to the Environmental Review," NRC3-09-0015 dated October 30, 2009
5) Letter from Peter W. Smith (Detroit Edison) to USNRC, "Detroit Edison Company Response to NRC Requests for Additional Information Related to the Environmental Review," NRC3-09-0016 dated November 23, 2009
6) Letter from Peter W. Smith (Detroit Edison) to USNRC, "Detroit Edison Company Response to NRC Requests for Additional Information Related to the Environmental Review," NRC3-09-0017 dated December 23, 2009

Subject: <u>Detroit Edison Company Response to NRC Requests for Additional Information Letter No. 2 Related to the Environmental Review</u>

D095
NRO

A DTE Energy Company

In Reference 2, the NRC requested additional information to support the review of Part 3 (Environmental Report) of the Fermi 3 Combined License Application (COLA). This letter provides responses to two of the twelve Requests for Additional Information (RAIs). These RAIs are identified in Appendix A. Appendix B identifies the remaining ten RAI responses that will be included in the February 15, 2010 response letter.

In addition, this letter is providing revised responses to seven RAIs previously submitted in References 3 through 5. These revised RAI responses are also identified in Appendix A and are distinguished by a footnote. Detroit Edison is revising these RAI responses as a result of telephone discussions with NRC staff. Detroit Edison plans to revise five additional RAI responses at the request of the NRC staff and submit them by February 15, 2010. These five RAIs are identified in Appendix B.

Enclosed with this letter is a disk containing electronic input and output files associated with the revised RAI AC7.2-1 included in this letter. Appendix C provides a list of files contained on the enclosed disk.

The file format and names on the enclosed disks do not comply with the requirements for electronic submission in NRC guidance document, "Guidance for Electronic Submissions to the NRC," dated November 20, 2009; the files are not ".pdf" formatted. The NRC staff requested the files be submitted in their native formats required by the software in which they are utilized to support the Environmental Report development.

If you have any questions, or need additional information, please contact me at (313) 235-3341.

I state under penalty of perjury that the foregoing is true and correct. Executed on the 29th day of January, 2010.

Sincerely,

Peter W. Smith, Director
Nuclear Development – Licensing
and Engineering
Detroit Edison Company

Appendices: Appendix A – List of RAI Responses in this Letter
Appendix B – List of Future RAI Response Dates
Appendix C – List of Electronic Files on the Enclosed Disk

Attachments: As listed in Appendix A

cc: Chandu Patel, NRC Fermi 3 Project Manager (w/o attachments)
Jerry Hale, NRC Fermi 3 Project Manager (w/o attachments)
Ilka T. Berrios, NRC Fermi 3 Project Manager (w/o attachments)
Bruce Olson, NRC Fermi 3 Environmental Project Manager (w/o attachments)
Fermi 2 Resident Inspector (w/o attachments)
NRC Region III Regional Administrator (w/o attachments)
NRC Region II Regional Administrator (w/o attachments)
Supervisor, Electric Operators, Michigan Public Service Commission (w/o attachments)
Michigan Department of Environmental Quality
Radiological Protection and Medical Waste Section (w/o attachments)

Appendix A
NRC3-10-0004

List of RAI Responses in this Letter

RAI Question	Subject	Attachment Number
AC7.2-1	Accidents[1]	1
AC7.2-2	Accidents[1]	2
AC7.3-1	Accidents[1]	3
AE2.4.2-6	Aquatic Ecology	4
HH5.4.3-1	Human Health[1]	5
HY2.3.1-16	Hydrology	6
SE2.5.2-1	Socioeconomics[1]	7
SE2.5.2-2	Socioeconomics[1]	7
SE4.4.2-7	Socioeconomics[1]	8

---

1. Supplemental RAI response

Appendix B
NRC3-10-0004

List of Future RAI Response Dates

Response Date	RAI Question	Subject
2/15/2010	AC7.1-1[1]	Accidents
	AE2.4.2-5	Aquatic Ecology
	CR4.1.3-4[1]	Cultural Resources
	CR4.1.3-10	Cultural Resources
	HH3.5-1	Human Health
	HH4.5-5	Human Health
	HH5.4.3-4	Human Health
	HH5.4.3-5	Human Health
	HH5.4.4-1[1]	Human Health
	TE2.4.1-12	Terrestrial Ecology
	TE2.4.1-13	Terrestrial Ecology
	TE4.3.1-8	Terrestrial Ecology
	TE4.3.1-9	Terrestrial Ecology
	TL4.1.2-1[1]	Transmission Lines
	TL4.1.2-2[1]	Transmission Lines

1. Supplemental RAI response

Appendix C
NRC3-10-0004

List of Electronic Files on Enclosed Disks

```
Directory of D:\

01/18/2010  01:49 PM        <DIR>          MACCS2_Files
               0 File(s)          0 bytes

Directory of D:\MACCS2_Files

01/18/2010  01:49 PM        <DIR>          ECON
01/18/2010  01:49 PM        <DIR>          EVAC
01/18/2010  02:06 PM        <DIR>          INPUT
01/18/2010  01:59 PM        <DIR>          MET
01/18/2010  01:48 PM        <DIR>          OUTPUT
01/18/2010  01:56 PM        <DIR>          POP
               0 File(s)          0 bytes

Directory of D:\MACCS2_Files\ECON

12/16/2009  08:37 AM            13,147     FERMEBWR.CHR
               1 File(s)     13,147 bytes

Directory of D:\MACCS2_Files\EVAC

12/16/2009  08:37 AM            13,620     FERMEBWR.ERL
               1 File(s)     13,620 bytes

Directory of D:\MACCS2_Files\INPUT

12/16/2009  08:39 AM            51,325     01MWRELH.ATM
12/16/2009  08:39 AM            51,327     10MWRELH.ATM
12/16/2009  08:39 AM           166,648     2XPR2002.MET
12/16/2009  08:39 AM             9,017     ATMOS.INP
12/16/2009  08:39 AM            13,650     DUBLDELY.ERL
12/16/2009  08:39 AM            13,682     DUBLEVAC.ERL
12/16/2009  08:39 AM             2,301     EVAC.BAT
12/16/2009  08:39 AM            51,292     FERMEBWR.ATM
12/16/2009  08:39 AM            13,652     HALFDELY.ERL
12/16/2009  08:39 AM            13,686     HALFEVAC.ERL
12/16/2009  08:39 AM             1,148     HEAT.BAT
12/16/2009  08:39 AM           166,649     HFPR2002.MET
12/16/2009  08:39 AM            51,324     MIDOFCNT.ATM
12/16/2009  08:39 AM               549     MOC.BAT
12/16/2009  08:39 AM               549     NORN.BAT
12/16/2009  08:39 AM             1,137     PRECIP.BAT
12/16/2009  08:39 AM           327,288     READRELF.EXE
```

```
12/16/2009  08:39 AM          4,861        READRELF.FOR
12/16/2009  08:39 AM          6,468        RELFRACS.CSV
12/16/2009  08:39 AM            549        RUN.BAT
12/16/2009  08:39 AM            201        RUNALL.BAT
12/16/2009  08:40 AM            549        TOC.BAT
12/16/2009  08:40 AM         51,376        TOC1MW.ATM
12/16/2009  08:40 AM            543        TOC1MW.BAT
12/16/2009  08:40 AM         51,319        TOPOFCNT.ATM
12/16/2009  08:40 AM     12,859,480        t_at_nin_tsl2x_r1.tab
              26 File(s)     13,910,570 bytes

Directory of D:\MACCS2_Files\MET

12/16/2009  08:41 AM        535,670        2001.csv
12/16/2009  08:41 AM         36,049        2001 Climate Summary for Detroit.DAT
12/16/2009  08:41 AM        590,236        2002.csv
12/16/2009  08:41 AM        549,403        2003.csv
12/16/2009  08:41 AM        541,892        2004.csv
12/16/2009  08:41 AM         40,689        2004 Climate Summary for Detroit.DAT
12/16/2009  08:41 AM        539,041 2      005.csv
12/16/2009  08:41 AM         38,990        2005 Climate Summary for Detroit.DAT
12/16/2009  08:41 AM        540,439        2006.csv
12/16/2009  08:41 AM        538,391        2007.csv
12/16/2009  08:41 AM      2,422,272        BV-2008-0044A01.xls
12/16/2009  08:41 AM      1,227,264        BV-2008-0044A02.xls
12/16/2009  08:41 AM      2,560,512        BV-2008-0044A03.xls
12/16/2009  08:41 AM      2,278,912        BV-2008-0044A04.xls
12/16/2009  08:41 AM      2,309,120        BV-2008-0044A06.xls
12/16/2009  08:42 AM      4,135,424        BV-2008-0044A07.xls
12/16/2009  08:41 AM      2,335,744        BV-2008-0044A05.xls
12/16/2009  08:42 AM        540,952        EDITMET.EXE
12/16/2009  08:42 AM         14,473        EDITMET.FOR
12/16/2009  08:42 AM             29        EDITMET.IN
12/16/2009  08:42 AM         12,844        EDITMET.OUT
12/16/2009  08:42 AM        166,642        FERM2001.MET
12/16/2009  08:42 AM        166,642        FERM2002.MET
12/16/2009  08:42 AM        166,642        FERM2003.MET
12/16/2009  08:42 AM        166,642        FERM2004.MET
12/16/2009  08:42 AM        166,642        FERM2005.MET
12/16/2009  08:42 AM        166,642        FERM2006.MET
12/16/2009  08:42 AM        166,642        FERM2007.MET
12/16/2009  08:42 AM          2,240        SUSPECT.DAT
              29 File(s)     22,957,080 bytes
```

```
Directory of D:\MACCS2_Files\OUTPUT

12/16/2009  08:43 AM       8,630,328        01MWRELH.OUT
12/16/2009  08:43 AM       8,630,328        10MWRELH.OUT
12/16/2009  08:43 AM       8,630,328        2XPR2002.OUT
12/16/2009  08:43 AM       8,630,328        DUBLDELY.OUT
12/16/2009  08:43 AM       8,630,328        DUBLEVAC.OUT
12/16/2009  08:44 AM       8,630,328        FERM2001.OUT
12/16/2009  08:44 AM       8,630,328        FERM2002.OUT
12/16/2009  08:44 AM       8,630,328        FERM2003.OUT
12/16/2009  08:44 AM       8,630,328        FERM2004.OUT
12/16/2009  08:44 AM       8,630,328        FERM2005.OUT
12/16/2009  08:44 AM       8,630,328        FERM2006.OUT
12/16/2009  08:44 AM       8,630,328        FERM2007.OUT
12/16/2009  08:44 AM       8,630,328        HALFDELY.OUT
12/16/2009  08:44 AM       8,630,328        HALFEVAC.OUT
12/16/2009  08:44 AM       8,630,328        HFPR2002.OUT
12/16/2009  08:44 AM       8,630,328        MIDOFCNT.OUT
12/16/2009  08:45 AM       8,630,328        NORN4050.OUT
12/16/2009  08:45 AM             201        READOUT.IN
12/16/2009  08:45 AM         339,896        READOUT1.exe
12/16/2009  08:45 AM          10,413        READOUT1.FOR
12/16/2009  08:45 AM         243,519        READOUT1.RSK
12/16/2009  08:45 AM         339,896        READOUT2.exe
12/16/2009  08:45 AM          10,502        READOUT2.FOR
12/16/2009  08:45 AM         221,381        READOUT2.RSK
12/16/2009  08:45 AM          70,144        READOUT3.xls
12/16/2009  08:46 AM          25,600        SAMDA (Fermi 3)-rev3.xls
12/16/2009  08:45 AM          15,872        SENSIT2 WITH % CHANGES FROM BASE-
rev3.xls
12/16/2009  08:45 AM       8,630,328        TOC1MW02.OUT
12/16/2009  08:45 AM       8,630,328        TOPOFCNT.OUT
          29 File(s)    165,253,656 bytes

Directory of D:\MACCS2_Files\POP

12/16/2009  08:46 AM         370,323        COUNTY97.DAT
12/16/2009  08:46 AM           1,664        FERM2000.POP
12/16/2009  08:46 AM           1,664        FERM2008.POP
12/16/2009  08:46 AM           1,664        FERM2013.POP
12/16/2009  08:46 AM           1,664        FERM2018.POP
12/16/2009  08:46 AM           1,664        FERM2020.POP
12/16/2009  08:46 AM           1,664        FERM2030.POP
12/16/2009  08:46 AM           1,664        FERM2040.POP
```

```
12/16/2009  08:46 AM           1,664     FERM2050.POP
12/16/2009  08:46 AM           1,664     FERM2060.POP
12/16/2009  08:46 AM          10,459     FERM2060.SIT
12/16/2009  08:46 AM          10,442     FERMSECP.SIT
12/16/2009  08:46 AM           9,254     FSARPOP.DAT
12/16/2009  08:46 AM          32,690     TXT2POP.EXE
12/16/2009  08:46 AM           1,775     TXT2POP.FOR
              15 File(s)        449,919 bytes

     Total Files Listed:
             101 File(s)    202,597,992 bytes
```

Attachment 1
NRC3-10-0004

Supplemental Response to RAI letter related to Fermi 3 ER

RAI Question AC7.2-1

NRC RAI AC7.2-1

Provide in electronic format the input and output files for the MACCS2 code used to evaluate the consequences of severe accidents in the ER. Include all files required to run the code for the base case calculation as well as sensitivities with respect to the release height, energy, meteorology, and precipitation assumptions.

Supplemental Information

During the site audit, Detroit Edison presented new severe accident consequence and risk estimates using DCD Revision 5, and Probabilistic Risk Assessment (PRA) Revision 3. The NRC staff will run the MACCS2 code and compare the results of its calculations with the results of Detroit Edison's calculations.

Supplemental Response

In the original response to RAI AC7.2-1 submitted in Detroit Edison letter NRC3-09-0014 (ML093350028), dated September 30, 2009, the input and output files for the MACCS2 code that were provided on an enclosed disk represented data used to evaluate consequences of severe accidents using DCD Revision 5 and Probabilistic Risk Assessment (PRA) Revision 3. Based on discussions with the NRC on October 20, 2009, it was determined that the values provided in the accident analysis are out of date and need to be updated to incorporate ESBWR DCD Revision 6, PRA Revision 4 (ML092030199), and Fermi Evacuation Time Estimate Revision 1 (ML092931618).

Electronic files used for the MACCS2 evaluation of the consequences of severe accidents in the Environmental Report are being provided in this letter as an enclosed disk. An inventory of the files on that disk is provided in Appendix C to this letter. These data files correspond to the updated severe accident analysis as presented in the supplemental response to RAI AC7.2-2, which is also provided in this letter.

Proposed COLA Revision

None

Attachment 2
NRC3-10-0004

Supplemental Response to RAI letter related to Fermi 3 ER

RAI Question AC7.2-2

NRC RAI AC7.2-2

Provide the revised results for accident-specific impacts to population and land from the Fermi 3 severe accident analysis, similar to that provided in Table 7.2-1 in the ER.

Supporting Information

Detroit Edison has revised the values in ER Table 7.2-1 based on new MACCS2 calculations using ESBWR DCD Rev 5 and PRA Rev 3. Therefore, revised values for the ER Table 7.2-1 are needed for review and confirmatory analysis.

Supplemental Response

In the original response to RAI AC7.2-2 submitted in Detroit Edison letter NRC3-09-0014 (ML093350028), dated September 30, 2009, the severe accident analysis results were based on ESBWR DCD Revision 5. Based on discussions with the NRC on October 20, 2009, it was determined that these results were outdated and need to be updated to incorporate ESBWR DCD Revision 6, PRA Revision 4, and Fermi Evacuation Time Estimate Revision 1 (ML092931618). These updated analyses are reflected in the attached markups.

Proposed COLA Revision

Fermi 3 COLA Part 3, ER Sections 7.2 and 7.3 will be revised to include the updated analysis as reflected in the attached markup.

Markup of Detroit Edison COLA

(following 14 pages)

The following markup represents how Detroit Edison intends to reflect this RAI response in a future submittal of the Fermi 3 COLA. However, the same COLA content may be impacted by revisions to the ESBWR DCD, responses to other COLA RAIs, other COLA changes, plant design changes, editorial or typographical corrections, etc. As a result, the final COLA content that appears in a future submittal may be different than presented here.

7.2 Severe Accidents

Severe accidents are those involving multiple failures of equipment to function. The likelihood of occurrence is lower for severe accidents than for design basis accidents, but the consequences of such accidents may be higher. Although severe accidents are not part of the design basis for the plant, the Nuclear Regulatory Commission (NRC), in its Policy Statement on Severe Reactor Accidents Regarding Future Designs and Existing Plants (50 FR 32138), requires the completion of a probabilistic risk assessment (PRA) for severe accidents for new reactor designs. This requirement is codified under 10 CFR 52.47.

General Electric (GE) completed a PRA for the ESBWR design (Reference 7.2-3) as part of the application for design certification. The GE analysis used generic, but conservative, meteorology and regional characteristics and determined that severe accident impacts are within the safety goals established by the NRC.

In this section, Detroit Edison presents an update of the generic PRA analysis, which includes Fermi site-specific characteristics. The analysis evaluates the impacts of a severe accident at Fermi 3 to demonstrate that the impacts are bounded in the generic analysis performed for the ESBWR certification and to support performing the severe accident mitigation alternatives analyses in Section 7.3.

7.2.1 GE Methodology

The GE PRA for the ESBWR established a containment event tree which defined the possible end states of the containment following a severe accident. Using EPRI's Modular Accident Analysis Program (MAAP) code, GE determined that 10 release categories ~~with 15 source term categories~~ would represent the entire suite of potential severe accidents. Five of the release categories were represented by dual source term categories. A release frequency was assigned to each of the ~~15 source term~~ 10 release categories (Table 7.2-1). For the dual source term release categories, GE assigned the entire frequency of the release category to each of the source terms.

The 10 release categories and associated source term categories are as follows:

1. Break Outside of Containment (BOC) – Radioactivity is released through an unisolated break outside of containment in the shutdown cooling piping allowing direct communication between the reactor pressure vessel and the environment outside of containment. This is followed by no injection of cooling water into the reactor pressure vessel. Two separate locations of a break in the piping were selected for determining source term categories in this release category, one mid-level in the reactor pressure vessel (BOCa) and the other at the lower-level (BOCb).
2. Containment Bypass (BYP) – Radioactivity is released directly to the atmosphere from containment due to a failure of the containment isolation system to function. Sequences in which the reactor pressure vessel is depressurized generally result in the core being uncovered earlier than those with a failure to depressurize. Both a low pressure sequence (BYPa) and a high pressure sequence (BYPb) were selected for determining the source term categories for this release category.

3. Core-Concrete Interaction Dry (CCID) – This release category applies to sequences in which the containment fails due to interaction between the core and the containment concrete. The deluge function is assumed to fail, and the lower drywell debris bed is uncovered. Sequences in which the containment vessel is not depressurized may result in earlier containment vessel failure. A low pressure sequence (CCIDa) and a high pressure sequence (CCIDb) were selected for determining the source term in this release category.
4. Core-Concrete Interaction Wet (CCIW) – This release category applies to sequences in which the containment fails due to interaction between the core and containment concrete. The deluge function works; however, the basemat internal melt arrest and coolability device is not effective in providing debris bed cooling. Unlike the CCID category, cooling water is present and provides the potential of scrubbing for the radionuclides that evolve from the debris bed, thus reducing the magnitude of the source term. Sequences in which the reactor vessel is not depressurized may result in earlier reactor vessel failure. A low pressure sequence (CCIWa) and a high pressure sequence (CCIWb) were selected for determining the source term categories associated with ~~each sequence in~~ this release category.
5. Ex-Vessel Steam Explosion (EVE) – This release category applies to sequences in which the reactor vessel fails at low pressure and a significant steam explosion occurs. Containment depressurization is assumed to occur when the vessel fails, at which time there is direct communication with the environment. Due to the uncertainties associated with equipment damage and water availability, no credit is taken for lower drywell water to reduce the source term.
6. Filtered Release (FR) – Radioactivity is released by manually venting the containment from the suppression chamber air space. This action may be implemented to limit the containment pressure increase if containment heat removal fails or the containment is over pressurized. Venting the suppression chamber forces the radionuclides through the suppression pool, which reduces the magnitude of the source term.
7. Overpressure-Vacuum Breaker (OPVB) – This release category applies to sequences in which the vacuum breaker failure has occurred (either by failing to close or by remaining open in a pre-existing condition), resulting in failure of the containment pressure function, which in turn causes failure in containment heat removal. ~~Two sequences are associated with this release category, both~~ high (OPVBa) and low pressure sequences (OPVBb) were selected for source term categories. Both
8. Overpressure - Early Containment Heat Removal Loss (OPW1) – This release category applies to sequences in which containment heat removal fails within 24 hours after event initiation. A sequence with the reactor pressure vessel failure at high pressure was selected because it has an earlier failure and higher probability of the loss of containment heat removal. Containment heat removal is assumed to be unavailable for the duration of the sequence.

9. Overpressure - Late Containment Heat Removal Loss (OPW2) – This release category applies to sequences in which containment heat removal fails in the period after that addressed by OPW1, above, until 72 hours after onset of core damage. The passive containment cooling system is assumed to be unavailable 24 hours after event initiation, and the availability of the fuel and auxiliary pool cooling system is determined. A sequence with the reactor pressure vessel failure at high pressure was selected because it has an earlier failure and higher probability of the loss of containment heat removal. Containment heat removal is terminated 24 hours after the event initiation.
10. Technical Specification Leakage (TSL) – This category applies to sequences in which the containment is intact and the only release is due to the maximum leak rate allowed by Technical Specifications. For additional conservatism, the area of containment leakage corresponding to the maximum allowable Technical Specification leak rate was doubled to produce the representative source term used for this release category.

In addition a direct containment heating (DCH) category was evaluated. The DCH category applies to sequences in which the reactor fails at high pressure and a significant DCH event occurs. GE subsequently determined that catastrophic containment failure due to DCH is physically unreasonable and studies local damage to the liner in the lower drywell as a sensitivity case. Thus, no DCH sequence was evaluated for the baseline case.

code

GE then used the MACCS2 (MELCOR Accident Consequence Code System) (Reference 7.2-9) to model the environmental consequences of severe accidents, using generic, but conservative, meteorological and population parameters to represent a generic ESBWR site. The analysis focused on the 24-hour period following core damage, as a measure of the consequences from a large release and, therefore, did not address the long-term exposure pathways such as ingestion, inhalation of re-suspended material, or groundshine subsequent to plume passage. GE also considered the releases for the first 72 hours after core damage. Additional details of analysis are found in the ESBWR PRA (Reference 7.2-3) and are reported in the ESBWR Design Control Document (Reference 7.2-4).

7.2.2 Site Specific Methodology

For Fermi 3, the MACCS2 computer code was used to evaluate offsite risks and consequences of severe accidents, using Fermi site-specific information. MACCS2 simulates the impact of severe accidents at nuclear power plants on the surrounding environment. The principal phenomena considered in MACCS2 include atmospheric transport, mitigation actions based on dose projection, dose accumulation by a number of pathways including food and water ingestion, early and latent human health effects, and economic costs. The specific pathways modeled include external exposure to the passing plume, external exposure to material deposited on the ground, inhalation of material in the passing plume or re-suspended from the ground, and ingestion of contaminated food and surface-water. The MACCS2 code primarily addresses dose from the air pathway, but also calculates dose from surface runoff and deposition on surface-water. The MACCS2 code also evaluates the extent of land contamination. For Fermi 3, the analysis used site-specific meteorology and population data (Subsection 2.5.1) and extended the analysis to include long-term exposure pathways, such as ingestion, over the life cycle of the accident. Ingestion exposure was determined using the COMIDA2 food model option of MACCS2.

To assess human health impacts, the analysis determined the collective dose to the 50-mi region population, number of latent cancer fatalities, and number of early fatalities associated with a severe accident. Economic costs were also determined, including the costs associated with short-term relocation of people, decontamination of property and equipment, interdiction of food supplies, and indirect costs resulting from loss of use of the property and incomes derived as a result of the accident.

Five files provide input to a MACCS2 analysis: ATMOS, EARLY, CHRONC, MET, and SITE.

ATMOS provides data to calculate the amount of material released to the atmosphere that is dispersed and deposited. The calculation uses a Gaussian plume model. Important inputs in this file include the core inventory, release fractions, and geometry of the reactor and associated buildings. This input data is taken from GE's generic PRA.

The second file, EARLY, provides inputs to calculations regarding exposure in the time period immediately following the release, including parameters describing breathing rates and sheltering. Important site-specific information includes emergency response information such as evacuation time.

The third input file, CHRONC, provides data for calculating long-term impacts and economic costs and includes region-specific data on agriculture and economic factors. These files access a meteorological file that uses actual Fermi meteorological monitoring data and a site characteristics file which is built using SECPOP2000 (Reference 7.2-5).

population dose and

Seven years of site specific meteorological data (2001 through 2007) were evaluated. MACCS2 requires a calendar year of meteorological data for the MET file. The year 2002 meteorological data was selected for subsequent analysis because it resulted in the greatest cost risk, ~~resulted in 99.7 percent of the maximum population dose risk,~~ and also was the most complete yearly data set. In addition, sensitivities were performed for the other six years of meteorological data.

2060

The SITE file requires the 50-mi population distribution as well as agricultural-economic data. SECPOP2000 (Reference 7.2-5) incorporates 2000 census data for the 50-mi region around the Fermi site. For this analysis, the census data were projected to the year ~~2077~~, using county-specific growth rates. MACCS2 also requires the spatial distribution of certain agriculture and economic data (fraction of land devoted to farming, annual farm sales, fraction of farm sales resulting from dairy production, and property value of farm and non-farm land) in the same manner as the population. This was done by applying the SECPOP2000 program, changing the regional economic data format to comply with MACCS2 input requirements. In this case, SECPOP2000 was used to access data from the 1997 National Census of Agriculture. The program's specification of crop production parameters for the 50-mi region (e.g., fraction of farmland devoted to grains, vegetables, etc.) was also applied.

The version 3.12.01 data file accessed by SECPOP2000, County97.dat, was modified to correct two errors (generally known as the missing notes parameter error and the missing county numbers error) in the issued version.

The analysis used the resulting MACCS2 calculations and release frequency information to determine risk. The sum of the accident frequencies is known as the core damage frequency and includes only internally initiated events during reactor operation. Risk is the product of frequency of an accident times the consequences of the accident. The consequence can be any measure of release impacts such as radiation dose and economic cost. Dose-risk is the product of the collective dose times the release frequency. Because the ESBWR's severe accident analysis addressed a suite of accidents, the individual risks were summed to provide a total risk. The same process was applied to estimating cost-risk. Risk from these consequences can be reported as person-rem per reactor year or dollars per reactor year.

Insert 1 Here

~~The analysis assumed a ground level release height and no release heat for each accident release hypothesized, consistent with the GE analysis. A sensitivity analysis was performed for each of these assumptions. A middle of containment and a top of containment release was compared to the ground level release and the dose-risk increased by 1.6 percent and 4 percent respectively. The cost-risk for the middle of containment and top of containment release had a similar increase of 0.98 percent and 4.7 percent respectively. A release heat of 1 MW and 10 MW was compared to the base case of no release heat and the dose-risk increased by 0.64 percent and 3.4 percent respectively, while the cost-risk increased by 0.87 percent and 5.3 percent respectively. A sensitivity analysis was performed on the precipitation input where the site specific precipitation rate was doubled and halved. The doubled precipitation resulted in a decrease in both the dose-risk and cost-risk of 0.64 percent and 0.78 percent respectively. The halved precipitation resulted in an increase in the dose-risk of 0.64 percent and no change in the cost-risk. In addition, a sensitivity analysis was performed on the conservative assumption that the final 40- to 50-mi ring has constant meteorology, including constant precipitation. This assumption forces the deposition of the remaining airborne radioactivity within 50-mi of the site. The precipitation in the 40- to 50-mi ring was set equal to the site-specific precipitation and resulted in a reduction in the dose-risk of 27 percent and a reduction in the cost-risk of 35 percent when compared to the base case.~~

7.2.3 Consequences to Population Groups

The pathway consequences to population groups including air pathways, surface-water, and groundwater pathways are discussed in the following sections. The presence of threatened and endangered species and federally designated critical habitat are discussed in Subsection 2.4.1 and Subsection 2.4.2. As necessary, the impacts on threatened and endangered species due to the previously calculated radiation exposure levels are discussed in Subsection 5.4.4.

7.2.3.1 Air Pathways

Each of the accident categories was analyzed with MACCS2 to estimate population dose, number of early and latent fatalities, cost, and farm land requiring decontamination. The analysis conservatively assumed that evacuation occurs during adverse weather conditions following declaration of a General Emergency. It was also conservatively assumed that the evacuation routes were already at full capacity. Therefore, the increased population expected in the year ~~2077~~ 2060 would take longer to evacuate. For each accident category, the risk for each analytical endpoint was calculated by multiplying the analytical endpoint by the accident category frequency and adding across all accident categories. The results are provided in Table 7.2-1.

Insert 1

The base case analysis assumed a ground level release height and no release heat for each hypothesized accident release. A sensitivity analysis was performed for these and other modeling assumptions. A middle of containment and a top of containment release was compared to the ground level release and the dose-risk increased by 0.7 percent and 2.6 percent respectively. The cost-risk for the middle of containment and top of containment release had increases of 1.6 percent and 5.0 percent respectively. A release heat of 1 MW and 10 MW was compared to the base case of no release heat and the dose-risk increased by 0.5 percent and 2.3 percent respectively, while the cost-risk increased by 0.9 percent and 4.9 percent respectively. A sensitivity analysis was performed on the precipitation input where the site specific precipitation rate was doubled and halved. The doubled precipitation resulted in a decrease in both the dose-risk and cost-risk of 0.9 percent and 0.7 percent respectively. The halved precipitation resulted in increases in the dose-risk of 0.1 percent and 0.3 percent in the cost-risk. In addition, a sensitivity analysis was performed on the conservative assumption that the final 40- to 50-mi ring has constant meteorology, including constant precipitation. The base case hourly precipitation in the 40- to 50-mi ring was set equal to the 12-hour average site-specific precipitation, forcing additional deposition of the remaining airborne radioactivity which reaches this ring. Allowing the meteorology, including the precipitation, in this ring to follow the hourly site measured meteorology, resulted in a reduction in the dose-risk of 24 percent and a reduction in the cost-risk of 35 percent when compared to the base case.

The site specific analysis assumed a ground level release height and no release heat for each accident release hypothesized. The GE analysis used this same assumption to report impacts during the first 24-hours after the onset of core damage, but reported impacts during the first 72-hours after the onset of core damage from an elevated release with one megawatt of release heat. The latter combination of release height and heat would increase the 50-mi population and cost-risks by 3.5 percent and 6.2 percent, respectively. However, near site risks decrease. An example of the latter would be the 66 percent decrease in early fatality risk from the base case; note, however, the very small base case early fatality risk as given in Table 7.2-1.

For each release category with a dual source term, the site specific analysis conservatively attributes the entire release category frequency to the source term which results in the greater 50-mi population dose. The sensitivity of this assumption to the calculated risks was investigated by considering a case with the entire release category frequency attributed to each of the dual source terms, and the greater calculated risk impact between the two source terms reported for each risk metric. All base case risks were within 0.5 percent of the sensitivity case risk except water ingestion, which was within 1.5 percent.

7.2.3.2 Surface-Water Pathways

People can be exposed to radiation when airborne radioactivity is deposited onto the ground and runs off into surface-water or is deposited directly onto surface-water. The exposure pathway can be from drinking the water, submersion in the water (swimming), undertaking activities near the shoreline (fishing and boating), or ingestion of fish or shellfish. For the surface-water pathway, MACCS2 only calculates the dose from drinking the water. It is conservatively assumed that all water within 50 mi of the site is drinkable. The ~~maximum~~ MACCS2 code severe accident dose-risk to the 50-mi population from drinking the water is ~~8.0×10^{-4}~~ 1.3×10^{-3} person-rem per year of ESBWR operation. As shown in Table 7.2-1, this value is the sum of all accident category risks.

Surface-water bodies within the 50-mi region of the Fermi site that are accessible to the public include Lake Erie, River Raisin, Huron River, Maumee River, Lake St. Clair, Detroit River, and other smaller water bodies. In NUREG-1437, the NRC evaluated doses from the aquatic food pathway (fishing) for the current nuclear fleet of reactors, including Fermi 2 (Reference 7.2-8). The aquatic food pathway dose for Fermi 2 was 1400 person-rem. Actual dose-risk values would be expected to be much less (by a factor of 2 to 10) due to interdiction of contaminated foods (Reference 7.2-8). Examination of the atmospheric dose-risk from severe accidents to the population within 50 mi of operating nuclear plants resulted in dose-risks ranging from 0.55 to 68 person-rem per reactor year for nuclear plants undergoing license renewal. The Fermi 3 atmospheric pathway dose of ~~0.031~~ 0.032 person-rem per reactor year is significantly lower. Given the dependency of surface-water doses on airborne releases, it is reasonable to conclude that the doses from surface-water sources would be consistently lower than that reported above for the Fermi 2 surface-water pathway.

Doses associated with submersion in the water and undertaking activities near the shoreline are not modeled by MACCS2, and NUREG-1437 does not provide specific data on submersion and shoreline activities. However, it does indicate that these contributors to dose are much less than for drinking water and consuming aquatic foods.

7.2.3.3 Groundwater Pathways

People can also receive dose from groundwater pathways. Radioactivity released during a severe accident can enter groundwater and may move through an aquifer and eventually be discharged to surface-water.

NUREG-1437 evaluated the groundwater pathway dose, based on the analysis in NUREG-0440, the Liquid Pathway Generic Study (LPGS) (Reference 7.2-6). NUREG-0440 analyzed a core meltdown that contaminated groundwater, which subsequently contaminated surface-water. NUREG-0440 did not analyze direct consumption of groundwater because it assumed a limited number of potable groundwater wells and limited accessibility.

The LPGS results provide conservative, uninterdicted population dose estimates for six generic categories of plants. These dose estimates were one or more orders of magnitude less than those attributed to the atmospheric pathway. Therefore, although the Fermi site was not one of the reactors analyzed, the doses from the Fermi 3 site groundwater pathway would be expected to be much less than the doses from the atmospheric pathway, given that all categories of plant locations showed the same trend. It is noted that, as discussed in Subsection 2.3.1, the Fermi site is not over or near a sole source aquifer.

7.2.4 Comparison to U.S. NRC Safety Goals

The ESBWR PRA evaluates performance of the ESBWR under generic conditions to three safety goals: (1) individual risk goal, (2) societal risk goal, and (3) radiation risk goal (Reference 7.2-3). These goals are defined in the following subsections. Table 7.2-2 provides the quantitative evaluation of these three safety goals and the Fermi site-specific calculation of these risk values.

7.2.4.1 Individual Risk Goal

The risk to an average individual in the vicinity of a nuclear power plant of experiencing a prompt fatality resulting from a severe reactor accident should not exceed one-tenth of one percent (0.1 percent) of the sum of "prompt fatality risks" resulting from other accidents to which members of the U.S. population are generally exposed. As defined in the Safety Goals Policy statement (51 FR 30028), "vicinity" is the area within one mile of the plant site boundary. "Prompt Fatality Risks" are defined as the sum of risks which the average individual residing in the vicinity of the plant is exposed to as a result of normal daily activities (driving, household chores, occupational activities, etc). For this evaluation, the sum of prompt fatality risks was taken as the U.S. accidental death risk value of 37.7 deaths per 100,000 people per year (Reference 7.2-2).

7.2.4.2 Societal Risk Goal

The risk to the population in the area near a nuclear power plant of cancer fatalities that might result from its operation should not exceed one-tenth of one percent (0.1 percent) of the sum of the cancer fatality risks resulting from all other causes. As defined in the Safety Goal Policy Statement (51 FR 30028), "near" is within 10 miles of the plant. The cancer fatality risk was taken as 191.4 deaths per 100,000 people per year based upon National Center for Health Statistics data for 2001–2004 (Reference 7.2-2).

7.2.4.3 Radiation Dose Goal

The probability of an individual exceeding a whole body dose of 25 rem at a distance of 0.5 mile from the reactor shall be less than one in a million per reactor year.

7.2.5 Conclusions

The total calculated dose-risk to the 50-mi population from airborne releases from an ESBWR reactor at the Fermi site would be ~~0.031~~ 0.032 person-rem per reactor year (Table 7.2-1). This value is less than the population risk for all current reactors that have undergone license renewal, and less than that for the five reactors analyzed in NUREG-1150 (Reference 7.2-7).

Comparisons with the existing nuclear reactor fleet (Subsection 7.2.3.2) indicate that risk from the surface-water pathway is SMALL. Under the severe accident scenarios, surface-water is primarily contaminated by atmospheric deposition. The ESBWR atmospheric pathway doses are significantly lower than those of the current nuclear fleet. Therefore, it is reasonable to conclude that the doses from the surface-water pathway at the Fermi site would be consistently lower than those reported in Subsection 7.2.3.2 for the current fleet.

The risks of groundwater contamination from a severe ESBWR accident (see Subsection 7.2.3.3) would be much less than the risk from currently licensed reactors. Additionally, interdiction could substantially reduce the groundwater pathway risks.

For comparison, as reported in Subsection 5.4.3, the total body dose from the Fermi site normal airborne releases is predicted to be 4.5 person-rem annually. As previously described, dose-risk is dose times frequency. Normal operations have a frequency of one. Therefore, the dose-risk for normal operations is 4.5 person-rem per reactor year. Comparing this value to the severe accident dose-risk of ~~0.031~~ 0.032 person-rem per reactor year indicates that the dose risk from severe accidents is approximately 0.7 percent of the dose-risk from normal operations.

The probability-weighted risk of cancer fatalities (early and late) from a severe accident for the Fermi site is reported in Table 7.2-1 as 2.0 × 10^{-5} fatalities per reactor year. The probability of an individual dying from any cancer from any cause is approximately 0.23 for men and 0.20 for women over a lifetime (Reference 7.2-1). Comparing this value to the 2.0 × 10^{-5} fatalities per reactor year indicates that individual risk is at ~~least~~ most 0.01 percent of the background risk, which is less than the societal risk goal of 0.1 percent of the background risk.

The results from the analysis discussed in this section are used in Section 7.3 to determine if there are any cost-beneficial design alternatives that should be considered to mitigate the impacts described herein.

7.2.6 References

7.2-1 American Cancer Society, "Lifetime Probability of Developing or Dying from Cancer," http://www.cancer.org/docroot/CRI/content/CRI_2_6x_Lifetime_Probability_of_Developing_or_Dying_From_Cancer.asp, accessed 1 May 2008.

7.2-2 Centers for Disease Control, "Deaths: Final Data for 2004," National Vital Statistics Reports, Volume 55 Number 19, August 21, 2007.

7.2-3 GE Energy, "ESBWR Probabilistic Risk Assessment," NEDO-33201, Revision ~~2,~~ 4 ~~September 2007.~~ June 2009

7.2-4 GE-Hitachi Nuclear Energy, "ESBWR Design Control Document - Tier 2," Revision ~~4,~~ 6 ~~September 2007~~. August 2009

7.2-5 U.S. Nuclear Regulatory Commission, "SECPOP 2000: Sector Population Land Fraction, and Economic Estimation Program," NUREG/CR-6525, August 2003.

7.2-6 U.S. Nuclear Regulatory Commission, "Liquid Pathway Generic Study: Impacts of Accidental Radioactive Releases to the Hydrosphere from Floating and Land-Based Nuclear Power Plants," NUREG-0440, February 1978.

7.2-7 U.S. Nuclear Regulatory Commission, “Severe Accident Risks: An Assessment for Five U.S. Nuclear Power Plants,” NUREG-1150, June 1989.

7.2-8 U.S. Nuclear Regulatory Commission, “Generic Environmental Impact Statement for License Renewal of Nuclear Plants,” NUREG-1437, Volumes 1 and 2, May 1996.

7.2-9 Chanin, D.I., and M.L. Young, “Code Manual for MACCS 2: User’s Guide,” NUREG/CR-6613, SAND97-0594, Volume 1, Sandia National Laboratories, Albuquerque, New Mexico, May 1998.

Table 7.2-1 Impacts to the Population and Land from Fermi 3 Severe Accidents Analysis

Accident Category[1]	Release Frequency (per reactor year)[2]	Population Dose-Risk (person-rem per reactor year)	Number of Fatalities (per reactor year)		Cost-Risk (dollars per reactor year)	Water Ingestion Dose (person-rem per reactor year)	Land Requiring Decontamination (acres per reactor year)
			Early	Late			
BOCa	7.4×10^{-11}	3.2×10^{-3}	2.3×10^{-8}	2.4×10^{-6}	8.1	1.3×10^{-4}	1.5×10^{-5}
BOCb	7.4×10^{-11}	1.5×10^{-3}	4.7×10^{-10}	9.3×10^{-7}	3.1	1.4×10^{-5}	1.3×10^{-5}
BYPa	1.5×10^{-12}	4.6×10^{-5}	8.6×10^{-11}	3.0×10^{-8}	0.12	8.9×10^{-7}	3.8×10^{-7}
BYPb	5.5×10^{-11}	1.9×10^{-3}	3.5×10^{-10}	1.6×10^{-6}	3.6	1.8×10^{-5}	1.0×10^{-5}
CCIDa	1.0×10^{-12}	2.5×10^{-5}	9.5×10^{-18}	1.5×10^{-8}	8.0×10^{-2}	5.9×10^{-7}	2.8×10^{-7}
CCIDb	1.0×10^{-12}	2.4×10^{-5}	7.8×10^{-14}	1.5×10^{-8}	6.1×10^{-2}	3.6×10^{-7}	2.4×10^{-7}
CCIWa	5.3×10^{-11}	4.3×10^{-6}	0.0	2.6×10^{-9}	1.8×10^{-4}	6.5×10^{-9}	3.9×10^{-9}
CCIWb	4.6×10^{-11}	4.4×10^{-4}	0.0	Insert 2 Here	1.2	5.4×10^{-6}	4.8×10^{-6}
EVE	6.1×10^{-10}	2.2×10^{-2}	2.4×10^{-11}	1.3×10^{-5}	74	6.2×10^{-4}	2.4×10^{-4}
FR	1.0×10^{-12}	5.2×10^{-6}	0.0	3.1×10^{-9}	4.2×10^{-3}	1.8×10^{-8}	2.6×10^{-8}
OPVBa	3.0×10^{-13}	3.0×10^{-6}	0.0	1.8×10^{-9}	3.6×10^{-3}	1.4×10^{-8}	2.1×10^{-8}
OPVBb	5.7×10^{-12}	4.7×10^{-5}	1.3×10^{-16}	2.8×10^{-8}	4.6×10^{-2}	1.9×10^{-7}	2.8×10^{-7}
OPW1	1.0×10^{-12}	8.7×10^{-6}	0.0	5.2×10^{-9}	9.3×10^{-3}	3.7×10^{-8}	5.7×10^{-8}
OPW2	1.0×10^{-12}	1.2×10^{-6}	0.0	7.2×10^{-10}	2.1×10^{-4}	3.2×10^{-9}	1.6×10^{-9}
TSL	1.1×10^{-8}	2.0×10^{-3}	0.0	1.2×10^{-6}	0.37	3.8×10^{-6}	3.2×10^{-6}
Total	1.2×10^{-8}	3.1×10^{-2}	2.4×10^{-8}	2.0×10^{-5}	91	8.0×10^{-4}	2.8×10^{-4}

Notes:

1. Reference 7.2-3, Table 9-1
2. Reference 7.2-3, Table 10.3-3a

Table 7.2-2 Comparison of Fermi 3 Results to U.S. NRC Safety Goals

	~~**Safety Risk**~~		
~~**Year of Fermi Site Meteorological Data**~~	~~**Prompt Fatality Risk (Individual 0-1 mi) (deaths per reactor year)**~~	~~**Cancer Fatality Risk (0-10 mi cancers) (deaths per year per reactor year)**~~	~~**Probability of Exceeding 0.25 Sv (25 rem) at 0.5 mi (per reactor-year)**~~
~~2001~~	~~9.04×10^{-12}~~	~~8.52×10^{-14}~~	~~2.42×10^{-9}~~
~~2002~~	~~8.32×10^{-12}~~	~~8.49×10^{-14}~~	~~2.35×10^{-9}~~
~~2003~~	~~9.31×10^{-12}~~	~~9.95×10^{-14}~~	~~2.88×10^{-9}~~
~~2004~~	~~8.15×10^{-12}~~	~~8.45×10^{-14}~~	~~2.43×10^{-9}~~
~~2005~~	~~8.31×10^{-12}~~	~~9.29×10^{-14}~~	~~2.53×10^{-9}~~
~~2006~~	~~8.45×10^{-12}~~	~~8.74×10^{-14}~~	~~2.48×10^{-9}~~
~~2007~~	~~8.37×10^{-12}~~	~~8.83×10^{-14}~~	~~2.79×10^{-9}~~
~~Safety Goal~~	~~3.77×10^{-7} (2)~~	~~1.91×10^{-6} (2)~~	~~$< 10^{-6}$ (1)~~
~~Generic ESBWR Analysis[1]~~	~~$8.2\text{x}10^{-11}$~~	~~$1.1\text{x}10^{-11}$~~	~~$2.10\text{x}10^{-9}$~~

Insert 3 Here

~~Notes:~~
1. Reference 7.2-3
2. Reference 7.2-2

Insert 2

Table 7.2-1 Impacts to the Population and Land from Fermi 3 Severe Accidents Analysis

Accident Category[1]	Accident Frequency (per reactor year)[2]	Population Dose-Risk (person-rem per reactor year)	Number of Fatalities (per reactor year)		Cost Risk (dollars per reactor year)	Water Ingestion Dose (person-rem per reactor-year)	Land Requiring Decontamination (acres per reactor year)
			Early	Late			
BOC	7.9E-11	2.6E-03	2.3E-09	1.8E-06	8.7E+00	1.5E-04	1.6E-05
BYP	5.7E-11	1.7E-03	5.4E-10	1.4E-06	3.5E+00	1.9E-05	1.0E-05
CCID	1.5E-12	3.2E-05	3.6E-12	2.0E-08	1.2E-01	1.6E-06	2.9E-07
CCIW	2.9E-12	2.6E-05	1.3E-13	1.5E-08	7.0E-02	3.9E-07	3.2E-07
EVE	1.1E-09	2.5E-02	3.4E-09	1.6E-05	9.2E+01	1.2E-03	2.2E-04
FR	9.2E-11	4.2E-04	1.5E-14	2.5E-07	4.6E-01	2.1E-06	3.2E-06
OPVB	2.1E-12	1.3E-05	2.6E-14	7.7E-09	2.9E-02	1.2E-07	1.5E-07
OPW1	2.0E-12	1.2E-05	7.6E-17	7.4E-09	3.0E-02	1.2E-07	1.5E-07
OPW2	8.5E-12	1.2E-05	0.0E+00	7.0E-09	2.1E-03	3.6E-08	1.7E-08
TSL	1.5E-08	2.2E-03	0.0E+00	1.3E-06	4.9E-01	4.8E-06	4.1E-06
Total	1.7E-08	3.2E-02	6.2E-09	2.0E-05	1.1E+02	1.3E-03	2.6E-04

Notes:

1. Reference 7.2-3, Table 9-1
2. Reference 7.2-3, Table 10.3-3a

Insert 3

Table 7.2-2 Comparison of Fermi-3 Results to NRC Safety Goals

Year of Fermi Site Meteorological Data	**Prompt Fatality Risk (Individual 0-1 mi) (deaths per reactor year)**	**Cancer Fatality Risk (0-10 mi cancers) (deaths per year per reactor year)**	**Probability of Exceeding 0.25 Sv (25 rem) at 0.5 mi (per reactor year)**
2001	4.46E-12	8.40E-14	1.20E-09
2002	4.07E-12	8.21E-14	1.14E-09
2003	4.82E-12	9.38E-14	1.23E-09
2004	4.05E-12	8.34E-14	1.11E-09
2005	4.30E-12	8.60E-14	1.09E-09
2006	4.31E-12	8.49E-14	1.11E-09
2007	4.47E-12	8.78E-14	1.14E-09
Safety Goal	3.77E-07 (2)	1.90E-06 (2)	< 1.00E-06 (1)
Generic ESBWR Analysis[1]	1.61E-10	2.56E-11	2.04E-09

Notes:

1. Reference 7.2-3, Table 10.4-2. Maximum At Power Internal case.
2. Reference 7.2-2

Attachment 3
NRC3-10-0004

Supplemental Response to RAI letter related to Fermi 3 ER

RAI Question AC7.3-1

NRC RAI AC7.3-1

Provide in electronic format the analysis and assumptions used in determining averted costs for SAMAs. Discuss the process for ensuring that SAMAs related to operating procedures and administrative controls will be evaluated prior to plant startup. Explain how completion of this analysis will be tracked. Also, evaluate the effect of changing the reported cost basis in NUREG/BR-184, which is in 1992-1993 dollars, to the current year, similar to the cost estimate process used in the MACCS2 analysis for determining offsite property losses resulting from severe accidents.

Supporting Information

Section 7.3.3 of the ER presents a discussion leading to the conclusion that no cost beneficial SAMDAs have been identified, and states that evaluation of specific administrative control measures for the ESBWR will be considered for implementation when they are developed prior to fuel load. The current analysis is based on cost bases in 1992-1993 dollars as given in NUREG/BR-184. For new reactors that are expected to have a 60-year lifetime, there is a need to readjust the cost values. NUREG/BR-184 states that the averted costs dollar measures "should be present valued and expressed in terms of the same year." Considering that the potential operation date for Fermi 3 is 2016 and beyond, there is a need for adjusting these costs estimates to the current date, especially for the replacement power costs that contribute the most to the estimated averted costs.

Supplemental Response

The original response to RAI AC7.3-1 was submitted in Detroit Edison letter NRC3-09-0015 (ML093090165), dated October 30, 2009. The response indicated that the electronic format of the analysis being requested above was provided on a disk enclosed with the response to RAI AC7.2-1 as an attachment to Detroit Edison letter NRC3-09-0014 (ML093350028), dated September 30, 2009. The specific electronic files included on the disk were the MACCS2 input and output files, along with a spreadsheet titled: "SAMDA (Fermi 3)-rev2.xls." Based on discussions with the NRC on November 12, 2009, it was determined that while the response was acceptable, the revised values that were provided in the analysis were out of date and must be updated to incorporate ESBWR DCD Revision 6 and PRA Revision 4 following methodologies consistent with the FSAR update.

The updated electronic MACCS2 input and output files, along with a spreadsheet titled: "SAMDA (Fermi 3)-rev3.xls are being provided in this letter as an enclosed disk. An inventory of the files on that disk is provided in Appendix C to this letter.

Proposed COLA Revision

ER Section 7.3.3 has been revised to:

1) update the core damage frequency to reflect PRA Revision 4
2) update cost risks to reflect the updated analyses
3) maintain clarification of the commitment described in the original response

Markup of Detroit Edison COLA
(following 6 pages)

The following markup represents how Detroit Edison intends to reflect this RAI response in a future submittal of the Fermi 3 COLA. However, the same COLA content may be impacted by revisions to the ESBWR DCD, responses to other COLA RAIs, other COLA changes, plant design changes, editorial or typographical corrections, etc. As a result, the final COLA content that appears in a future submittal may be different than presented here.

7.3 Severe Accident Mitigation Alternatives

U.S. Environmental Protection Agency regulations require that a discussion on environmental consequences include mitigation measures (40 CFR 1502.16(h)). Mitigation measures should be considered even for impacts that would not be significant by themselves, if the overall proposed action could have significant impacts.

As described in Section 7.2, General Electric (GE) performed a probabilistic risk analysis (PRA) for the ESBWR as part of the design certification process (Reference 7.3-1). This analysis determined that severe accident impacts are within the safety goals established by the NRC. Detroit Edison extended the GE generic PRA to examine Detroit Edison's proposed ESBWR unit at the Fermi site and concluded that the generic analysis remains valid for the site. The analysis discussed in this section provides assurance that there are no cost-beneficial design alternatives that would need to be implemented at Fermi 3 to mitigate the small impacts described in Section 7.2.

7.3.1 The SAMA Analysis Process

Design or procedural modifications that could mitigate the consequences of a severe accident are known as severe accident mitigation alternatives (SAMAs). In the past, SAMAs were known as SAMDAs, severe accident mitigation design alternatives, which primarily focused on design changes and did not consider procedural modifications. For an existing plant with a well-defined design and established procedural controls, the normal evaluation process for identifying potential SAMAs includes four steps:

1. Define the base case – The base case is defined by the dose-risk and cost-risk of a severe accident before implementation of any SAMAs. A plant's PRA is the primary source of data in calculating the base case. The base case risks are converted to a monetary value for subsequent use in screening SAMAs. Section 7.2 presents the base case dose- and cost-risk for a single ESBWR at the Fermi site.
2. Identify and screen potential SAMAs – Potential SAMAs can be identified from the plant's Individual Plant Examination, the plant's probabilistic risk assessment, and the results of other plants' SAMA analyses. Each potential SAMA in the list is assigned a conservatively low implementation cost based on historical costs for similar design changes and/or engineering judgment, and is then compared to the base case value from Step 1, above. SAMAs with higher implementation cost than the base case value are not evaluated further. SAMAs with a lower implementation cost than the base case screening value go to Step 3.
3. Determine the cost and net value of each SAMA – Each SAMA remaining after Step 2 receives a detailed engineering cost evaluation, developed using current plant engineering processes. If the SAMA continues to pass the screening value, Step 4 is performed.
4. Determine the benefit associated with each screened SAMA – Each SAMA that passes the screening in Step 3 is evaluated using the PRA model to determine the reduction in risk associated with implementation of the proposed SAMA. The reduction-in-risk

benefit is converted to a monetary value and is then compared to the detailed cost estimate. Those SAMAs with reasonable cost-benefit ratios are considered for implementation.

In the absence of a completed plant with established procedural controls, the analysis process is limited to demonstrating that the severe accident analysis using Fermi-specific parameters is bounded by the GE severe accident analysis and to determining what magnitude of plant-specific design or procedural modification would be cost-effective. Determining the magnitude of cost-effective design or procedural modifications is the same as defining the base case (Step 1) for existing nuclear units. The base case benefit value is calculated by assuming the current dose-risk of the unit could be reduced to zero and assigning a defined dollar value for this change in risk. Any design or procedural change cost that exceeded the benefit value would not be considered cost-effective.

The dose-risk and cost-risk results (Section 7.2 analyses) are converted to a monetary value in accordance with methods established in NUREG/BR-0184 (Reference 7.3-3). NUREG/BR-0184 presents methods for determining the value of decreases in risk using four types of attributes: public health, occupational health, offsite property, and onsite property. Any SAMAs in which the conservatively low implementation cost exceeds the base case valuation would not be expected to pass the screening in Step 2. If the baseline analysis produces a value that is below that expected for implementation of any reasonable SAMA, no matter how inexpensive, then the remaining two steps of the SAMA process are not necessary.

7.3.2 The GE-Hitachi ESBWR SAMDA Analysis

The GE-Hitachi (GEH) SAMDA analysis was provided to the NRC in Reference 7.3-2. GEH compiled a list of potential SAMDAs based on the Advanced Boiling Water Reactor SAMA study and license renewal environmental reports. Some SAMDAs were then screened out based on their inapplicability to the ESBWR design or because they were already included in the ESBWR design. SAMDAs with implementation costs that far exceeded any reasonable benefit or had very low benefits were also excluded. None of the SAMDAs passed the screening process.

GEH compared the implementation costs for each SAMDA to the maximum severe accident risk reduction value possible and found that none of the SAMDAs would be cost-effective.

7.3.3 Monetary Valuation of the Fermi 3 Base Case

The principal inputs to the calculations are: core damage frequency, dose-risk and cost-risk, dollars per person-rem, licensing period, and economic discount rate.

- The core damage frequency, including both internal and external events, is ~~6.61 x 10^{-8}~~ 1.16 x 10^{-7} per year (Reference 7.3-1).
- The dose-risk and cost-risk are reported in Table 7.2-1.
- The calculations use $2000 per person-rem, provided in NUREG/BR–0184.
- The licensing period is assumed to be 60 years for the calculations, rather than the 40-year period in the Combined License (COL) application, to be consistent with the GEH analysis.

- The economic discount rate is assumed to be 7 percent, consistent with the GEH analysis. In addition, a sensitivity analysis is included using 3 percent. The NRC recommends using a 7 percent discount rate and performing a sensitivity analysis using 3 percent (Reference 7.3-3).

Using these inputs, the maximum monetary value associated with complete risk reduction is presented in Table 7.3-1. The monetary value (the maximum averted cost-risk) is conservative because no SAMA can reduce the core damage frequency to zero.

22,804

The maximum averted cost-risk of $~~15,381~~ for a single ESBWR at the Fermi site is sufficiently small that no design changes would be cost-effective to implement. This is consistent with the GEH analysis that demonstrates that cost-effective designs to mitigate severe accidents have already been incorporated into the design submitted for certification. Even with a conservative 3 percent discount rate, the valuation of the averted risk is only $3~~2,957. These values compare closely to the GEH generic analysis result of $4628 for the best estimate and $41,383 for the upper bound estimate.~~

49,557

A review was performed of the compilation of SAMAs in NEDO-33206 to identify procedural and administrative measures that were not considered design alternatives (Reference 7.3-2). Most of these items related to PWRs and have no relevance to the ESBWR. ~~These administrative and procedural measures applicable to the ESBWR will be considered for implementation when procedures are developed prior to fuel load, as long as their cost does not exceed the maximum value associated with averting all risk of severe accidents.~~

Insert 1

Accordingly, no cost-beneficial SAMDAs have been identified. Further, pursuant to 10 CFR 51.30(d), the NRC will, as part of its design certification rulemaking, prepare an environmental assessment evaluating the costs and benefits of SAMDAs for the ESBWR. Pursuant to 10 CFR 51.50(c)(2) and 51.75(c)(2), this environmental assessment may be incorporated by reference into the ER upon completion.

7.3.4 References

4

7.3-1 GE Energy, "ESBWR Probabilistic Risk Assessment," NEDO-33201, Revision ~~2, September 2007.~~

June 2009

7.3-2 GE-Hitachi Nuclear Energy Americas LLC, "ESBWR Severe Accident Mitigation Design Alternatives," NEDO-33306, Revision 1, August 2007.

7.3-3 U.S. Nuclear Regulatory Commission, "Regulatory Analysis Technical Evaluation Handbook," NUREG/BR-0184, January 1997.

Insert 1

[START: COM ER-7.3-002] A SAMA analysis to comply with 40 CFR 1502.16(h) shall be conducted of the administrative and procedural measures applicable to Fermi 3 and considered for implementation prior to fuel load if the associated cost does not exceed the maximum value associated with averting all risk of severe accidents. **[END: COM ER-7.3-002]**

Table 7.3-1 Valuation of the Detroit Edison ESBWR Base Case

	~~7% Discount Rate~~	~~3% Discount Rate~~
~~Offsite exposure cost~~	~~$4,789~~	~~$9,469~~
~~Offsite economic cost~~	~~$6,984~~	~~$13,809~~
~~Onsite exposure cost~~	~~33~~	~~$76~~
~~Onsite cleanup cost~~	~~$1,004~~	~~$2,384~~
~~Replacement power cost~~	~~$2,571~~	~~$7,219~~
~~Total~~	~~$15,381~~	~~$32,957~~

Insert 2 Here

Insert 2

Table 7.3-1 Valuation of the Detroit Edison ESBWR Base Case

	7% Discount Rate	3% Discount Rate
Offsite exposure cost	$6,289	$12,435
Offsite economic cost	$10,184	$20,137
Onsite exposure cost	$58	$133
Onsite cleanup cost	$1,761	$4,184
Replacement power cost	$4,512	$12,668
Total	$22,804	$49,557

Attachment 4
NRC3-10-0004

Response to RAI letter related to Fermi 3 ER

RAI Question AE2.4.2-6

NRC RAI AE2.4.2-6

Provide copies of references and other documentation containing information pertaining to the potential for the rayed bean (Villosa fabalis) to occur in the vicinity of the Fermi site.

Supporting Information

Additional information is needed to adequately address the potential for Fermi 3 construction and operations to affect the rayed bean, a mussel species that is a candidate for listing under the Endangered Species Act. The rayed bean was not considered a potential species of concern in the ER (Section 2.4.2.4).

It was indicated during discussions with Detroit Edison that there is information suggesting that the rayed bean is not present and unlikely to occur in Lake Erie in the vicinity of the Fermi 3 site. Sources for this information are derived from the results of surveys and research conducted by DTE Energy and others (e.g., Michigan Natural Features Inventory, the U.S. Army Corps of Engineers [USACE], and U.S. Geological Survey [USGS]), including:

- *Ongoing native mussel surveys conducted near Detroit Edison's Monroe Plant.*
- *Approximately 30 years of information on mussels in the western basin of Lake Erie have been collected and evaluated by the USGS (including samples collected near the Fermi site). Reportedly, no rayed bean specimens have been identified in those data.*
- *Results of sampling by DTE Energy researchers at the Monroe Plant from 1983 to 1993 that are documented in a 1993 paper. Reportedly, no rayed bean mussels were observed.*
- *Surveys for mussels by the USACE approximately 2 miles south of the Fermi site reportedly found no live or dead rayed bean specimens.*
- *Observations during sediment sampling and buoy maintenance by Detroit Edison staff within the Fermi exclusion area indicate that the sediment is predominantly hardpan, which is not suitable habitat for the rayed bean.*
- *Rayed bean have reportedly not been observed in surveys conducted by the Michigan Natural Features Inventory at the mouth of Swan Creek in Lake Erie (near the northern boundary of the Fermi site) or in Swan Creek.*

Original source documents or a summary of these findings (provided to the NRC under oath and affirmation) are needed to serve as references for the analysis to be presented in the EIS.

Response

The rayed bean *(Villosa fabalis)* is not believed to reside in the area of Lake Erie potentially impacted by the construction of the Fermi 3 power plant. A memo from Matthew Shackelford (Detroit Edison) to Craig Tylenda (Detroit Edison) with subject, "Notes from 8-12-09 Conference Call Pertaining to Rayed Bean Mussel," dated January 15, 2010 provides the basis for this belief and is included in Enclosure 1. Matthew Shackelford is a Detroit Edison employee with an expertise in mussels and their habitat in and around Detroit Edison's power plants. This telephone conference call was also documented in an attached email from Stephen Lemont (USNRC) to Craig Tylenda (Detroit Edison) with subject, "Notes from 8-12-09 Conference Call Pertaining to Rayed Bean Mussel," dated August 13, 2009 (Enclosure 2).

The references cited in the memo contained in Enclosure 1 have been provided in subsequent enclosures to this response. The first paper referenced in the memo has not been published, however, a presentation was given at a conference in May, 2009. Enclosure 3 contains the presentation slides and Enclosure 4 contains the presentation abstract. In addition, the best available copies of the United States Army Corps of Engineers (USACE) references cited in the Enclosure 1 memo have been provided. Please note that page 11 of Enclosure 7 is missing. Pristine copies of these USACE documents were not readily available.

Proposed COLA Revision

None

Attachment 4
NRC3-10-0004

Enclosure 1

Memo from Matthew Shackelford to Craig Tylenda with subject, "Notes from 8-12-09 Conference Call Pertaining to Rayed Bean Mussel," dated January 15, 2009
(following 7 pages)

DTE Energy

January 15, 2010

To: Craig Tylenda
Principal Engineering Specialist
MEP Design and Project Engineering

From: Matthew Shackelford
Biologist
EM&R-Land and Water Management

Subject: Notes from 8-12-09 Conference Call Pertaining to Rayed Bean Mussel

Mr. Tylenda,

This memo is in response to the August 12th, 2009 conference call on concerns for the rayed bean mussel (*Vilosa fabalis*). As described in the conference call a set of references are included below to facilitate the steps we have taken to the conclusion that the presence of the *V. fabalis* should not be an issue if dredging in the area of the intake at Fermi. These conclusions are mainly based on historical surveys and the resulting list of live and dead species encountered during those surveys. As mentioned in the conference call all surveys reviewed did not result in the presence of *V. fabalis*.

DTE Energy, Land and Water Management group has been conducting native unionid surveys off of Monroe Power Plant for the past three years. These surveys have not resulted in the presence of *V. fabalis* (threatened and endangered species permit No. 1721 report attached).

Also to a lesser extent the information provided on sediment type by the DTE Energy dive team was used to make this determination. DTE Energy dive team operations regularly collects sediment samples as part of Fermi 2's REMP studies directly offshore of Fermi decant discharge. The sediment samples are taken by divers because PONAR dredge, traditionally used to collect sediment samples, cannot penetrate the clay "hard-pan" in the area. Records of such detail are contained within archived dive logs for each dive operation the DTE Energy dive team performs. Also ice scour, seiche activity, zebra mussel (*Dreiseina polymorpha*) and quagga mussel (*D. bugensis*) settlement will prohibit the colonization of native mussel species in the vicinity of the Fermi site.

Lastly a personal communication with Peter Badra, Interim Director of Aquatic Studies for Michigan Natural Features Inventory (MNFI), where survey activity by MNFI within the lower Swan Creek watershed was performed, and the presence of *V. fabalis* was not observed during these surveys.

Below is a list of references put forth during the conference call discussion fulfilling action items documented in the conference call meeting notes.

M. T. Shackelford, G. D. Longton, J. T. Bateman, J. C. Rachwal, J. A. Neruda, W. P. Kovalak and D. W. Schloesser, **Distribution and Abundance of Native Mussels (Bivalvia: Unionidae) in a Thermal Discharge in Western Lake Erie.** Incomplete/Unpublished

Schloesser,D. W., Smithee, R. D., Longton, G. D., and W.P. Kovalak. 1997. **Zebra mussel induced mortality of unionids in firm substrata of western basin of Lake Erie and a habitat of survival.** American Malacological Bulletin 14:67-74

Nalpa, T. F., Manny, B.A., Roth, J.C., Mozley, S.C. and D.W. Schloesser. 1991. **Long-term decline in freshwater mussels (Bivalvia: Unionidae) of the western basin of Lake Erie.** Journal of Great Lakes Research 17:214-219.

Clarke, A.H. 1980. **Survey of the area between Sandy Creek and the Raisin River, in Lake Erie, for univalve and bivalve mollusks.** Report to the U.S. Army Corps of Engineer District, Detroit. (Contract No. DACW35-81-R-0004) 29pp.

Clarke, A.H. 1981. **Intensive follow-up survey of the area between Sandy Creek and the Raisin River, in Lake Erie, for univalve and bivalve mollusks.** Report to U.S. Army Corps of Engineers District, Detroit. (Contract No. DACW35-81-M-588) 35pp.

Clarke, A.H. 1981. **Suppliment to Intensive follow-up survey of the area between Sandy Creek and the Raisin River, in Lake Erie, for univalve and bivalve mollusks.** Report to U.S. Army Corps of Engineers District, Detroit. (Contract No. DACW35-81-M-588)

Action Item 2 from conference call notes requests Information from Matthew Shackelford on credentials as a mollusk expert.

Credentials as a unionid expert possessed by Matthew Shackelford are a Bachelor of Science Degree from University of Michigan. Course of studies had an intense emphasis on aquatic ecology where mayflies (ephemeroptera) and unionids were a main focus.

W.P. Kovalak PhD was a mentor to Matthew Shackelford, both academically and professionally. Here research on the distribution and abundance of native unionids was a main focus. "The distribution and abundance of native unionids in the head waters of the Raisin River, Michigan" was the title of senior thesis work done as an undergraduate and presented to the Michigan Academy of Science in 1993. Professional literature has not been published, though the paper that will result from the Monroe Power Plant native unionid survey (referenced above) is being written and will be completed when the field survey work is complete. This study has resulted in a presentation at the International Association of Great Lakes Researchers Annual Conference this year in Toledo (abstract attached).

Action Item 3 from conference call notes requests contact information for A.H. Clarke
Contact information as provided by USACE reports from 1980-81:

A.H. Clarke, President
ECOSEARCH, Inc.
3106 North Taylor Street
Arlington Virginia 22207

Please contact me if you need further information or clarification.

Matthew T Shackelford
Staff Biologist-EM&R
DTE Energy Corporate Services LLC
Office: 313 897 1021
H-136 Warren Service Center
7940 Livernois, Detroit, MI 48210

Endangered Species Permit No. 1721

Report on Mussel Collecting during 2008

Black River

No quantitative mussel sampling in the Black River at Applegate Road (Sanilac Co.) was conducted during 2008.

Western Lake Erie

Collecting of native freshwater mussels (Unionidae) in western Lake Erie (Monroe Co.) in 2008 was a continuation of work started in 2007 to determine the status of native mussels in the vicinity of DTE Energy's Monroe Power Plant. Collections made in 2007 suggested live unionids occurred primarily in nearshore water influenced by the thermal discharge from the plant. In 2008 the primary objective was to map the distribution and abundance of unionids in nearshore waters adjacent to the mouth of the discharge canal.

Mussels were collected by scuba divers at 23 sites during August-October 2008 (Fig. 1 and Table 1). At each site handpicking was done in two steps. Initially, either one diver collected for 30 minutes or, more typically, two divers collected for 15 minutes each. If no live mussels were found, collecting was terminated. If at least one live mussel was found, collecting was continued for another 30 minutes (one diver) or 15 minutes (two divers). Hence total collecting time at each site was either 30 or 60 minutes as noted in Table 1. (All collections were made by DTE Energy divers: G. Longton, J. Neruda, J. Rachwal and M. Shackelford.) Live mussels were identified and smaller individuals aged by counting 'annuli'. Live mussels were carefully embedded in bottom sediment when returned to the lake. Valves of dead mussels were identified, counted and redistributed on the lake bottom.

Nine species (457 individuals) were collected alive (Table 2) including *Pleurobema sintoxia* (*=coccineum*) (round pigtoe), Michigan-listed special concern species. The dominant species was *Amblema plicata* (threeridge) that accounted for 81% of live mussels. Other species collected alive were *Quadrula pustulosa* (pimpleback), *Leptodea fragilis* (fragile papershell), *Quadrula quadrula* (mapleleaf), *Fusconaia flava* (Wabash pigtoe), *Potamilus alatus* (pink heelsplitter), *Truncilla truncata* (deertoe) and *Obliquaria reflexa* (threehorn wartyback).

Overall mussel abundance (all species combined) was highest near the mouth of the discharge canal, decreased rapidly to the north and east but diminished more slowly toward the south and west (Fig. 2). The resulting distributional boundary for live mussels coincided (more or less) with the 3 foot (low water datum) contour interval (≈ 4 feet at present lake level) (Fig. 2). Overall mussel distribution reflected the distribution of *A. plicata*, the most abundant and widely distributed species. Other species exhibited more restricted distributions but abundance was greater near the mouth of the discharge canal.

Fourteen species (226 valves) were represented among dead shells (Table 3) including five species not collected alive: *Obovaria subrotunda* (round hickorynut), Michigan-listed endangered species, *Elliptio dilatata* (spike), *Lampsilis cardium* (plain pocketbook), *Lampsilis siliquoidea* (fat mucket) and *Ligumia nasuta* (eastern pondmussel). The most common species were *P. alatus, E. dilatata, A. plicata, L. siliquoidea* and *L. fragilis* that together represented 72% of dead valves.

Table 1. Water depth (low water datum), GPS coordinates and total search time at 23 sites in western Lake Erie sampled for mussels in 2008.

	Water	GPS Coordinates						Total
Station	Depth	Latitude			Longitude			Diver
Number	(ft)	Deg	Min	Sec	Deg	Min	Sec	Minutes
1	1-2	41	52	45	83	20	24	30
2	1-2	41	52	39	83	20	16	60
3	1	41	52	30	83	21	00	60
4	1	41	52	30	83	20	30	60
5	1	41	52	15	83	22	30	60
6	2-3	41	52	15	83	22	00	60
7	1-2	41	52	15	83	21	00	60
8	1-2	41	52	15	83	20	15	30
9	1-2	41	52	00	83	23	00	60
10	1-2	41	52	00	83	22	00	60
11	1-2	41	52	00	83	21	30	60
12	1-2	41	52	00	83	21	00	60
13	1-2	41	52	00	83	20	15	30
14	3	41	51	53	83	22	16	60
15	3-4	41	51	45	83	23	00	30
16	5-6	41	51	46	83	22	31	60
17	2	41	51	45	83	22	00	30
18	1-2	41	51	45	83	21	30	60
19	3	41	51	45	83	21	00	30
20	2-3	41	51	45	83	20	30	30
21	2-3	41	51	30	83	21	00	30
22	1-2	41	51	30	83	21	30	60
23		41	52	37	83	21	08	60

Table 2. Number of live mussels collected at 23 sites in western Lake Erie near Monroe, MI during August-October, 2008.

	Collecting Site																							Total	
Species	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	No.	%
Amblema plicata			26	16	27	21	89		1	17	106	23		31			1	7				1	4	370	81
Fusconaia flava					1	1	4					1												7	2
Leptodea fragilis						3	8			2	3	1		2		4		1						24	5
Obliquaria reflexa					1						1													2	>1
Pleurobema sintoxia												1												1	>1
Potamilus alatus						1					2	2												5	1
Quadrula pustulosa			4	1		4	8			1	4	2						3					2	29	6
Quadrula quadrula			2				13																	15	3
Truncilla truncata					1						1	1		1										4	1
Total	0	0	32	17	30	30	122	0	1	20	117	31	0	34	0	4	1	11	0	0	0	1	6	457	

Table 3. Number of valves of dead mussels collected at 23 sites in western Lake Erie near Monroe, MI during August-October, 2008.

	Collecting Site																							Total	
Species	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	No.	%
Amblema plicata		2	4	4			6		1		1	4		2	2	1		2						29	13
Elliptio dilatata		3					25				8	3		1	4									44	19
Fusconaia flava		3	1						3		1	6		1	2	1								18	8
Lampsilis cardium		1	1				6				3	4			1			3						19	8
Lampsilis siliquoidea		5					1		3		2	5			5	1		1						23	10
Leptodea fragilis						6	4		2	5	1					4								22	10
Ligumia nasuta									5															5	2
Ligumia recta							1																	1	>1
Obliquaria reflexa									1															1	>1
Obovaria subrotunda							1				1	3												5	2
Pleurobema sintoxia							1					3												4	2
Potamilus alatus		4			2	4	3			25	1	2			1			1					2	45	20
Quadrula pustulosa			1						4													1		6	3
Quadrula quadrula			2		1							1												4	2
Total	0	18	9	4	3	10	48	0	19	30	18	31	0	4	15	7	0	7	0	0	0	1	2	226	

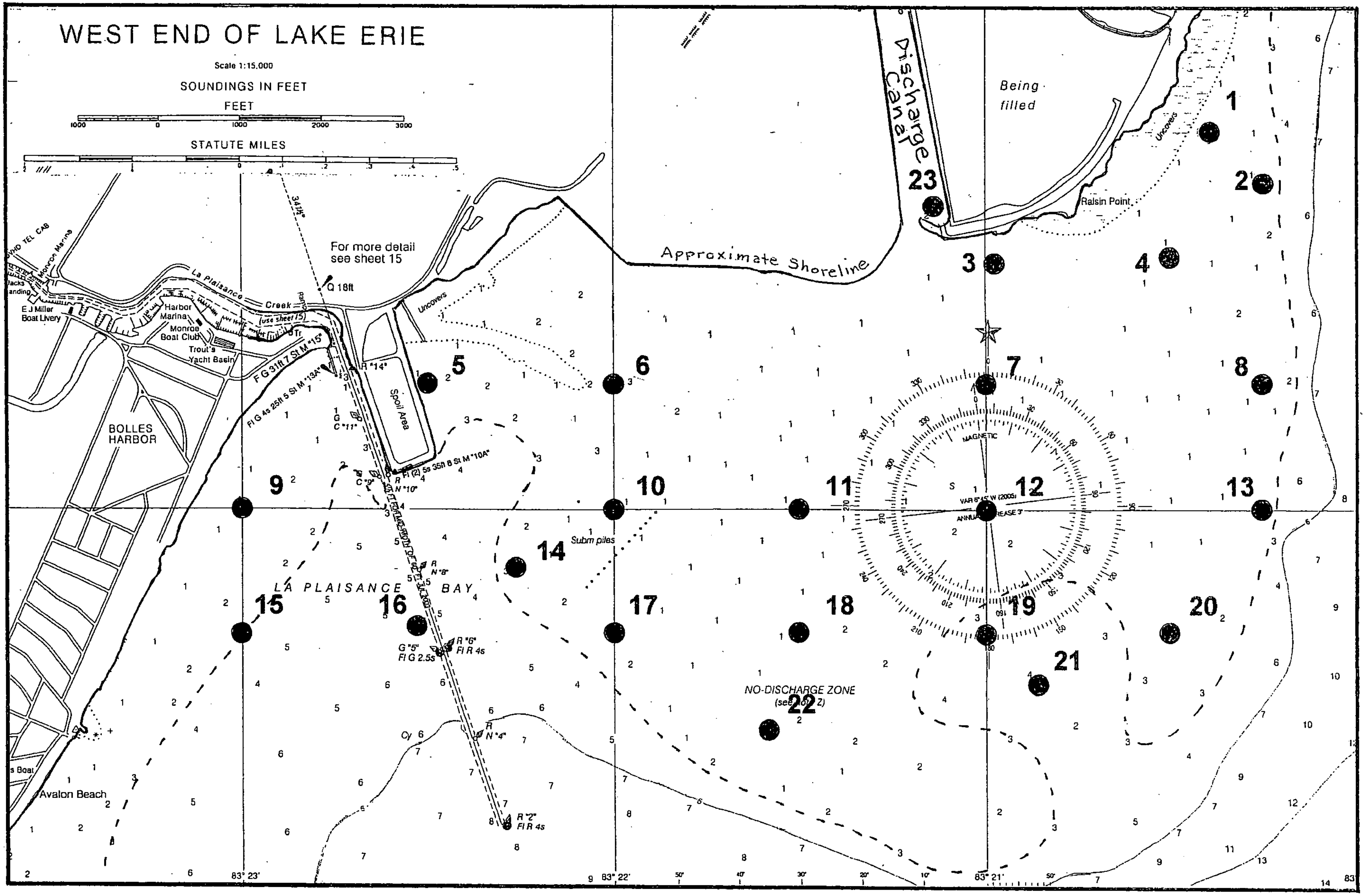


Figure 1. Map of western Lake Erie at the mouth of the discharge canal at DTE Energy's Monroe Power Plant showing the location of 23 sites where unionid mussels were sampled during 2008.

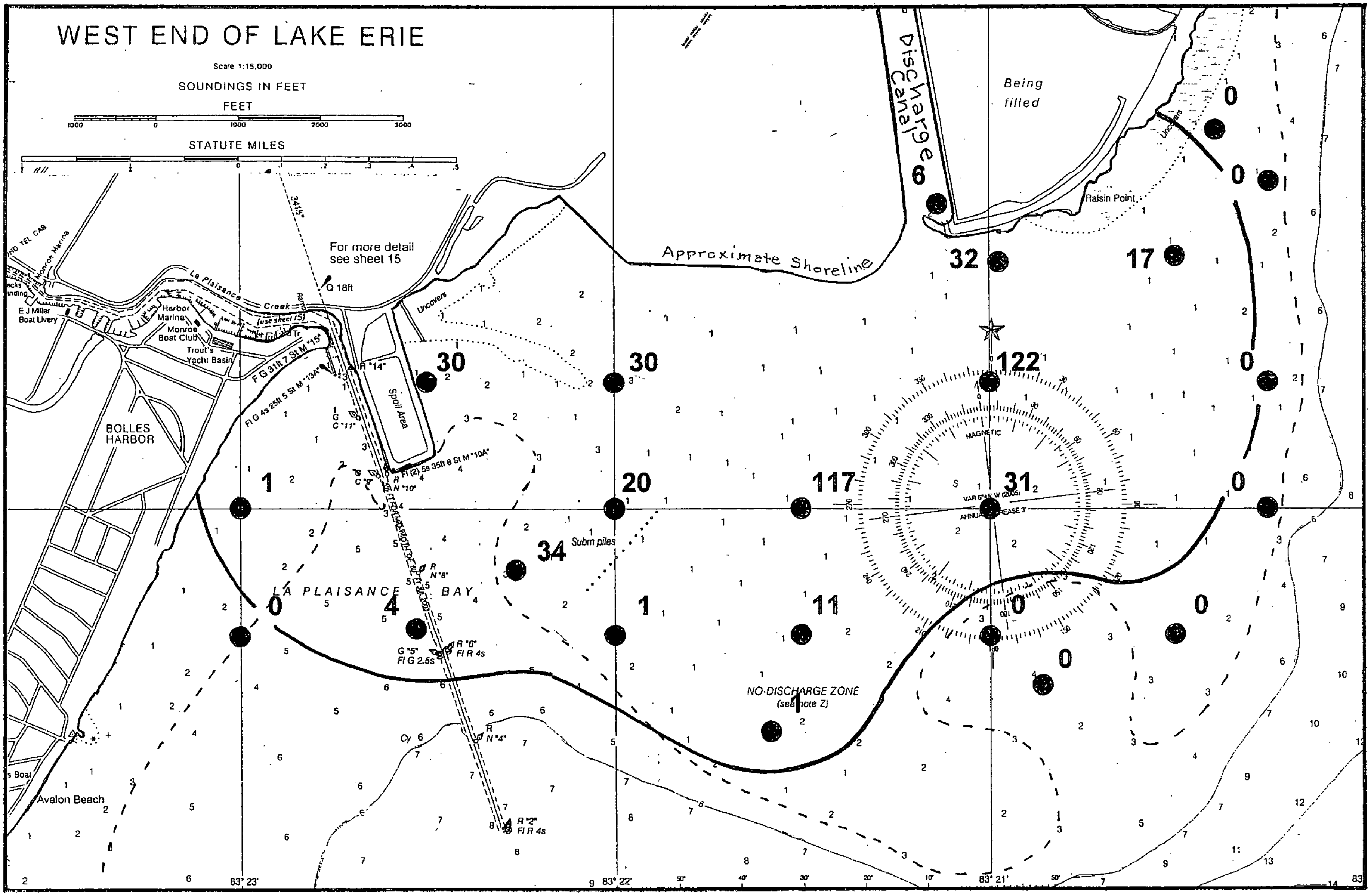


Figure 2. Map of western Lake Erie at the mouth of the discharge canal at DTE Energy's Monroe Power Plant showing mussel distribution (boundary marked by solid line) and abundance (all species combined) at 23 sites sampled during 2008. The 3 foot (low water datum) contour interval is marked by dashed line.

Attachment 4
NRC3-10-0004

Enclosure 2

NRC email titled "Notes from 8-12-09 Conference Call Pertaining to Rayed Bean Mussel"
(following 4 pages)

To: Craig D Tylenda <tylendac@dteenergy.com>
From: "Lemont, Stephen" <Stephen.Lemont@nrc.gov>
Date: 08/13/2009 11:52AM
cc: "shacklefordm@dteenergy.com" <shacklefordm@dteenergy.com>, Randall Westmoreland <westmorelandr@dteenergy.com>, "Masnik, Michael" <Michael.Masnik@nrc.gov>, "Hayse, John" <hayse@anl.gov>, "LaGory, Kirk E." <lagory@anl.gov>, FermiCOL Resource <FermiCOL.Resource@nrc.gov>
Subject: Notes from 8-12-09 Conference Call Pertaining to Rayed Bean Mussel

Craig,

This email summarizes the discussions during our conference call on August 12, 2009, to discuss the availability of information related to the potential for the rayed bean (*Villosa fabilis*), a mussel that is a candidate for listing under the Endangered Species Act (ESA), to occur at or near the Fermi site. This information would be used to assist with the NRC's preparation of a Biological Assessment (BA) for the site, as required under Section 7 of the ESA. Also provided below are the action items for Detroit Edison and NRC from the call. If you have any comments on, or suggested changes to these notes, please let me know.

CONFERENCE CALL PARTICIPANTS

NRC - Stephen Lemont, Michael Masnik

Detroit Edison - Matt Shackleford, Randy Westmoreland, Craig Tylenda

Argonne National Laboratory (Argonne) - John Hayse

ISSUES DISCUSSED

1. Mike Masnik and John Hayse stated that, as part of the NEPA process for Fermi 3, a BA will be prepared by NRC. While we are not required to conduct field investigations or sampling to prepare the BA, we do need to evaluate the potential for federally listed species and candidate species to occur on or near the site. In the case of the rayed bean, we need to know if Detroit Edison has any information that would allow us to address the potential occurrence of this species. Ideally, this would be information we could reference in the BA.

2. Matt Shackleford, Detroit Edison's expert on mollusks, provided the following information pertaining to the rayed bean's presence in the vicinity of the Fermi site:

a) Ongoing native mussel surveys conducted near Detroit Edison's Monroe Plant have shown that, even though there are healthy populations of native mussels associated with the thermal plume there (Western basin, south of the Fermi site), no rayed bean mussels have been collected.

b) In partnership with the USGS, about 30 years of information on mussels in the western basin of Lake Erie (including some samples collected near the Fermi site) have been evaluated. No rayed bean specimens have been identified in those data. Literature searches and sampling have been documented in a 1991 paper.

c) Results of sampling at the Monroe Plant from 1983 to 1993 are documented in a 1993 paper. No rayed bean mussels were observed.

d) Surveys for mussels by Clark (U.S. Army Corps of Engineers, USACE) approximately 2 miles south of the Fermi site found no live or dead rayed bean specimens.

e) Observations during sediment sampling and buoy maintenance by Detroit Edison within the Fermi exclusion area have shown that the sediment is predominantly hardpan, which is not suitable habitat for the rayed bean.

f) Peter Badra with the Michigan Natural Features Inventory has conducted surveys at the mouth of Swan Creek in Lake Erie (near the northern boundary of the Fermi site) and in Swan Creek, and has not observed any evidence of the rayed bean.

3. Matt Shackleford stated that he would send NRC copies of references and other documentation associated with the issues discussed in item 2 above.

Matt also stated that he could send NRC a letter or email summarizing information not provided in other documentation (including, but not necessarily limited to diver observations pertaining to sediments in the exclusion area), subject to the approval of Detroit Edison's management. Mike Masnik and Steve Lemont pointed out that a letter from Matt would be best, and that obtaining this letter need not require an additional RAI.

ACTION ITEMS

Detroit Edison

1. Provide copies of references and other documentation containing information pertaining to the potential occurrence of the rayed bean in the vicinity of the Fermi site.

2. Provide a letter from Matt Shackleford summarizing information not provided in other documentation (including, but not limited to diver observations pertaining to sediments in the exclusion area). NRC requests that this letter from Matt Shackleford include information on his credentials as a mollusk expert.

3. Please provide contact information for Clark of the USACE.

NRC/Argonne

1. Contact the USACE to obtain available information on surveys for mussels by Clark, approximately 2 miles south of the Fermi site.

2. Contact Peter Badra of the Michigan Natural Features Inventory to obtain available information on surveys he has conducted, as discussed in item 2f above.

Please contact me if you have any questions or need additional information.

Thanks,

Steve

Stephen Lemont, Ph.D.

Environmental Project Manager

United States Nuclear Regulatory Commission

Office of New Reactors

Mail Stop: T-7E30

Washington, DC 20555-0001

Telephone: 301-415-5163

Fax: 301-415-5397

Email: Stephen.Lemont@nrc.gov

Attachment 4
NRC3-10-0004

Enclosure 3

Distribution and Abundance of Native Mussels (Bivalvia: Unionidae) in a Thermal Discharge in Western Lake Erie

(following 15 pages)

DTE Energy®

Distribution and Abundance of Native Mussels (Bivalvia: Unionidae) in a Thermal Discharge in Western Lake Erie.

Matthew Shackelford
Associate Biologist
Land and Water Management Group
DTE Energy Corporate Services LLC

May 21, 2009

Introduction: Overview

DTE Energy

- Recent history of surveys in the area
  - Clark (depth contours)
  - USGS Schloesser (Unionid decline)
- Zebra Mussel Invasion
  - Change in ecosystem
  - Native mussel population decline
- 316(a)
  - Biological survey of thermal plume
  - Conduct status surveys
- Present study

A. H. Clark and the Army Corps

- Contracted to survey mollusks for Army Corps dredge spoil storage project
- Surveyed in late 1980 and early 1981
- Western shore of Lake Erie from Sandy Creek to River Raisin, off Sterling State Park, MI.
- Nearshore at 3, 6 and 9 foot (LWD) contours.
- Most unionid species found at 6 foot (LWD) depth contour
- 12 species of unionids in 1980, 18 species of unionids in 1981

Zebra Mussel Invasion and Settlement

- Introduced into Lake St. Clair

- 1989 became abundant in Western Lake Erie

- Changed ecosystems

- Devastate unionid populations

Schloesser et al surveys 1983, 1990, and 1993

- Survey before and after the zebra mussel (*Dreissena polymorpha)* invade Lake Erie
- Surveys in same study area as this current study
- Unionid mortality induced by zebra mussel
- 1983 to 1993, offshore (2m-4m) populations decreased from 85 individuals to 5
- Near shore population remained relatively high
- Unionids appear to persist nearshore despite 100% mortality offshore
- Why the nearshore?

DTE Energy

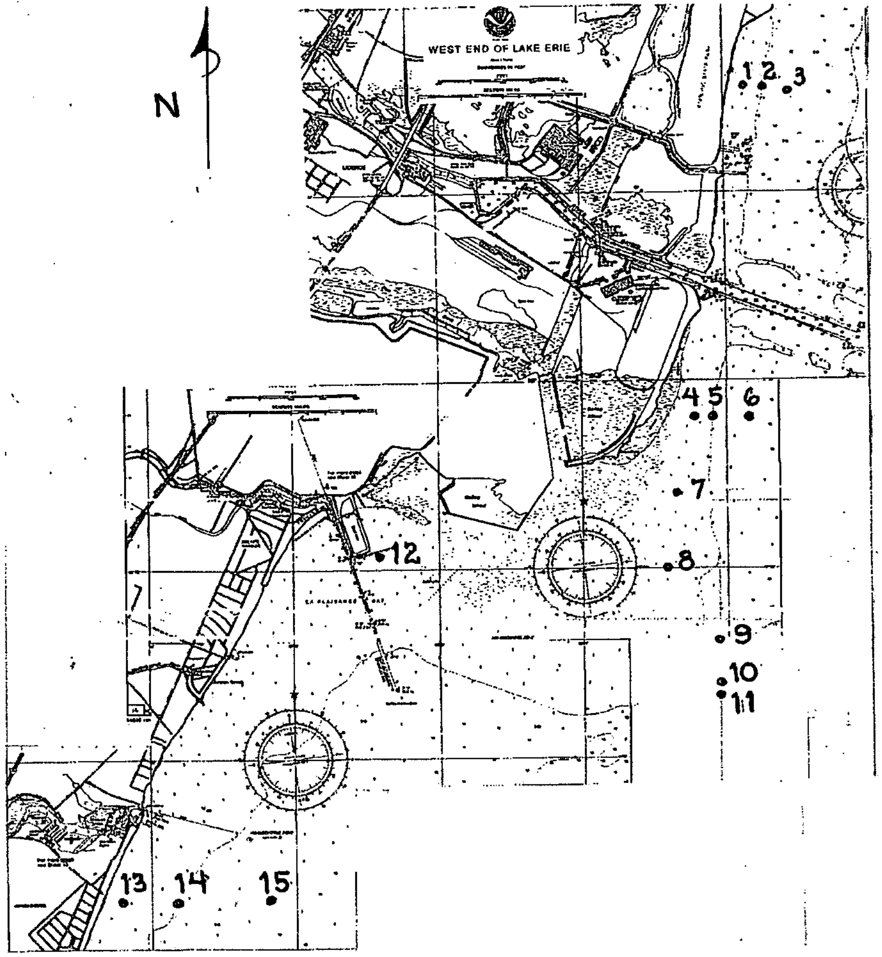
CWA section 316(a) Thermal Discharges

Methods: Mussels per Diver Hour

- Collected By SCUBA
- 15 minutes/Diver
- Live Mussels found then 30 Minutes/Diver
- Total 60 minutes per station
- Random hand search ~20M radius
- Mussels Identified
- Returned immediately, carefully embedded in sediment.

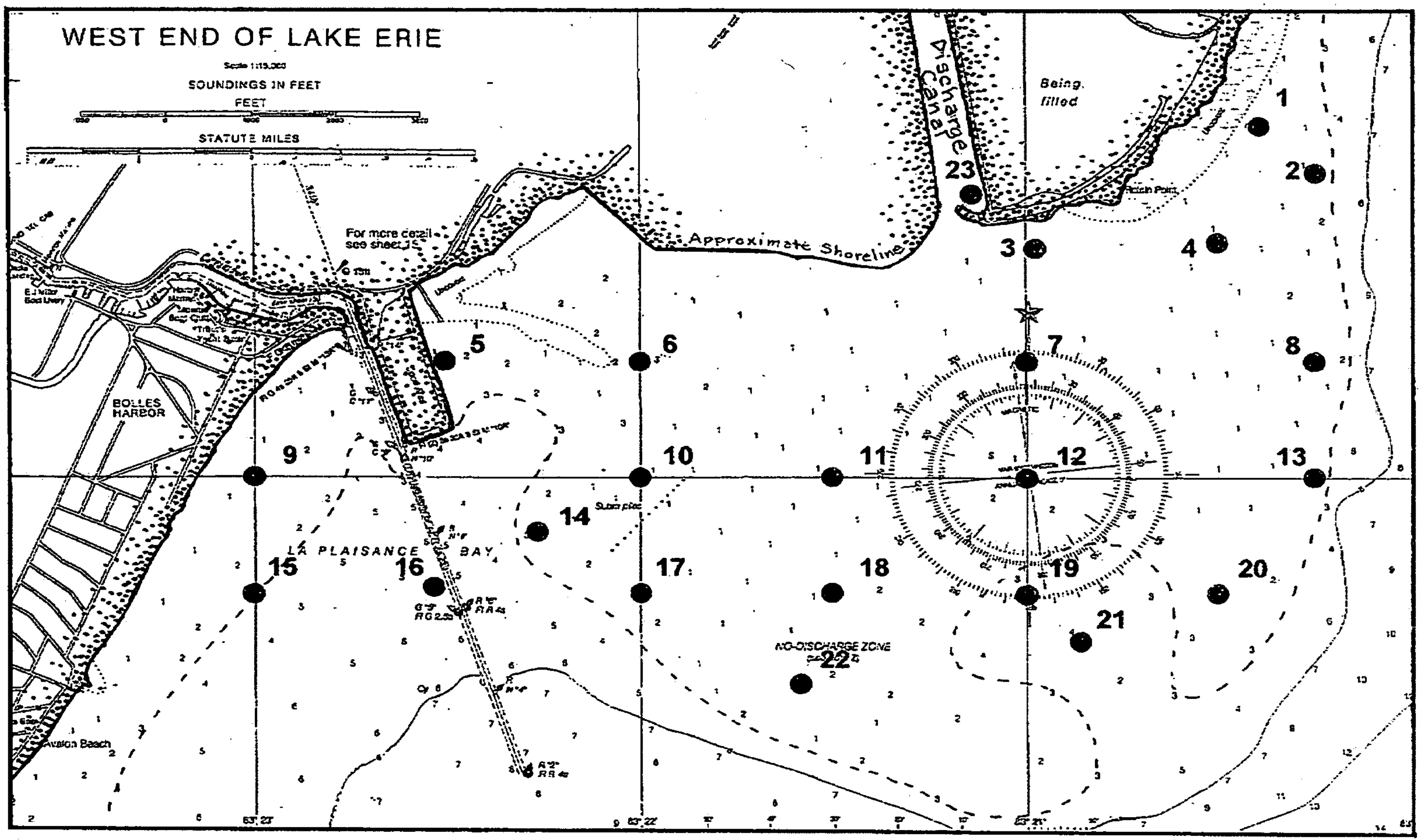
2007 Survey Locations

- Incorporated depth contour sampling
- Utilized same sites as Clark and Schloesser
- Control sites outside influence of thermal discharge
- Live unionids at stations: 6, 7, 8, and 12
- Live unionids sparked intensive 2008 survey



2008 Survey Locations

DTE Energy

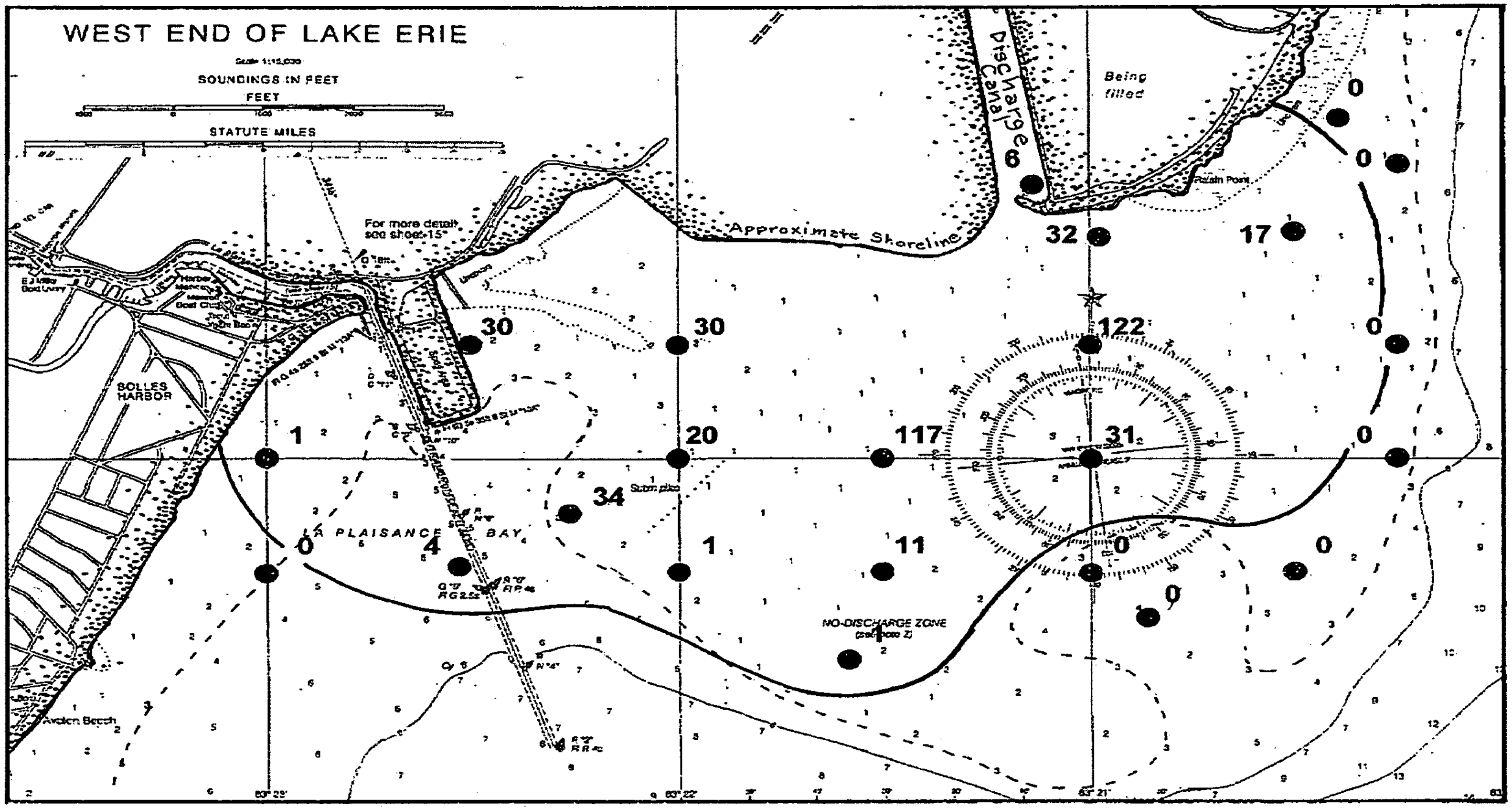


Live mussels found at 23 sites in 2008

DTE Energy

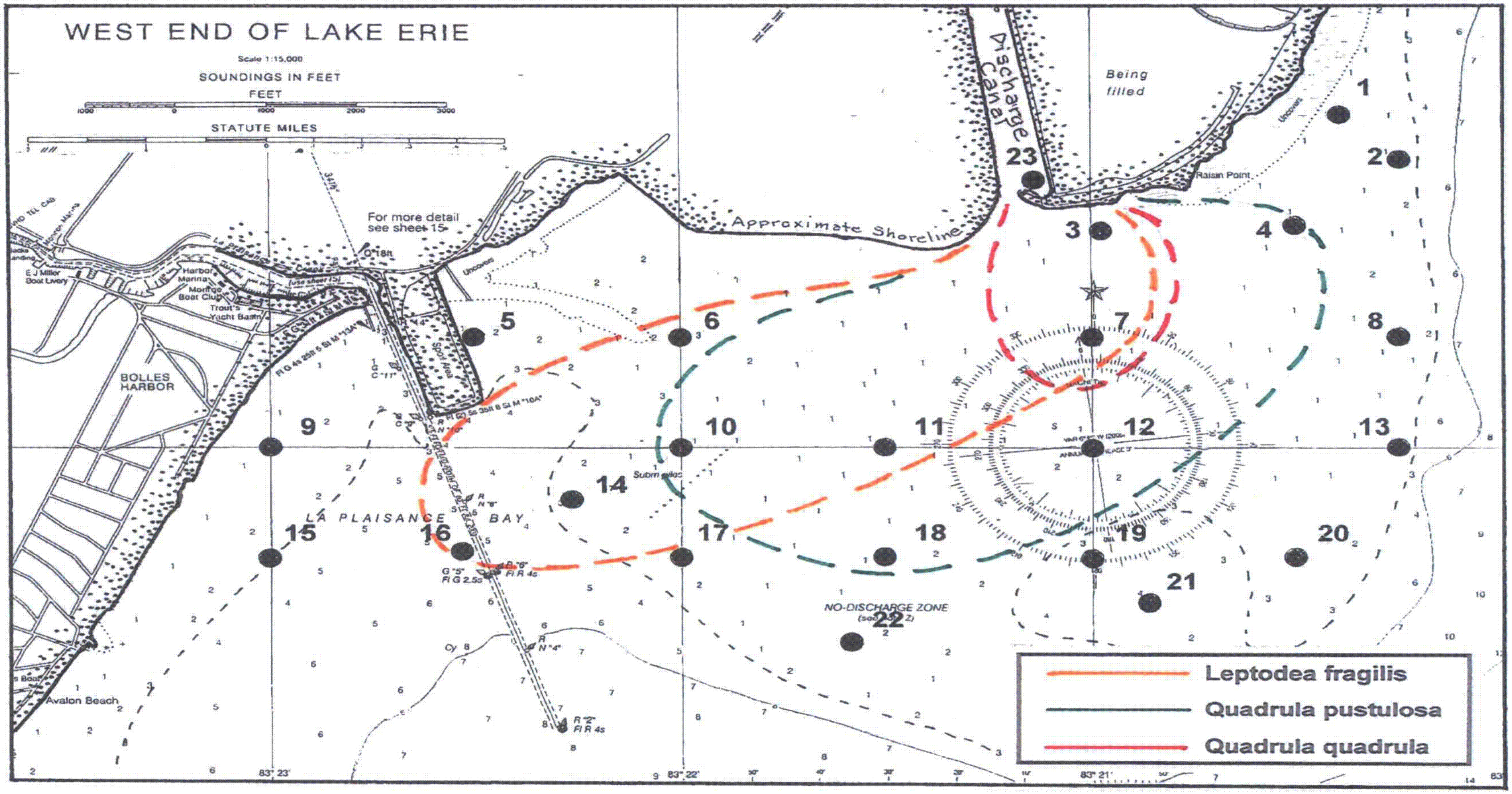
		Total	
Species	Common Name	No.	%
Amblema plicata	Three Ridge	370	81
Quadrula pustulosa	Warty-Back	29	6
Leptodea fragilis	Fragile Papershell	24	5
Quadrula quadrula	Maple-Leaf	15	3
Fusconaia flava	Pig-Toe	7	2
Potamilus alatus	Pink Heelsplitter	5	1
Truncilla truncata	Deer-Toe	4	1
Obliquaria reflexa	Three-horned Warty Back	2	>1
Pleurobema sintoxia	Round Pigtoe	1	>1
Total		457	100

Total abundance per station



Inferred distribution of most abundant species after *A. plicata*

DTE Energy



Conclusion:

- Distribution of population within main influence of thermal plume
- Unionids not found deeper than 3 foot contour, thermal plume is floating above cooler water
- Warm water protecting unionids from ZM settlement

2009 work to be accomplished

- Complete mapping distribution and abundance of unionids
- Begin quantitative sampling
- Zebra mussel mortality study

Questions?

DTE Energy

Attachment 4
NRC3-10-0004

Enclosure 4

Abstract from: Distribution and Abundance of Native Mussels (Bivalvia: Unionidae) in a Thermal Discharge in Western Lake Erie

(following 1 page)

Distribution and Abundance of Native Mussels (Bivalvia: Unionidae) in a Thermal Discharge in Western Lake Erie

[1]M.T. Shackelford, [1]G.D. Longton, [1]J.T. Bateman, [1]J.C. Rachwal, [1]J.A. Neruda,
[1]W.P. Kovalak and [2]D.W. Schloesser,

[1]DTE Energy Corporate Service LLC
Land and Water Management Group
7940 Livernois H-136
Detroit, MI 48210

[2]United States Geological Survey
Great Lakes Science Center
1451 Green Road
Ann Arbor, MI 48105

ABSTRACT

Because dreissenid mussels have extirpated native freshwater mussels (Bivalvia: Unionidae) from most of Lake Erie, the present status of unionids inhabiting the thermal discharge at DTE Energy's Monroe Power Plant in western Lake Erie was assessed. Scuba divers collected mussels by handpicking at 38 sites during August-October of 2007 and 2008. Nine species (491 individuals) were collected alive. For all species combined, mean catch/diver-hour was 32 (range 1-122). Estimated mean density was 11/m2 (range 0.3-42/m2). For all species, abundance was highest near the mouth of the discharge canal, decreased rapidly to the north and east but diminished more slowly toward the south and west. The overall distributional boundary coincided with the 3 ft contour interval (lwd); an area of ≈1,100 acres that supports an estimated 2-4 million unionids. Greater abundance of unionids near the discharge canal suggests survival in this habitat is directly related to elevated temperature that dreissenids cannot tolerate. Protection from dreissenids decreases with distance from the canal and disappears at depths > 3 ft (lwd) because discharge water no longer contacts the bottom but is suspended over cooler lake water.

Attachment 4
NRC3-10-0004

Enclosure 5

Zebra mussel induced mortality of unionids in firm substrata of western basin of Lake Erie and a habitat of survival

(following 8 pages)

Zebra mussel induced mortality of unionids in firm substrata of western Lake Erie and a habitat for survival

Don W. Schloesser[1], R. D. Smithee[2], G. D. Longton[2], and W. P. Kovalak[2]

[1]U.]S. Geological Service, Biological Resources Division, Great Lakes Science Center, 1451 Green Road, Ann Arbor, Michigan 48105 U. S. A.
[2]Environmental Assessment, Detroit Edison Company, 6100 W. Warren, Detroit, Michigan 48226 U. S. A.

Abstract: The present study was conducted to determine impacts of zebra mussel [*Dreissena polymorpha* (Pallas, 1771); Dreissenidae] infestation on unionids in firm substrata in western Lake Erie. Unionid mollusks were collected at a total of 15 stations on three offshore depth contours (2, 3, and 4 m) in 1983 (before zebra mussel infestation), in 1990 and 1993 (after zebra mussel infestation), and at one station on a nearshore 2-m depth contour and along one transect on a nearshore 1-m depth contour in 1993. Numbers of living unionids on substrata along offshore contours remained similar between 1983 and 1990 and then decreased from 97 individuals in 1990 to only five individuals in 1993. In addition, the number of species decreased from nine to four between 1990 and 1993. In contrast, on nearshore contours 85 living individuals representing nine species were found in 1993. About 48% of the living and 79% of the dead unionids at the two nearshore locations were covered with byssal threads of dreissenid mussels, but were not actively infested by mussels. The presence of living unionids on nearshore contours of western Lake Erie in 1993 indicates that survival of unionids in the presence of abundant zebra mussel populations can be possible in firm substrata and that these habitats can provide natural "refugia" for unionid populations. At present, we do not know what allows unionids to survive in the presence of zebra mussel colonization, but believe that water-level fluctuations and waves could contribute to the removal of mussels from unionids. This information could be of major concern in the mitigation of impacts of infestation on unionids in waters throughout North America.

Key words: *Dreissena*, Unionidae, refugia, Great Lakes, unionid mortality

Zebra mussels [*Dreissena polymorpha* (Pallas, 1771); Dreissenidae] have been shown to be ectoparasites causing reduced fitness, shell deformities, and mortality of unionids (Bivalvia: Unionidae) in waters of Europe and North America (Ricciardi *et al.*, 1995; Schloesser *et al.*, 1996). In the Laurentian Great Lakes, infestation of unionids by zebra mussels was one of the first and most visible ecological impacts of the early invasion of mussels into North America (Hebert *et al.*, 1989, 1991; Mackie, 1991; Schloesser and Kovalak, 1991; Hunter and Bailey, 1992; Haag *et al.*, 1993; Nalepa and Schloesser, 1993). Unionid mortality increased as a result of infestation and unionid populations were nearly eliminated in some areas (Gillis and Mackie, 1994; Schloesser and Nalepa, 1994; Nalepa *et al.*, 1996). In addition, zebra mussels have invaded and are believed to be causing unionid mortality in major rivers of North America, such as the Detroit, St. Lawrence, Mississippi, Ohio, and Tennessee Rivers (Tucker, 1994; Ricciardi *et al.*, 1996; Strayer and Smith, 1996; reviewed by Schloesser *et al.*, 1996).

In western Lake Erie, increased mortality of unionids attributed to zebra mussel infestation has only been documented in soft-mud substrata of open waters (> 6 m deep) (Schloesser and Nalepa, 1994). Soft substrata are believed to suffocate unionids that cannot maintain themselves at the substrate-water interface due to the added weight of infesting zebra mussels (Schloesser and Nalepa, 1994). However, unionid mortality caused by infestation has occurred in some firm-substratum habitats (*e. g.* sand and gravel) where suffocation caused by sediments is unlikely (Nalepa, 1994; Tucker, 1994; Schloesser *et al.*, 1996), but observations indicate that unionids do survive in the presence of zebra mussels on some firm substrata (DWS: unpub. data; D. Blodgett, Illinois Natural History Survey, Havana, Illinois, pers. comm.).

The present study was performed to determine changes in the unionid population in firm compacted sand substrata along the perimeter of western Lake Erie in 1983, before zebra mussels were present, and 1991 and 1993, after mussels were present. We hypothesized that if smothering in soft substrata is the only mechanism causing unionid mortality in western Lake Erie, then unionids should survive infestation in firm substrata along the perimeter of western Lake Erie.

American Malacological Bulletin, Vol. 14(1) (1997):67-74

METHODS

Unionid bivalve mollusks and infesting zebra mussels were collected at 15 stations located on three offshore depth contours (2, 3, and 4 m depths) along the perimeter of western Lake Erie between 23 August and 15 October 1983, 31 October and 11 November 1990, and 8 September and 27 October 1993 (Fig. 1). Unionids were also collected at one station on a nearshore 2-m depth contour, 9 September 1993 and in a transect area on a nearshore 1-m depth contour, 21 October 1993. The offshore 2-m and nearshore 2-m depth contours were separated by a deeper 3-m contour. Fluctuations of daily water levels were corrected based on the frame of reference of low water data at Father Point, Quebec (Great Lakes Basin Commission, 1975). In general, sampling depths were about 1 m deeper than low water datum, except for the period of time when the nearshore transect was sampled during a seiche. All living and dead unionids (represented by both valves) were collected and used in the present study. In addition, total counts of valves and shell pieces of unionids were determined in 1990 and 1993.

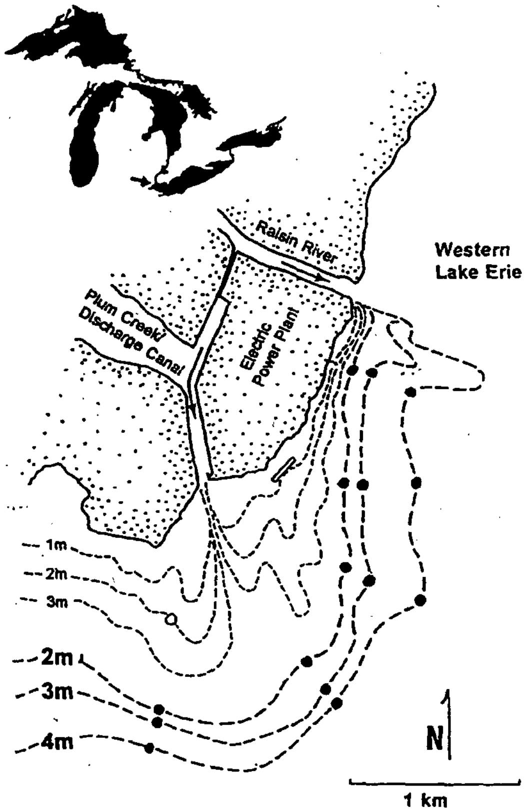


Fig. 1. Locations in western Lake Erie where unionid mollusks were sampled: at 15 stations (●) on three offshore depth contours (dark dashed lines; 2-, 3-, and 4-m) in 1983, 1990, and 1993, and at one station (○) on a nearshore 2-m depth contour (light-dashed line) and along one transect (☐) on the nearshore 1-m depth contour (light-dashed line) in 1993.

Unionids at stations on offshore contours and the nearshore 2-m depth contour were collected by SCUBA (Fig. 1). At each station, random searching was conducted for 30 min within a 50-m diameter circle. Unionids were removed from the water, individually separated, and taken to the laboratory.

Unionids in the transect area (7 m by 150 m) along the nearshore 1-m depth contour were collected by walking and manually removing exposed specimens (Fig. 1). This was possible because water in western Lake Erie was pushed away from shore by westerly winds causing a seiche, thereby dewatering substrata on the nearshore 1-m depth contour for a period of about 6 hr.

In the laboratory, up to ten randomly selected unionids and attached zebra mussels from one station on the offshore 4-m depth contour, the station on the nearshore 2-m depth contour, and the transect on the nearshore 1-m depth contour were analyzed. Living infested unionids were selected, except from the offshore, 4-m depth contour in 1993 when only dead unionids were present. Schloesser and Nalepa (1994) have shown that length-frequency distributions of zebra mussels from living and dead unionids in western Lake Erie are similar. Infesting zebra mussels were removed from individual host unionids and retained in a U. S. Standard Number 60 sieve (0.25-mm mesh). Length-frequency distributions of infesting zebra mussels were constructed from shell-length measurements in 1-m size classes. All mussels or a randomly selected sub-sample of 200-300 mussels (< 6-mm long per unionid) and all mussels > 7-mm long were measured in each sampling period. All mussels were identified and counted. All mussels were zebra mussels (*Dreissena polymorpha*); no quagga mussels (*Dreissena bugensis* Andrusov, 1897) were present in western Lake Erie (Mills *et al.*, 1993; MacIsaac, 1994). Length-frequency distributions of unmeasured mussels < 6-mm long were based on the proportions of measured sub-sampled mussels in each whole millimeter size group. This procedure has been shown to adequately determine length-frequency distributions of zebra mussels in western Lake Erie (Schloesser and Kovalak, 1991; Schloesser and Nalepa, 1994). Dry weights (in g at 105°C for 48 hr) of individual unionids and infesting mussels (a measure of infestation intensity; Schloesser and Kovalak, 1991) were determined.

Unionids were identified following Clarke (1981) and by comparison with bivalve taxonomic reference collections (Detroit Edison Company, Detroit, Michigan, and Great Lakes Science Center, Ann Arbor, Michigan). Taxonomic nomenclature follows Williams *et al.* (1993) with the exception that *Lampsilis radiata radiata* (Gmelin, 1791) was combined with *L. siliquoidea* because these two species are believed to interbreed in the Great Lakes

(Clarke, 1981). Mean numbers of living and dead unionids per station at 15 stations on the three offshore depth contours were tested by Student's t-test after $\log_{(10)} + 1$ transformation (Snedecor and Cockran, 1967).

RESULTS

UNIONIDS ON OFFSHORE CONTOURS

Numbers of living and dead unionids changed substantially on the three offshore depth contours in western Lake Erie between 1983 and 1993 (Table 1). In 1983, total mean number of living unionids per station was significantly greater (paired t-tests, $P \leq 0.05$) than dead unionids. In 1990 and 1993, total mean numbers of dead unionids were significantly higher than living unionids. Numbers of living unionids remained about the same between 1983 and 1990: 85 and 97 individuals, respectively. Then they decreased significantly from 97 in 1990 to only five in 1993. Numbers of dead unionids increased significantly from nine in 1983 to 360 in 1990, then decreased to 157 in 1993. In 1983, mean numbers of living individuals were significantly greater than numbers of dead individuals on the 2-m and 4-m depth contours; in 1990, there were significantly more numbers of dead than living individuals on the 3-m and 4-m depth contours. In 1993, the numbers of dead individuals was greater than the number of living on all contours. Between 1983 and 1990, the number of living unionids increased on the 2-m and 3-m depth contours and decreased on the 4-m depth contour. The greatest increase in the number of dead unionids occurred on the 4-m depth contour between 1983 and 1990.

Numbers of living unionid species decreased on offshore depth contours in western Lake Erie between 1983 and 1993 (Table 2). Twelve living species were found in 1983, nine species in 1990, and four species in 1993. Between 1983 and 1990, the number of species on the 2-m and 3-m depth contours increased from seven to nine, whereas the number on the 4-m depth contour decreased from 12 to six species. In 1993, only four species (*Amblema plicata plicata, Lampsilis siliquoidea, Potamilus alatus,* and *Quadrula quadrula*) represented by five individuals were found on the 2-m and 3-m depth contours.

Table 1. Numbers of living and dead unionids collected at 15 stations on three offshore depth contours in western Lake Erie, 1983, 1990, and 1993. (*; significant difference [$P \leq 0.05$] in mean number of unionids per station).

Depth (m)	1983			1990			1993		
	Living		Dead	Living		Dead	Living		Dead
2	19	*	1	31		26	2		20
3	12		3	27	*	59	3		41
4	54	*	5	39	*	[1]275	0	*	96
Total	85	*	9	97	*	360	5	*	157

[1] significant (P = 0.060).

UNIONIDS ON NEARSHORE CONTOURS

Relatively large numbers of living unionids occurred in sampled areas on the nearshore 2-m and 1-m depth contours (Table 3). A total of 85 living unionids represented by nine species occurred at nearshore locations. Only living unionids (55 individuals, represented by eight species) were collected at the nearshore 2-m depth station. Both living (30 individuals, represented by five species) and dead (29 individuals, represented by ten species) unionids were found in the transect area on the nearshore 1-m depth contour.

Only 15% (17 of 114 individuals) of the unionid shells collected on nearshore contours were infested with zebra mussels (Table 3). In addition, 70% (80 of 114) only showed evidence of past infestation (*i. e.* only byssal threads present on unionid shells). Evidence of infestation was absent on 15% (17) of individual shells (10% [11] of these were living and 5% [6] were dead unionids).

INFESTING ZEBRA MUSSELS

Mean dry weights of infesting zebra mussels were substantially higher on the offshore 4-m depth contour than on the nearshore 2-m depth contour; no infestation occurred on the 1-m nearshore depth contour (Table 4). On the offshore contour in 1990, mean infestation weights on living and dead unionids were 41.1 and 36.3 g/unionid, respectively; in 1993, infestation weights decreased to 32.9 and 27.6 g/unionid, respectively. In general, weights of infesting zebra mussels were about equal to host unionid weights on the offshore contour. In nearshore areas, weights of infesting zebra mussels ranged between 0.5 and 4.4 g/unionid, and mean infestation weights were substantially less than mean unionid weights.

Length-frequency distributions of zebra mussels removed from unionids collected on the offshore 4-m depth contour and the nearshore 2-m depth contour in Fall 1993 were substantially different (Fig. 2). Mussels on the offshore contour were larger (mean = 12 mm long) than those on the nearshore contour (mean = 6 mm long). Peak distribution of mussels on unionids from the offshore contour was between 12 and 16 mm, whereas the peak distribution of mussels on the nearshore contour was between 3 and 7 mm.

DISCUSSION

UNIONID MORTALITY ON OFFSHORE CONTOURS

The present study, that by Nalepa (1994) in Lake St. Clair immediately upstream of western Lake Erie, observations by Tucker (1994) in the Mississippi River, and data of

Table 2. Numbers of living unionids collected at 15 stations on three offshore depth contours in western Lake Erie, 1983, 1990, and 1993. (–, none collected).

Species	1983 Depth (m)			1990 Depth (m)			1993 Depth (m)		
	2	3	4	2	3	4	2	3	4
Amblema plicata plicata (Say, 1817)	1	1	2	12	3	12	–	2	–
Elliptio dilata (Rafinesque, 1820)	–	–	1	–	–	–	–	–	–
Fusconaia flava (Rafinesque, 1820)	2	1	16	1	2	8	–	–	–
Lampsilis ovata (Say, 1817)	–	–	2	–	1	–	–	–	–
L. siliquoidea (Barnes, 1823)	6	6	14	7	16	9	1	–	–
Leptodea fragilis (Rafinesque, 1820)	1	2	1	3	1	1	–	–	–
Ligumia recta (Lamarck, 1819)	–	–	1	–	–	–	–	–	–
Obliquaria reflexa (Rafinesque, 1820)	1	–	1	2	–	1	–	–	–
Potamilus alatus (Say, 1817)	–	–	2	–	–	–	1	–	–
Pyganodon grandis (Say, 1829)	–	–	6	–	1	–	–	–	–
Quadrula pustulosa pustulosa (Lea, 1831)	6	1	7	5	1	8	–	–	–
Q. quadrula (Rafinesque, 1820)	2	1	1	1	2	–	–	1	–
Total Species	7	6	12	7	8	6	2	2	0

Schloesser (unpub. data) indicate that high unionid mortality can occur on firm substrata where smothering by soft substrata is unlikely. In addition, recent data indicate that high unionid mortality could be occurring in areas where infestation does not exist, but zebra mussels are found on surrounding substrata (Ricciardi *et al.*, 1996; Strayer and Smith, 1996).

In the present study, zebra mussel infestation caused substantial unionid mortality (94%) in firm-sand substrata located on offshore contours of western Lake Erie between 1983 and 1993. Mortality occurred between 1990 and 1993 after five years (1989-1993) of zebra mussel colonization of nearshore waters; not between 1983 and 1990 (after one year of zebra mussel colonization) when densities of unionids actually increased. In the fall of 1989, zebra mussels became very abundant in western Lake Erie reaching densities in excess of 340,000/m^2 in open waters (> 6 m depth) and 700,000/m^2 in nearshore waters (2-3 m depth) and infestation intensities in excess of 10,000/unionid (Schloesser and Kovalak, 1991; Kovalak *et al.*, 1993;

Table 3. Numbers of living and dead unionid species with attached zebra mussels and with attached byssal threads of zebra mussels collected at one station on a nearshore 2-m depth contour, 8 September 1993, and in one transect area on a nearshore 1-m depth contour, 21 October 1993, in western Lake Erie.

	Station on Nearshore 2-m Depth Contour[1]			Transect on Nearshore 1-m Depth Contour[2]			
	Living Unionids			Living Unionids		Dead Unionids	
	Attached Zebra Mussels	Byssal Threads		Byssal Threads		Byssal Threads	
		Present	Absent	Present	Absent	Present	Absent
Amblema plicata plicata (Say, 1817)	13	12	2	13	3	8	–
Fusconaia flava (Rafinesque, 1820)	1	2	–	2	2	1	1
Lampsilis ovata (Say, 1817)	–	–	–	–	–	1	–
L. siliquoidea (Barnes, 1823)	–	1	–	1	–	2	2
Leptodea fragilis (Rafinesque, 1820)	–	1	–	–	–	2	–
Obliquaria reflexa (Rafinesque, 1820)	–	1	–	–	–	1	–
Pleurobema cordatum (Rafinesque, 1820)	–	1	1	–	–	–	–
Potamilus alatus (Say, 1817)	1	7	–	–	–	3	1
Pyganodon grandis (Say, 1829)	–	–	–	–	–	2	2
Quadrula pustulosa pustulosa (Lea, 1831)	2	7	1	3	1	2	–
Q. quadrula (Rafinesque, 1820)	–	3	–	4	1	1	–
Total Number	17	34	4	23	7	23	6
Total Species	4	8	3	5	4	10	4

[1] No dead unionids.

[2] No attached zebra mussels.

Leach, 1993; Schloesser and Nalepa, 1994). To date, mortality of unionids induced by abundant densities of zebra mussels has been documented in Europe in the mid-1930s, waters of the Great Lakes, the Hudson River and, possibly, the Mississippi River in the early-1990s (Sebestyen, 1938; Gillis and Mackie, 1994; Schloesser and Nalepa, 1994; Tucker, 1994; Nalepa *et al.*, 1996; reviewed by Schloesser *et al.*, 1996; Ricciardi *et al.*, 1996; Strayer and Smith, 1996; DWS, unpub. data).

Changes in the number of dead unionids in the study area are partly attributable to the movement of dead shells into and out of the study area. The large increase in the number of dead unionids (nine to 360) between 1983 and 1990 suggests that dead unionid shells were entering the sampled area from other areas of western Lake Erie prior to 1990. Schloesser and Nalepa (1994) have shown that at one station in open waters (> 6m deep) of western Lake Erie, mortality of infested unionids increased between Fall 1989 and Spring 1990, and by Fall 1990 was 100%. This period of time corresponds with the large increase in the number of dead unionids in the study area, especially on the offshore, 4-m depth contour in Fall 1990. In 1990, most shells appeared fresh-dead; some contained decaying tissues, many exhibited pearly nacre, and few were decalcified. In 1993, however, few shells appeared fresh-dead; no decaying tissues were found, few exhibited a pearly nacre, and most were decalcified and difficult to identify. Loss of pearly nacre is believed to occur within 6-12 mo after death (Schloesser and Nalepa, 1994; D. Neves, National Biological Service, Blacksburg, Virginia, pers. comm.). In addition, less than 5% of the valves (n = 252) collected in 1990 were described as pieces, whereas about 25% of the valves (n = 256) collected in 1993 were described as pieces. The decrease in the number of dead unionids between 1990 and 1993 is attributed to transport of shells out of the study area into shallow bays of the lake. Substrata in shallow water bays near the sampling area were largely covered with shells of dead unionids in 1993 and 1994 (DWS, GDL, RS, pers. obs.). Several of these areas (50 m by 1000 m transects) were described as "union-

Table 4. Mean (± S.E. per unionid) and range of dry weights (g) of infesting zebra mussels and, in parentheses, mean (± S.E.) and range of dry weights of unionids at stations on offshore and nearshore depth contours in western Lake Erie 1990 and 1993.

Location/Date	Living Unionids	Dead Unionids
Offshore 4-m depth contour		
1 November 1990[1]	n = 10[2]	n = 10
	41.1 ± 2.9	36.3 ± 4.9
	29.7 - 61.2	17.3 - 67.3
	(50.5 ± 9.2)	(46.1 ± 3.1)
	(21.8 - 119.9)	(29.0 - 62.1)
8 September 1993	n = 5[3]	n = 10
	32.9 ± 7.6	27.6 ± 2.8
	6.8 - 49.0	15.1 - 40.3
	(39.8 ± 18.0)	(73.3 ± 10.5)
	(32.8 - 118.1)	(27.5 - 123.0)
Nearshore 2-m depth contour		
9 September 1993	n = 10	n = 0
	4.4 ± 2.0	
	0.5 - 19.0	
	(106.9 ± 12.4)	
	(61.7 - 188.0)	
Nearshore 1-m depth contour		
21 October 1993	n = 30	n = 29
	0	0
	0	0
	(85.7 ± 8.0)	(79.8 ± 7.2)
	(28.4 - 158.5)	(24.4 - 164.6)

[1] Most southwestern station (Fig. 1, open circle) on offshore, 4-m depth contour.

[2] Number of unionids.

[3] Offshore 2-m and 3-m depth contour; no living unionids along the offshore 4-m depth contour.

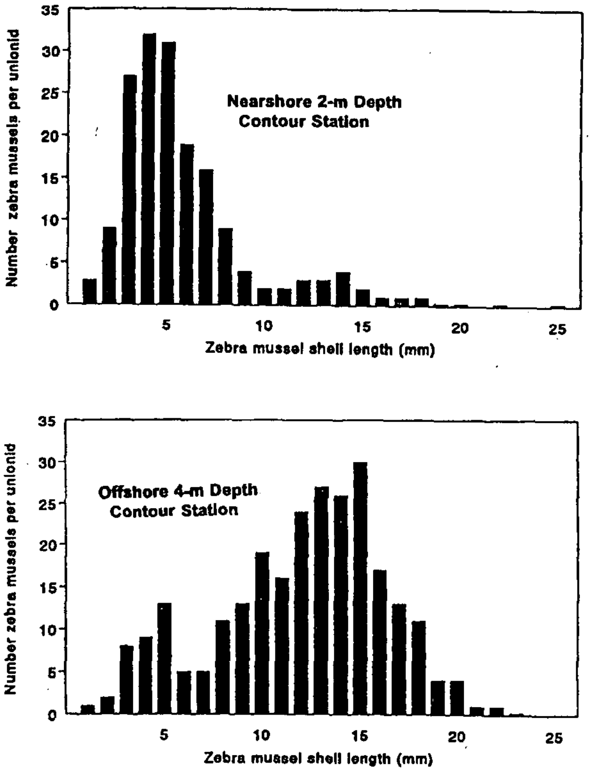


Fig. 2. Length-frequency distributions of zebra mussels infesting unionid mollusks collected on the nearshore 2-m depth contour and the most western station on the offshore 4-m depth contour in western Lake Erie, 8 September 1993.

id graveyards" with a paved-like bottom of unionid shells. Large accumulations of dead unionids has rarely been seen in the Great Lakes prior to colonization by zebra mussels (Neves, 1987; WPK, Michigan, pers. obs.).

Survival of a few unionids on offshore contours in western Lake Erie supports the data of Schloesser and Nalepa (1994) and Nalepa *et al.* (1996) that infestation on unionids by zebra mussels does not cause 100% mortality of all unionids, but does reduce the population to < 5% of pre-zebra mussel colonization. The survival of a few unionids along the offshore 2-m and 3-m depth contours (five living of 157 total unionids) in 1993 is similar to that (four living of 191 total unionids) found in open waters of western Lake Erie in 1991 (Schloesser and Nalepa, 1994). However, the long-term viability of unionid populations at low densities has been questioned, even in the absence of infestation (Lefevre and Curtis, 1910; Downing and Downing, 1992; Downing *et al.*, 1993). To date, artificial maintenance of infested unionids has shown that survival of individual unionids in waters of western Lake Erie is possible (Schloesser, 1996).

Mean weights of zebra mussels infesting unionids on offshore contours (27.6-41.1 g/unionid) were similar to weights of infesting mussels that have caused nearly 100% mortality of unionids in other studies in western Lake Erie (Schloesser and Kovalak, 1991; Schloesser and Nalepa, 1994; GDL and RS, pers. obs.). In 1989, immediately after zebra mussels increased exponentially in western Lake Erie, weights of infesting mussels were between 30.0 and 54.9 g/unionid in nearshore waters and between 9.0 and 75.3 g/unionid in open waters (Schloesser and Kovalak, 1991; Schloesser and Nalepa, 1994). In 1990, weights in open waters ranged from 2.3 to 40.8 g/unionid (Schloesser and Nalepa, 1994). These data indicate that weights of infestation that equal or exceed host unionid weights cause severe mortality of unionids in western Lake Erie (similarly noted as mean:mass ratios by Ricciardi *et al.*, 1996).

UNIONID SURVIVAL IN NEARSHORE WATERS

Relatively large numbers of living infested unionids and living unionids showing evidence of past infestation on nearshore-depth contours indicates that zebra mussel induced mortality of unionids could be minimal or does not exist in some areas along the perimeter of western Lake Erie. The high incidence of infestation (90%) of living unionids on nearshore contours indicates that infestation did occur and that mortality of unionids could have occurred. However, temporal variation in the number of mussels per unionid and densities of mussels colonizing adjacent bottom substrata were not assessed in the present study, and these factors are believed to influence zebra mussel induced mortality of unionids (Schloesser and Kovalak, 1991; Ricciardi *et al.*, 1995; Schloesser *et al.*, 1996).

At present, the reason unionids survive in the nearshore area of western Lake Erie is not known. Several studies have suggested that some species of unionids are more likely to survive zebra mussel infestation than other species (Haag *et al.*, 1993; Nalepa, 1994; Gillis and Mackie, 1994; Tucker, 1994). Possible explanations for these observations include; unionid sex (males less impacted), robustness of shells (unionid species with robust shells less impacted), and length of brooding time (unionid species with short brooding periods less impacted) (reviewed by Schloesser *et al.*, 1996). In the present study, robust species with short brooding times (*Amblema plicata plicata, Fusconaia flava, Quadrula pustulosa pustulosa, Q. quadrula*) accounted for about one-half (57%) the individuals on offshore contours in 1990. By 1993, nearly all unionid individuals were extirpated from offshore contours and of those individuals remaining, three of five were robust, short-term brooder species. However, robust species with short brooding times (four above and *Pleurobema cordatum*) accounted for 87% of living unionids on nearshore contours in 1993. These data support the belief that robust shelled, short-term brooders appear to survive longer than thin-shelled, long-term brooders. But, to date, a total of 31 species of unionids have been infested by zebra mussels in North America, and none appear to be immune to impacts (reviewed by Schloesser *et al.*, 1996).

Possible explanations for survival of unionids in shallow waters of western Lake Erie is that infesting zebra mussels could be removed from unionids and surrounding substrata by predators such as fish and ducks, or mussels could release from substrata in response to unfavorable habitat conditions (Stanczykowska, 1977; French and Bur, 1993; Mitchell and Carlson, 1993; Stanczykowska and Lewandowski, 1993; Hazlett, 1994).

Length-frequency distributions of zebra mussels infesting unionids and SCUBA observations from offshore and nearshore areas indicate that removal of mussels in the nearshore area by predators is not the likely cause for low infestation of unionids in the nearshore area. Length-frequency distributions indicate that mostly small, young mussels were present on unionids in the nearshore area, whereas mostly larger, older mussels were present in the offshore area. This indicates that mussels probably leave unionids between their first and second year of life because peak modes often correspond to year-classes of mussels (Morton, 1969; Stanczykowska, 1977; Schloesser and Kovalak, 1991) and typically, length-frequency distributions of zebra mussels in Fall in western Lake Erie are bimodal (Griffiths *et al.*, 1991; Schloesser and Kovalak, 1991; Schloesser and Nalepa, 1994). In addition, similar observation by SCUBA indicate that zebra mussels attached to substrata in the nearshore area were of low density and small size compared to mussels in the offshore area (GDL and RS, pers. obs.). Because mussels have been shown to have great adhesive strength and predators tend to remove smaller mussels rather than larger mussels (Ackerman *et al.*, 1993; Eckroat *et al.,* 1993; French and Bur, 1993; Hamilton *et al.*, 1994), we believe that mussels were not removed by predators in the nearshore area. Rather, zebra mussels voluntarily released from unionids, perhaps because of factors such as waves, water-level fluctuations, and ice scour in nearshore areas (< 2-m depth). In Lake Erie, mortality of unionids has occurred in another nearshore area (2-3 m depth) where no waves, exposure due to water-level fluctuations, or ice scour occur (Schloesser and Kovalak, 1991; Schloesser 1996; WPK, unpub. data). Movement *en masse* of zebra mussels has been observed and attributed to fall storms, wave action, and ice scour in Europe and western Lake Erie (Ehrenberg, 1957; Lewandowski, 1976; Griffiths *et al.*, 1991; Nalepa and Schloesser, 1993). In the Illinois River, Tucker and Atwood (1995) suggested that changing water levels (among other factors) could have contributed to substantial decreases in numbers of zebra mussels in an area.

Areas where unionids survive in the presence of zebra mussel colonization appear to be natural "refugia" where long-term survival of unionids could be possible. Although long-term studies have not been completed, several sites have been found where unionids continue to live in the presence of zebra mussel colonization and large year-to-year fluctuations in the density of mussels in surrounding areas (Tucker and Atwood, 1995; Schloesser *et al.*, 1996; DWS, unpub. data; D. Blodgett, Illinois Natural History Survey, Havana, Illinois, and D. Miller, U. S. Army Corps of Engineers, Vicksburg, Mississippi, pers. comm.). Observations such as these lead Clarke, (1992), Masteller *et al.*, (1993), Tucker and Atwood (1995), and Schloesser (1996 and unpub. data) to identify possible refugia and/or suggest the need for the establishment of managed refugia to save unionid populations. These refugia would only be needed in a few areas where unique unionid species and populations are found because many waters in North America are unlikely to be heavily colonized by zebra mussels (Strayer, 1991). Indeed, dreissenid mussels in rivers appear to be a threat to unionids immediately below impoundments and lakes that provide mussel veligers contributing to infestation (Schloesser *et al.*, unpub. data; DWS and D. Hunter, Oakland University, Rochester, Michigan, unpub. data).

CONCLUSIONS

Results of the present study, conducted in firm-substratum areas along the perimeter of western Lake Erie, were similar to those of Schloesser and Nalepa (1994) who studied soft-substratum areas in open waters of western Lake Erie and found infestation of unionids by zebra mussels can equal 100% unionid mortality at individual sites, but not 100% mortality of unionids throughout the study area. However, the presence of living unionids in two nearshore areas in the present study indicate that natural "refugia" could exist in beach/littoral areas of western Lake Erie.

ACKNOWLEDGMENTS

This is Contribution Number 985 of the Great Lakes Science Center, U. S. Geological Survey, Biological Resources Division, Ann Arbor, Michigan.

LITERATURE CITED

Ackerman, J. D., C. R. Ethier, D. G. Allen, and J. K. Spelt. 1993. The biomechanics of adhesion in zebra mussels (*Dreissena polymorpha*): tests with a rotating disk. *In: Zebra Mussels: Biology, Impacts, and Control.* T. F. Nalepa and D. W. Schloesser, eds. pp. 265-281. Lewis/CRC Press, Boca Raton, Florida.

Clarke, A. H. 1981. *The Freshwater Molluscs of Canada.* National Museum of Natural Sciences, Ottawa, Canada. 446 pp.

Clarke, A. H. 1992. Ontario's Sydenham River, an important refugium for native freshwater mussels against competition from the zebra mussel, *Dreissena polymorpha. Malacology Data Net* 3(1-4):43-55.

Downing, J. A. and W. L. Downing. 1992. Spatial aggregation, precision and power in surveys of freshwater mussel populations. *Canadian Journal of Fisheries and Aquatic Sciences* 49:985-991.

Downing, J. A., Y. Rochon, and M. Perusse. 1993. Spatial aggregation, body size, and reproductive success in the freshwater mussel *Elliptio complanata. Journal of the North American Benthological Society* 12(2):148-156.

Eckroat, L. R., E. C. Masteller, J. C. Shaffer, and L. M. Steele. 1993. The byssus of the zebra mussel (*Dreissena polymorpha*): morphology, byssal thread formation, and detachment. *In: Zebra Mussels: Biology, Impacts, and Control.* T. F. Nalepa and D. W. Schloesser, eds. pp. 239-263. Lewis/CRC Press, Boca Raton, Florida.

Ehrenberg, H. 1957. Die Steinfauna der Brandungsufer ostholsteinrischer Seen. *Archives de Hydrobiologia* 53:87-159.

French, J. R. P. and M. T. Bur. 1993. Predation by the zebra mussel (*Dreissena polymorpha*) by freshwater drum in western Lake Erie. *In: Zebra Mussels: Biology, Impacts, and Control.* T. F. Nalepa and D.W. Schloesser, eds. pp. 453-463. Lewis/CRC Press, Boca Raton, Florida.

Gillis, P. L. and G. L. Mackie. 1994. Impact of the zebra mussel, *Dreissena polymorpha*, on populations of Unionidae (Bivalvia) in Lake St. Clair. *Canadian Journal of Zoology* 72:1260-1271.

Great Lakes Basin Commission. 1975. *Great Lakes Basin Framework Study: Appendix 11. Levels and Flows.* Great Lakes Basin Commission, Ann Arbor, Michigan. 206 pp.

Griffiths, R. W., D. W. Schloesser, J. H. Leach, and W. P. Kovalak. 1991. Distribution and dispersal of the zebra mussel (*Dreissena polymorpha*) in the Great Lakes. *Canadian Journal of Fisheries and Aquatic Sciences* 48:1381-1388.

Haag, W. R., D. J. Berg, D. W. Garton, and J. L. Farris. 1993. Reduced survival and fitness in native bivalves in response to fouling by the introduced zebra mussel (*Dreissena polymorpha*) in western

Lake Erie. *Canadian Journal of Fisheries and Aquatic Science* 50:13-19.

Hamilton, D. J., C. D. Ankney, and R. C. Bailey. 1994. Predation of zebra mussels by diving ducks—an exclosure study. *Ecology* 75(2):521-531.

Hazlett, B. A. 1994. Crayfish feeding responses to zebra mussels depend on microorganisms and learning. *Journal of Chemical Ecology* 20(10):2623-2630.

Hebert, P. D. N., B. W. Muncaster, and G. L. Mackie. 1989. Ecological and genetic studies on *Dreissena polymorpha* (Pallas): a new mollusc in the Great Lakes. *Canadian Journal of Fisheries and Aquatic Science* 46:1587-1591.

Hebert, P. D. N., C. G. Wilson, M. H. Murdoch, and R. Lazar. 1991. Demography and ecological impacts of the invading mollusc *Dreissena polymorpha. Canadian Journal of Zoology* 69(2):405-409.

Hunter, R. D. and J. F. Bailey. 1992. *Dreissena polymorpha* (zebra mussel): colonization of soft substrata and some effects on unionid bivalves. *The Nautilus* 106(2):60-67.

Kovalak, W. P., G. D. Longton, and R. D. Smithee. 1993. Infestation of power plant water systems by the zebra mussel (*Dreissena polymorpha*). *In: Zebra Mussels: Biology, Impacts, and Control.*, T. F. Nalepa and D. W. Schloesser, eds. pp. 359-380. Lewis/CRC Press, Boca Raton, Florida.

Leach, J. H. 1993. Impacts of the zebra mussel (*Dreissena polymorpha*) on water quality and fish spawning reefs in western Lake Erie. *In: Zebra Mussels: Biology, Impacts, and Control,* T. F. Nalepa and D. W. Schloesser, eds. pp. 381-397. Lewis/CRC Press, Boca Raton, Florida.

Lefevre, G. and W. C. Curtis. 1910. Studies on the reproduction and artificial propagation of freshwater mussels. *Bulletin of the United States Bureau of Fisheries* 30:105-202.

Lewandowski, K. 1976. Unionidae as a substratum for *Dreissena polymorpha* Pall. *Polskie Archiwum Hydrobiologii* 23(3):409-420.

Mackie, G. L. 1991. Biology of the exotic zebra mussel, *Dreissena polymorpha,* in relation to native bivalves and its potential impact in Lake St. Clair. *Hydrobiologia* 219:251-268.

Masteller, E. C., K. R. Maleski, and D. W. Schloesser. 1993. Unionid bivalves (Mollusca: Bivalvia: Unionidae) of Presque Isle Bay, Erie, Pennsylvania. *Journal of Pennsylvania Academy of Science* 67(3):120-126.

MacIsaac, H. J. 1994. Comparative growth and survival of *Dreissena polymorpha* and *Dreissena bugensis,* exotic molluscs introduced to the Great Lakes. *Journal of Great Lakes Research* 20(4):783-790.

Mills, E. L., R. M. Dermott, E. F. Roseman, D. Dustin, E. Mellina, D. B. Conn, and A. P. Spidle. 1993. Colonization, ecology, and population structure of the quagga mussel (Bivalvia, Dreissenidae) in the lower Great Lakes. *Canadian Journal Fisheries and Aquatic Sciences* 50(11):2305-2314.

Mitchell, C. A. and J. Carlson. 1993. Lesser scaup forage on zebra mussels at Cook Nuclear Plant, Michigan. *Journal of Field Ornithology* 64(2):219-222.

Morton, B. S. 1969. Studies on the biology of *Dreissena polymorpha* Pall. III. Population dynamics. *Proceedings of the Malacological Society of London* 38:417-482.

Nalepa, T. F. 1994. Decline of native bivalves (Unionidae: Bivalvia) in Lake St. Clair after infestation by the zebra mussel, *Dreissena polymorpha. Canadian Journal Fisheries and Aquatic Science* 51:2227-2233.

Nalepa, T. F., D. J. Hartson, G. W. Gostenik, D. L. Fanslow, and G. A. Lang. 1996. Changes in the freshwater mussel community of Lake St. Clair: from Unionidae to *Dreissena polymorpha* in eight years. *Journal of Great Lakes Research* 22(2):354-369.

Nalepa, T. F. and D. W. Schloesser, eds. 1993. *Zebra Mussels: Biology, Impacts, and Control.* Lewis/CRC Press, Boca Raton, Florida. 810 pp.

Neves, R. J. 1987. Recent die-offs of freshwater mussels in the United States: an overview. *In: Proceedings of a Workshop on Die-Offs of Freshwater Mussels in the United States.* R. J. Neves, ed. pp. 7-18. U. S. Fish and Wildlife Service/Upper Mississippi River Conservation Committee, Arlington, Virginia.

Ricciardi, A., F. G. Whoriskey, and J. B. Rasmussen. 1995. Predicting the intensity and impact of *Dreissena* infestation on native bivalves from *Dreissena* field density. *Canadian Journal of Fisheries and Aquatic Science* 52(7):1449-1461.

Ricciardi, A., F. G. Whoriskey, and J. B. Rasmussen. 1996. Impact of the *Dreissena* invasion on native unionid bivalves in the upper St. Lawrence River. *Canadian Journal of Fisheries and Aquatic Sciences* 53:1434-1444.

Schloesser, D. W. 1996. Mitigation of unionid mortality caused by zebra mussel infestation: cleaning of unionids. *North American Journal of Fisheries Management* 16:942-946.

Schloesser, D. W. and W. P. Kovalak. 1991. Infestation of unionids by *Dreissena polymorpha* in a power plant canal in Lake Erie. *Journal of Shellfish Research* 10(2):355-359.

Schloesser, D. W. and T. F. Nalepa. 1994. Dramatic decline of unionid bivalves in off shore waters of western Lake Erie after infestation by the zebra mussel, *Dreissena polymorpha. Canadian Journal of Fisheries and Aquatic Science* 51:2234-2242.

Schloesser, D. W., T. F. Nalepa, and G. L. Mackie. 1996. Zebra mussel infestation of unionid bivalves (Unionidae) in North America. *American Zoologist* 36:300-310.

Sebestyen, O. 1938. Colonization of two new fauna-elements of Ponto-origin (*Dreissena polymorpha* Pall. and *Corophium curvispinum* G. O. Sars from a devium Wundsch) in Lake Balaton. *Internationale Vereinigung für Theoretische und Angewandte Limnologie Verhandlungen* 8:169-182.

Snedecor, G. W. and W. G. Cockran. 1967. *Statistical Methods.* Iowa State University Press, Ames, Iowa. 593 pp.

Stanczykowska, A. 1977. Ecology of *Dreissena polymorpha* (Pallas) (Bivalvia) in lakes. *Polskie Archiwum Hydrobiologii* 24:461-530.

Stanczykowska, A. and K. Lewandowski. 1993. Thirty years of studies of *Dreissena polymorpha* ecology in Mazurian Lakes of Northern Poland. *In: Zebra Mussels: Biology, Impacts, and Control.* T. F. Nalepa and D. W.Schloesser, eds. pp. 3-37. Lewis/CRC Press, Boca Raton, Florida.

Strayer, D. L. 1991. Projected distribution of the zebra mussel, *Dreissena polymorpha,* in North America. *Canadian Journal Fisheries and Aquatic Sciences* 48:1389-1395.

Strayer, D. A. and L. C. Smith. 1996. Relationships between zebra mussels (*Dreissena polymorpha*) and unionid clams during the early stages of the zebra mussel invasion of the Hudson River. *Freshwater Biology* 36:771-779.

Tucker, J. K. 1994. Colonization of unionid bivalves by the zebra mussel, *Dreissena polymorpha,* in pool 26 of the Mississippi River. *Journal of Freshwater Ecology* 9(2):129-134.

Tucker, J. K. and E. L. Atwood. 1995. Continuous backwater lakes as possible refugia for unionid mussels in areas of heavy zebra mussel (*Dreissena polymorpha*) colonization. *Journal of Freshwater Ecology* 10(1):43-47.

Williams, J. D., M. L. Warren, K. S. Cummings, J. L. Harris and R. J. Neves. 1993. Conservation status of freshwater mussels of the United States and Canada. *Fisheries* 18(9):6-22.

Date of manuscript acceptance: 06 June 1997

Attachment 4
NRC3-10-0004

Enclosure 6

Long-term decline in freshwater mussels (Bivalvia: Unionidae) of the western basin of Lake Erie

(following 6 pages)

J. Great Lakes Res. 17(2):214-219
Internat. Assoc. Great Lakes Res., 1991

LONG-TERM DECLINE IN FRESHWATER MUSSELS (BIVALVIA: UNIONIDAE) OF THE WESTERN BASIN OF LAKE ERIE

Thomas F. Nalepa[1], Bruce A. Manny[2], James C. Roth[3], Samuel C. Mozley[4], and Donald W. Schloesser[2]

ABSTRACT. Long-term trends in the abundance of unionids in the western basin of Lake Erie were examined from data collected at 17 stations in 1961, 1972, and 1982. The mean number of unionids at these stations declined over this time period, decreasing from 10 m^{-2} in 1961, to 6 m^{-2} in 1972, down to 4 m^{-2} in 1982. This decline in abundance was reflected in the decrease in the number of stations where mussels were found; unionids were found at 16 of the 17 stations in 1961, but at only 6 stations in 1982. Reasons for the decrease in the unionid population are not generally apparent, but are probably related to the decline in water quality and periods of low oxygen levels over the time period of the surveys.

INDEX WORDS: Mussels, mollusks, benthic fauna, Lake Erie, pollution effects.

INTRODUCTION

Through the years, the macroinvertebrate community of the western basin of Lake Erie has undergone some dramatic changes. The decline of *Hexagenia* populations in the 1950s and the subsequent increase in the number of oligochaetes, chironomids, and sphaeriids in the 1960s clearly demonstrated the negative impact of pollutant loadings into the basin (Britt 1955, Carr and Hiltunen 1965). Since the early 1970s, water quality conditions have generally improved as a result of phosphorus control measures (El-Shaarawi 1987), and, at least in certain areas of the basin, *Hexagenia* is becoming re-established (Thornley 1985) and oligochaete numbers have declined (D. W. Schloesser *et al.* unpublished manuscript).

Historically, the western basin of Lake Erie has been characterized as having one of the richest and most abundant unionid assemblages in North America (Goodrich and van der Schalie 1932). The basin's relatively shallow depth and high flushing rate ("river-lake habitat") provide conditions that are highly favorable to unionid populations. In addition, former stream connections in the postglacial period allowed a diverse assemblage of species from the Ohio-Mississippi basin to populate the area (van der Schalie 1941). Of the 39 species recorded in the Great Lakes, 36 are known to have inhabited Lake Erie, and most of these were once found in the western basin (Mackie *et al.* 1980).

While unionid populations in the western basin have apparently declined over the past few decades (Wood and Fink 1984), quantitative evidence of these declines are lacking. When Carr and Hiltunen (1965) documented changes of most benthic groups in the period between 1930 and 1961, quantitative changes in unionid populations were not included because the 1930 data set (Wright 1955) did not include abundance estimates for unionids. Wood and Fink (1984) compared unionid populations in 1973-74 to populations found in 1951-52; however, they used a drag-dredge which did not allow abundances to be reported with certainty.

This paper documents changes in the abundance and species composition of mussel populations in the western basin of Lake Erie over the 21-year period between 1961 and 1982. The data were obtained from surveys conducted in 1961 (Carr and Hiltunen 1965), 1972 (J. C. Roth and S. C. Mozley unpublished data), and 1982 (B. A. Manny *et al.* unpublished manuscript).

---

[1] Great Lakes Environmental Research Laboratory, 2205 Commonwealth Blvd., Ann Arbor, Michigan 48105
[2] National Fisheries Research Center—Great Lakes, 1451 Green Rd., Ann Arbor, Michigan 48105
[3] Sanitary Engineering and Environmental Health Laboratory, University of California—Berkeley, 1301 S. 46th St., Richmond, California 94804
[4] Department of Zoology, North Carolina State University, Raleigh, North Carolina 27695

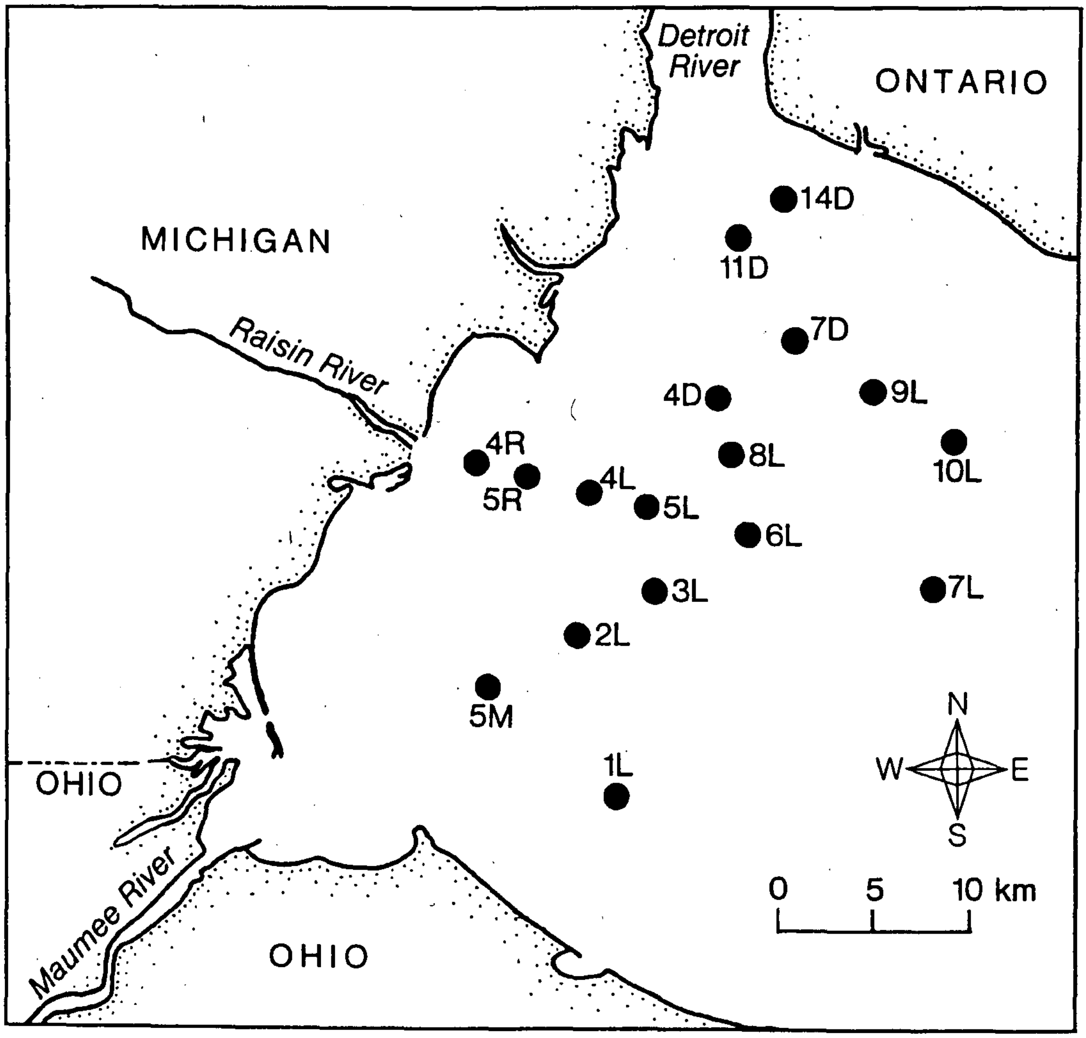


FIG. 1. Location of sampling stations in western Lake Erie.

METHODS

Locations of the 17 stations sampled in each of the three surveys are given in Figure 1. Most of the stations were located in the open, offshore waters of the basin. An additional 23 stations, located over a broader area of the basin, were sampled in 1961 and 1982 only. Exact locations (longitude and latitude) of all stations are given in Carr and Hiltunen (1965). Sampling methods and procedures were basically similar in the three surveys (Table 1). Carr and Hiltunen (1965) used a Peterson grab, while both Roth and Mozley (unpublished data) and Manny *et al.* (unpublished manuscript) used a Ponar grab. Although the Peterson grab is less efficient than the Ponar in collecting most benthic invertebrate forms (Flannagan 1970), efficiencies of the two grabs are likely to be similar when collecting unionids. The greater "shock-wave" of the Peterson, which blows away small organisms at the sediment surface just before impact, should not have any effect on these large, heavy-shelled forms. The effect is minimal even for the shelled but much smaller Sphaeriidae (Flannagan 1970, Nalepa *et al.* 1988). While grab samplers generally underestimate unionid abundances (Haukioja and Hakala 1974, Isom and Gooch 1986, Nalepa and Gauvin 1988), any bias in abun-

TABLE 1. Summary of sampling methods of the three surveys that have given density estimates of Unionidae in the western basin of Lake Erie.

	Survey		
	Carr and Hiltunen (1965)	Roth and Mozley (unpublished)	Manny *et al.* (unpublished)
Year sampled	1961	1972	1982
Replicates/Station	3	5	3
Grab sampler	Peterson	Ponar	Ponar
Sieve size	0.6 mm	1.3 mm	0.6 mm

dance estimates should be reflected similarly in the three surveys. The coarser mesh screen used by Roth and Mozley to sieve sediments was fine enough to retain all mussels older than 1 year.

The 1961 survey data, as published by Carr and Hiltunen (1965), contained some errors in the reported abundance and species composition of unionids Jarl K. Hiltunen, personal communication, 1990); the 1961 data given in this paper contain the necessary corrections.

RESULTS AND DISCUSSION

A general decline in the abundance and distribution of unionids in the western basin of Lake Erie between 1961 and 1982 was apparent (Table 2). Mean abundances at the 17 stations in 1961, 1972, and 1982 were 10 m^{-2}, 6 m^{-2}, and 4 m^{-2}, respectively. This decline in mean abundance is reflected in the dramatic decrease in the number of stations at which unionids were collected. In 1961, mussels were found at 16 of the 17 stations, but this number declined to 11 in 1972 and to only 6 by 1982. The number of species collected also declined over this period, with 7 species found in 1961, 6 in 1972, and 5 in 1982. Two of the species collected in 1982, *Lampsilis r. siliquoidea* and *Ligumia nasuta*, were the most common species in 1961 and 1972. To provide a broader perspective on the decline of species in the western basin, the species reported from surveys conducted in 1930 (Wright 1955), in 1951-52 (Wood 1963), and in 1973-74 (Wood and Fink 1984) are presented, along with the species reported in the surveys of 1961, 1972, and 1982 (Table 3). The species found in the 1961 and 1982 surveys include those species found at all 40 of the sampled stations. The same 40 stations were originally sampled in 1930 (Wright 1955) so, at least qualitatively, these three surveys may be considered directly comparable. The number of species did not change substantially between 1930 and 1961, with 12 species being found in the former year and 10 in the latter; however, only 5 species were found in 1982 (Table 3). A similar decline was reported by Wood and Fink (1984); a total of 14 species were found in the open lake in 1951-52 but only 4 species were found in 1973-74 (Table 3). Further, they reported that the proportion of recently dead shells (two valves attached and

TABLE 2. Abundances of Unionidae (numbers per square meter) in the western basin of Lake Erie at 17 stations that were sampled in each of the three surveys; 1961 (Carr and Hiltunen), 1972 (Roth and Mozley unpublished), and 1982 (Manny et al. *unpublished manuscript).*

	Year		
Station	1961	1972	1982
1L	13	0	7
2L	0	0	0
3L	30	8	0
4L	8	8	0
5L	4	12	7
6L	22	8	0
7L	8	4	14
8L	18	20	0
9L	4	8	0
10L	4	4	0
4D	8	0	14
7D	8	12	0
11D	4	0	0
14D	4	8	21
4R	8	0	0
5R	14	4	7
5M	9	0	0
Mean	9.8	5.6	4.1
SE	1.9	1.4	1.6
% of stations with unionids	94.1	64.7	35.3

TABLE 3. A list of unionid species collected and the percent each species comprised of the total number collected in various surveys in the western basin of Lake Erie; 1930 (Wright 1955), 1951-52 (Wood 1963), 1961 (Carr and Hiltunen 1965), 1972 (Roth and Mozley unpublished), 1973-74 (Wood and Fink 1984), and 1982 (Manny et al. *unpublished manuscript). Because a drag-dredge was used to collect unionids in the surveys of 1952-53 and 1973-74 and the area sampled was much larger than in the other surveys, the number of species collected in these two surveys is not directly comparable to the number collected in the other surveys. Also, only 17 stations were sampled in the 1972 survey while 40 stations were sampled in the 1930, 1961, and 1982 surveys.*

1930*	1951-52	1961
Lampsilis r. siliquoidea	*Lampsilis r. siliquoidea* (62.4)	*Lampsilis r. siliquoidea* (30.8)
Liqumia nasuta	*Liqumia nasuta* (7.8)	*Liqumia nasuta* (25.6)
Anodonta grandis	*Leptodea fraqilis* (6.9)	*Anodonta grandis* (20.5)
Lampsilis ventricosa	*Lampsilis ventricosa* (4.2)	*Lampsilis ventricosa* (5.1)
Elliptio dilatatus	*Elliptio dilatatus* (4.2)	*Leptodea laevissima* (5.1)
Fusconia flava	*Anodonta grandis* (3.3)	*Elliptio dilitata* (2.6)
Leptodea fragilis	*Fusconia flava* (3.0)	*Obliquaria reflexa* (2.6)
Proptera alata	*Proptera alata* (3.0)	*Leptodea fraqilis* (2.6)
Truncilla donaciformis	*Truncilla donaciformis* (2.4)	*Proptera alata* (2.6)
Truncilla truncilla	*Amblema costata* (1.5)	*Truncilla donaciformis* (2.6)
Obovaria leibii	*Obliquaria reflexa* (0.6)	
Strophitus rugosus	*Quadrula pustulosa* (0.3)	
	Pleurobema cordatum (0.3)	
	Obovaria subrotunda (0.3)	
1972	1973-74**	1982
Lampsilis r. siliquoidea (62.5)	*Lampsilis r. siliquoidea* (76.4)	*Lampsilis r. siliquoidea* (46.2)
Liqumia nasuta (8.3)	*Leptodea fraqilis* (16.8)	*Liqumia nasuta* (23.1)
Anodonta grandis (8.3)	*Liqumia nasuta* (3.40)	*Amblema plicata* (15.4)
Leptodea laevissina (8.3)	*Proptera alata* (3.4)	*Proptera alata* (7.6)
Lampsilis ventricosa (8.3)		*Anodonta grandis* (7.6)
Proptera alata (4.2)		

*Relative abundances of the various species were not given.

**Percentages were extrapolated from pie graphs.

intact) in the samples increased from 29% in 1951-52 to 79% in 1973-74.

Specific reasons for the decrease in unionid populations of the western basin are not immediately apparent, but are likely related to the general decline in water quality over the time period of these surveys (Burns 1985). Studies have shown that mussels are sensitive to low oxygen concentrations, with at least 6 ppm required for normal growth and between 2.5 and 5 ppm needed for continued survival (Fuller 1974). Between 1961 and 1982, oxygen concentrations in the western basin fell below these critical levels during periods of calm weather; concentrations of less than 3 ppm were recorded in the summers of 1963 (Carr *et al.* 1965.), 1966 (Britt *e al.* 1968), 1971 (Hartman 1972), and 1973 (Zapotsky and Herdendorf 1980). Shifts in the composition of the fish community can also have an impact on mussel populations, but populations of fish species that may serve as potential hosts for mussel glochidia, i.e., yellow perch, white bass, freshwater drum, channel catfish, etc. (Fuller 1974), have remained stable or increased in the western basin over the past few decades (Hartman 1972, Leach and Nepszy 1976).

Besides western Lake Erie, other areas which once had developed unionid populations, such as Green Bay and Saginaw Bay, now have an impoverished fauna (Mackie *et al.* 1980). However, an abundant and diverse mussel population still exists in Lake St. Clair (Nalepa and Gauvin 1988); this is probably because this lake is continuously flushed with high quality water from Lake Huron and oxygen concentrations remain close to saturation (Herdendorf *et al.* 1986). Although conditions in the western basin have generally improved since the 1960s, as evidenced by a recovering *Hexagenia* population (Thornley 1985), it may take several decades before these improvements are reflected, if at all, in a recovery of the unionid population. Many of the species that are no longer found in the offshore waters of the basin are still present in shallow, nearshore areas where wave action keeps the waters well-oxygenated (J. C. Roth and S. C. Mozley unpublished, Wood and Fink 1984). Over time, these areas may be a source of individuals to repopulate offshore areas. However, a new threat to the unionid population is the recent introduction and rapid increase of the zebra mussel, *Dreissena polymorpha*. Samples from the western basin in the fall of 1989 showed that all unionids were covered with *Dreissena* at densities of up to 10,000 per individual (D. W. Schloesser and T. F. Nalepa, unpublished data). Given these densities, the long-term impacts of *Dreissena* on an already stressed unionid population needs to be closely monitored.

ACKNOWLEDGMENTS

We thank John H. Judd (deceased) for assistance in the 1982 survey and Jarl K. Hiltunen for interpretation and corrections of the 1961 survey data. The 1972 survey was conducted while the authors JCR and SCM were at the Great Lakes Research Division, University of Michigan. The support of that institution is appreciated. Contribution No. 717 of the Great Lakes Environmental Research Laboratory and No. 766 of the National Fisheries Research Center-Great Lakes.

REFERENCES

Britt, N. W. 1955. Stratification in western Lake Erie in summer 1953: effects on the *Hexagenia* (Ephemeroptera) population. *Ecology* 36:239-244.

________, Skoch, E. J., and Smith, K. R. 1968. Record low dissolved oxygen in the island area of Lake Erie. *Ohio J. Sci.* 68:157-179.

Burns, N. M. 1985. *Erie The Lake That Survived.* Totowa, N.J.: Rowan and Allanheld.

Carr, J. F., and Hiltunen, J. K. 1965. Changes in the bottom fauna of western Lake Erie from 1930 to 1961. *Limnol. Oceanogr.* 10:551-569.

________, Applegate, V. C., and Keller, M. 1965. A recent occurrence of thermal stratification and low dissolved oxygen in western Lake Erie. *Ohio J. Sci.* 65:319-327.

El-Shaarawi, A. H. 1987. Water quality changes in Lake Erie, 1968-1980. *J. Great Lakes Res.* 13: 674-683.

Flannagan, J. F. 1970. Efficiencies of various grabs and corers in sampling freshwater benthos. *J. Fish. Res. Board Can.* 27:1691-1700.

Fuller, S. L. H. 1974. Clams and mussels (Mollusca and Bivalvia). In *Pollution Ecology of Freshwater Invertebrates*, eds. C. W. Hart, Jr. and S. L. H. Fuller, pp. 215-273. New York: Academic Press.

Goodrich, C., and van der Schalie, H. 1932. The naiad species of the Great Lakes. *Occ. Papers Mus. Zool. University Michigan* 238:8-14.

Hartman, W. L. 1972. Lake Erie: effects of exploitation, environmental changes, and new species on the fisheries resources. *J. Fish. Res. Board Can.* 29: 899-912.

Haukioja, E., and Hakala, T. 1974. Vertical distribution of freshwater mussels (Pelycepoda, Unionidae) in southwestern Finland. *Ann. Zool. Fennici.* 11: 127-130.

Herdendorf, C. E., Raphael, C. N., and Jaworski, E. 1986. *The ecology of Lake St. Clair wetlands: a community profile.* U.S. Fish. Wildl. Ser. Viol. Rep. 85(7.7), Washington, D.C.

Isom, B. G., and Gooch, C. 1986. Rationale and sampling designs for freshwater mussels Unionidae in streams, large rivers, impoundments, and lakes. In *Rationale for sampling and interpretation of ecological data in the assessment of freshwater systems*, ed. B. G. Isom, pp. 46-59. Philadelphia, PA: ASTM STP, American Society for Testing and Materials.

Leach, J. H., and Nepszy, S. J. 1976. The fish community in Lake Erie. *J. Fish. Res. Board Can.* 33: 622-638.

Mackie, G. L., White, D. S., and Zdeba, T. W. 1980. *A guide to freshwater mollusks of the Laurentian Great Lakes with special emphasis of the genus* Pisidium. U.S. Environmental Protection Agency EPA-600/3-80-068. Office of Research and Development, Duluth, Minnesota.

Nalepa, T. F., and Gauvin, J. M. 1988. Distribution, abundance, and biomass of freshwater mussels (Bivalvia: Unionidae) in Lake St. Clair. *J. Great Lakes Res.* 14:411-419.

________, Quigley, M. A., and Ziegler, R. W. 1988. Sampling efficiency of the Ponar grab in two different benthic environments. *J. Great Lakes Res.* 14: 89-93.

Thornley, S. 1985. Macrozoobenthos of the Detroit and St. Clair rivers with comparisons to neighboring waters. *J. Great Lakes Res.* 11:404-418.

van der Schalie, H. 1941. The taxonomy of naiades inhabiting a lake environment. *J. Conchol.* 21: 246-253.

Wood, K. G. 1963. The bottom fauna of western Lake Erie. In *Univ. Michigan Great Lakes Res. Div. Publ. No. 10*, pp. 258-265. Ann Arbor, Michigan.

________, and Fink, T. J. 1984. Ecological succession of macrobenthos in deep- and shallow-water environments of western Lake Erie: 1930-1974. In *Proc. 4th Internat. Conf. Ephemeroptera*, eds. V. Landa *et al.*, pp. 263-279. CSAV.

Wright, S. 1955. *Limnological survey of western Lake Erie*. U.S. Fish Wildl. Ser. Spec. Sci. Rept. Fisheries No. 139, Washington, D.C.

Zaptosky, J. E., and Herdendorf, C. F. 1980. Oxygen depletion and anoxia in the central and western basins of Lake Erie, 1973-1975. In *Lake Erie Nutrient Control Program*, ed. C. F. Herdendorf, pp. 71-102. EPA-600/3-8-062.

Attachment 4
NRC3-10-0004

Enclosure 7

Survey of the area between Sandy Creek and the Raisin River, in Lake Erie, for univalve and bivalve mollusks

(Best Available Copy – Please note that page 11 is missing)

(following 28 pages)

Project Report
For
U. S. Army Engineer District, Detroit
477 Michigan Avenue, 6th Floor
P. O. Box 1027
Detroit, Michigan 48231

at Sterling 3 ft
State Park 6 ft
9 ft
[illegible] at
1800 ft [illegible]
12 ft+

From
ECOSEARCH, INC.
3106 North Taylor Street
Arlington, Virginia 22207

Title
Survey of the Area Between Sandy Creek and the River Raisin, in Lake Erie, for Univalve and Bivalve Mollusks
Solicitation No. DACW35-81-R-0004

Submitted by Arthur H. Clarke, President,
ECOSEARCH, INC.

Date Submitted: December 22, 1980

Contents

Introduction

The U. S. Army Corps of Engineers plans to construct a diked storage enclosure for dredged materials at Sterling State Park in Monroe, Michigan. The enclosure will extend into Lake Erie at the northern end of Sterling State Park to the 6 - foot depth contour. It was desirable to determine if any endangered or threatened species of mollusks occur alive in the area.

In November, 1980, ECOSEARCH, INC. was invited to bid on the project of conducting a survey of the freshwater mollusks of Lake Erie, to the 6 - foot below MLW contour, in the area between Sandy Creek and the Raisin River, by sampling at 38 pre-selected sites. On November 19, 1980, prior to the deadline for bids, it did so. On about December 4, 1980, the company was notified that its bid had been accepted and the authorized contract was received from the Corps of Engineers on December 11. ECOSEARCH, INC. began its field work at Sterling State Park on December 15 and completed it on December 20, 1980.

Materials and Methods

Two certified divers, experienced in molluscan field work, were engaged through a subcontract agreement with Integrated Explorations. Diving equipment supplied by that company was as follows: two Poseidon dry suits (Unisuits) with automatic inflation couplings, two Poseidon regulators adapted with antifreeze devices, two full face masks, five SCUBA tanks, and other conventional diving gear.

The prime contractor, ECOSEARCH, INC., supplied the other necessary equipment, viz.: one-14 foot inflateable rubber boat with wooden floor and seats, two-1 meter square metal frames, two metal scoops, one shovel, two screening boxes with ¼ inch metal screens, one screening box with 1/8 inch metal screen, bags, jars, sorting trays, specimen preserving chemicals (formaldehyde, nembutal, ethyl alcohol), labels, record books, and a Dodge Ram Van for equipment and personnel transport and as a portable warm-up station for the divers.

The collecting sites were fixed to correspond with the 38 pre-selected stations specified in the contract. A surveyor's measuring tape was used to establish bases for the 12 lines of 3 stations each (lines 1 through 12 on the grid) which are spaced at 1000-foot intervals along the beach.

The two other sites were located by triangulation from shore.

At each three-station set the divers waded into the lake at the base of each station-line and, towing the inflated boat containing gear, proceeded directly away from the beach to depths of 3.0 ± .5, 5.4 ± .5, and 8.4 ± .5 feet. (Lake level was 2.4 feet above MLW so these depths are on lines A, B, and C of the grid, i.e. they correspond to depths of 0.6 ± .5, 3.0 ± .5, and 6.0 ± .5 feet at below MLW). ?? The sample sites 150 feet into the mouths of Sandy Creek and the Ford Motor Company intake channel were simply approached directly . Upon reaching the desired location, and where appropriate, one diver would randomly cast a square meter frame and, using a shovel in shallow water or a metal scoop in deeper water, would then scoop all of the sediment and infauna (to a depth of about 3 inches) into a weighted screening box fitted with ¼ inch mesh. The infauna was then screened from the substrate, placed in bags, labelled and returned to shore for processing and identification. At each station three-one meter subsamples were taken and the resulting specimens were combined and constituted a single unified sample.

This procedure was used at all stations where it was applicable but at some stations it was inappropriate. Because of the cold water temperature and windy weather the lake was undergoing overturn and vertical mixing, the water was turbid, and visibility was very low. The bottom at the hand sampling at some stations

3-foot stations and at the Sandy Creek (2 feet) and Ford intake channel (1½ feet) stations was of sand, at the 5.4-foot stations it contained patches of sand (ca. 30% coverage) interspersed with areas of exposed hard clay, and at the 8.4 foot stations there was very little sand (0 - 10%) and hard clay. The clay at the 5.4 and 8.4 foot stations was not flat but was pockmarked with rounded holes, ranging in size from about 4 inches to about 12 inches, in diameter and in depth. The clay at these depths was also covered with a layer of fine silt, about ½ inch thick between the holes and much thicker within the holes, which swirled up to occlude all visibility when it was disturbed. Nearly all of the live freshwater mussels (Unionidae) were partly buried in silt in the holes. The cold water temperature (4°C at the start of the sampling period declining to 0.5°C at the end of the period) and the cold air temperature (+ 2°C to - 15°C during the period) made it necessary for the divers to wear heavy diving mitts and feeling for specimens in the substrate was impossible. The only method which could be used at the 5.4 and 8.4 foot depths was therefore for the diver to swim along the bottom, with his face mask about 3 to 4 inches from the bottom, and to seize any specimen which came into view. That method was therefore utilized and areas of about 8 to 10 square meters were covered at each 5.4 and 8.4 foot site. The significance of this collecting technique will be discussed below.

Identifications were done by Arthur H. Clarke, Ph. D., an experienced freshwater malacologist (formerly Curator of Mollusks (1959 - 1976) at National Museum of Canada and Associate Curator of Mollusks, Smithsonian Institution (1977 - 80)). Corroboration of identifications and additional information was obtained by using the following references:

Burch, J.B., 1973. Freshwater Unionacean Clams (Mollusca; Pelecypoda) of North America. Biota of Freshwater Ecosystems, Identification Manual No. 11: i-xii+1-177. U. S. Environmental Protection Agency.

Clarke, A.H., 1981. The Freshwater Mollusks of Canada. Special Publication, National Museums of Canada, Ottawa, Canada. 450 pp (in press).

Goodrich, Calvin, 1932. The Mollusca of Michigan. Michigan Handbook Series, No. 5: 1-120, 7pls. The University of Michigan Press.

Results

A tabulation of all of the mollusks collected during this survey is given in Table 1. The species found on the beach, represented by empty shells or by dead specimens containing soft parts, are listed by relative abundance (common, rare, or single specimen only). For the other stations the number of living individuals collected at each sample site is given.

A total of 23 species of mollusks were found. All of these, except *Corbicula fluminea*, occurred on the beach. Two of the four species of gastropods found on the beach, and 12 of the 18 species of mussels found on the beach, were also collected alive in the lake.

The collection sites where each species of mollusk was found alive are shown as filled-in circles in maps 1 - 15.

It will be seen from Table 1 that, except for 2 specimens of *Corbicula fluminea*, no living mollusks were found in samples along series A, i.e. in depths of about 0 to 1 foot ~~below~~ at MLW. The two *Corbicula* specimens came from sites A2 and A3. They are each young specimens (8.0 and 8.6 mm long, respectively) and exhibit the 3 purple radial bands and coarse concentric ridges characteristic of the species. They have apparently settled as swimming larvae only a few months ago and have certainly not overwintered at that shallow depth. Presumably other

check this

mollusks did not occur there because winter ice-scouring and freezing to the bottom in very shallow water is inimical to their survival. (Among North American freshwater mollusks, only *Corbicula fluminea* has pelagic, free-swimming, larvae).

At any rate, the discovery of *C. fluminea* in Lake Erie is of considerable interest because it constitutes the first record of the species from the Great Lakes - St. Lawrence System. If this prolific clam is able to survive the cold winters at this latitude it may eventually spread elsewhere in the Great Lakes. It is an Asian Asiatic species which, during the 45 years since it was first introduced to North America, has spread widely in the United States. In many areas, it now constitutes a commercial nuisance and a serious threat to the native freshwater mussel fauna.

Table 1

Tabulation of Beach Shells and of Numbers of Living Specimens at Collecting Stations

Species / Stations		BEACH SHELLS	N + S	A1 to A12	B 1	B 2	B 3	B 4	B 5	B 6	B 7	B 8	B 9	B 10	B 11	B 12	C 1	C 2	C 3	C 4	C 5	C 6	C 7	C 8	C 9	C 10	C 11	C 12
CLASS GASTROPODA																												
Family Viviparidae																												
Campeloma decisum (Say)		R	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Viviparus japonicus (Von Martens)		1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Family Pleuroceridae																												
Goniobasis livescens (Menke)		C	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pleurocera acuta (Rafinesque)		C	0	0	0	0	0	1	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1 CLASS PELECYPODA																												
Family Unionidae																												
Amblema plicata (Say)	10	C	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	2	0	3	0	0	1	0	1	0	2	0
Fusconaia flava (Rafinesque)	9	C	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	2	3	0	0	1	1	0	0	0
Quadrula quadrula (Rafinesque)	3	R	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0
Quadrula pustulosa (Lea)	1	R	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
Elliptio dilatata (Rafinesque)	1	R	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
Pleurobema coccineum (Conrad)	1	C	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
Lasmigona complanata (Barnes)		1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Anodonta grandis Say	6	C	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	1	2	0	0	0
Obliquaria reflexa Rafinesque	2	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0
Truncilla donaciformis (Lea)		R	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Truncilla truncata Rafinesque		R	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Proptera alata (Say)	12	C	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	2	1	1	1	0	0	0	1	3	1	0
** Obovaria subrotunda (Rafinesque)		C	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Leptodea fragilis (Rafinesque)	5	R	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	2	0	1	0	0	0
Ligumia nasuta (Say)		R	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ligumia recta (Lamarck)	1	R	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
Lampsilis radiata siliquoidea (Barnes)	17	C	0	0	0	0	0	0	0	0	0	0	0	2	0	2	0	3	1	1	2	1	0	1	1	1	2	0
Lampsilis ventricosa (Barnes)		R	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Family Corbiculidae																												
Corbicula fluminea (Muller)		0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total Specimens		ABUND.	0	2	1	5	0	1	8	0	0	0	0	2	0	2	0	11	4	8	8	3	3	3	9	4	5	0
Total Species		22	0	1	1	5	0	1	2	0	0	0	0	1	0	1	0	7	4	5	5	2	2	3	8	2	3	0
CUM. NUMBER					1	6							6	8	8	10	10	21	25	33	41	44	47	50	59	63	68	
CUM. SPECIES					1	5							5	6	6	6	6	9	10	11	12	12	12	12	12		[illegible]	

* Abbreviations are: C, common; R, rare; 1, 1 specimen; O, absent.

** = Obovaria leibii (Lea), a species included on the Michigan state list of endangered species

Conclusion and Discussion

One small species of mollusk which was found on the beach in some numbers (30 or more specimens) is included on the State of Michigan List of Endangered Species. The mussel is listed there as _Obovaria leibii_ (Lea). We did not find the species alive in the lake, but since some of the beach specimens were fresh-looking and with both valves still joined together, we believe that it probably occurs alive there, and possibly within the area to be covered by the disposal facility.

The difficulties encountered during the collecting procedure, brought about by the poor visibility during this period of lake turbulence, by the need for divers to wear heavy mitts in the freezing water and the resultant inability to feel small buried specimens, and by the further inability of the divers to remain exposed in the frigid water or air for long periods without retreating to the van for warming, have all been alluded to above. It is also significant that the three smallest species of freshwater mussels which occurred dead on the beach, i.e. _Obovaria_ "_leibii_" , _Truncilla truncata_, and _T.donaciformis_, were all absent from among live-collected material. We believe that this is probably an artifact and that the apparent absence of these three species from the living mussel communities may have been caused by our inability to collect them during this very cold time of year.

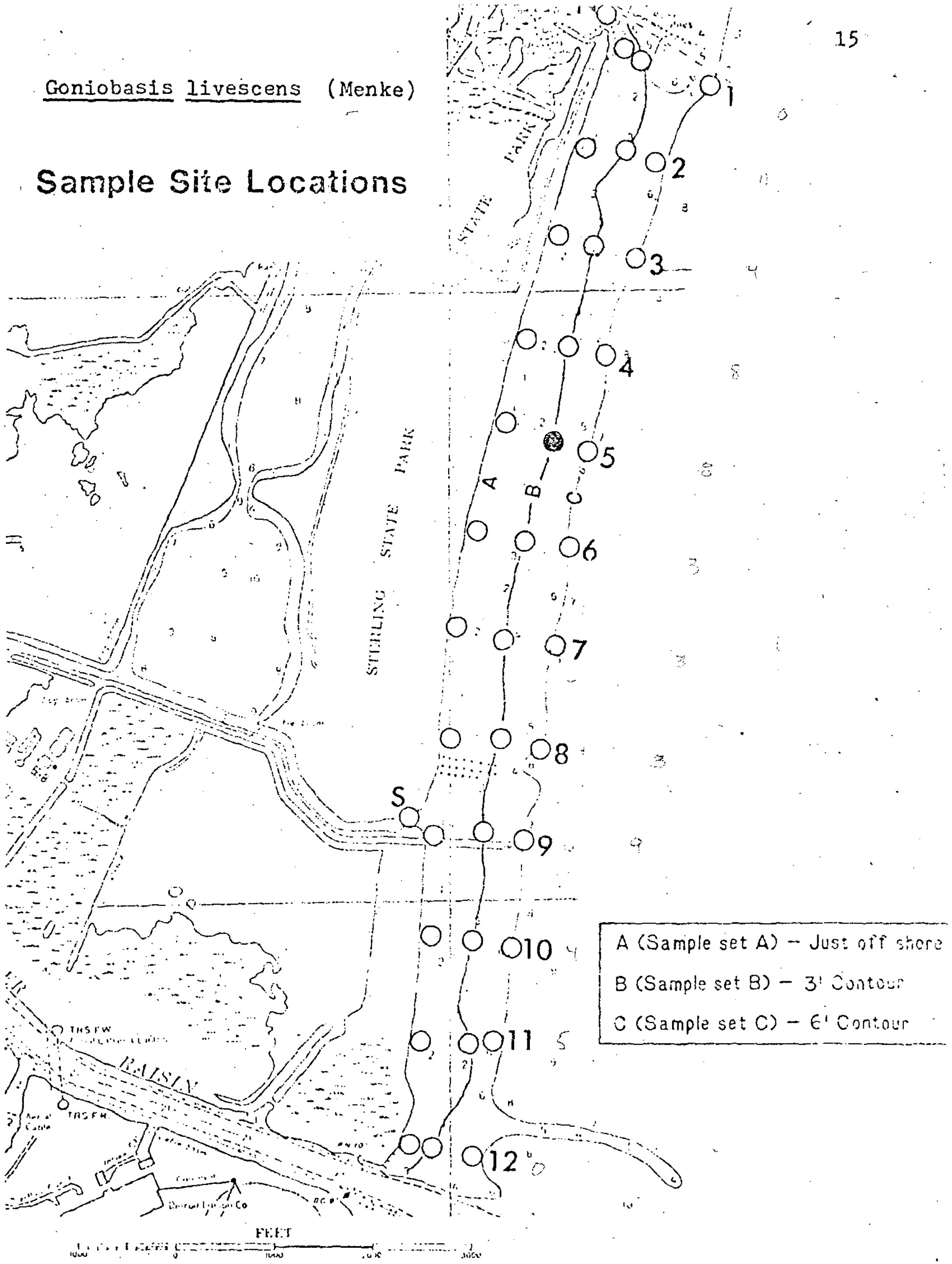
Remote methods, such as by using long-handled rakes from boats, we believe, would be ineffective in securing specimens from holes in the hard clay found at 6 feet below MLW.

It is also necessary to comment on the taxonomic status of *Obovaria leibii*. We have listed it in Table 1 as *O. subrotunda* (Rafinesque) and we believe that it is that species. *O. subrotunda* occurs in Lake Erie and Lake St. Clair and in rivers draining into those lakes, and also in many parts of the Ohio-Mississippi River System. In our opinion "*Obovaria leibii*" is simply a lake ecophenotype of the normally riverine species, *O. subrotunda*. Several parallels exist in regard to other river and lake populations of mussels, e.g. in *Amblema plicata* (river) and *A. plicata* morph *costata* (lake), in *Ligumia recta* (lake) and *L. recta** (river), morphs of *Fusconaia flava*, *Pleurobema coccineum*, and other species of *Pleurobema*. Whether or not the lake population of *Obovaria subrotunda* is genetically distinct remains to be tested, but in our opinion it is probably not distinct.

In our view the proper procedure to be used to establish whether or not the lake population of *O. subrotunda* (i.e. *O. leibii*) occurs in the area to be covered by the disposal facility, and elsewhere offshore from Sterling State Park, is to conduct another survey when weather conditions improve, i.e. when the lake water becomes non-turbid and when temperatures are such that heavy mitts are not necessary. A new survey in May or June of 1981, is recommended. The methods to be employed should be modified to allow for intensive sampling, say 3 to 4 hours of SCUBA investigation from a boat at each of the sampling stations at the 6-foot below MLW contour, i.e. along sample line C. That is the depth in which we have shown that diverse mussel beds occur and it is the area in which *Obovaria* "*leibii*" probably lives, if it occurs at all in Lake Erie off shore from Sterling State Park.

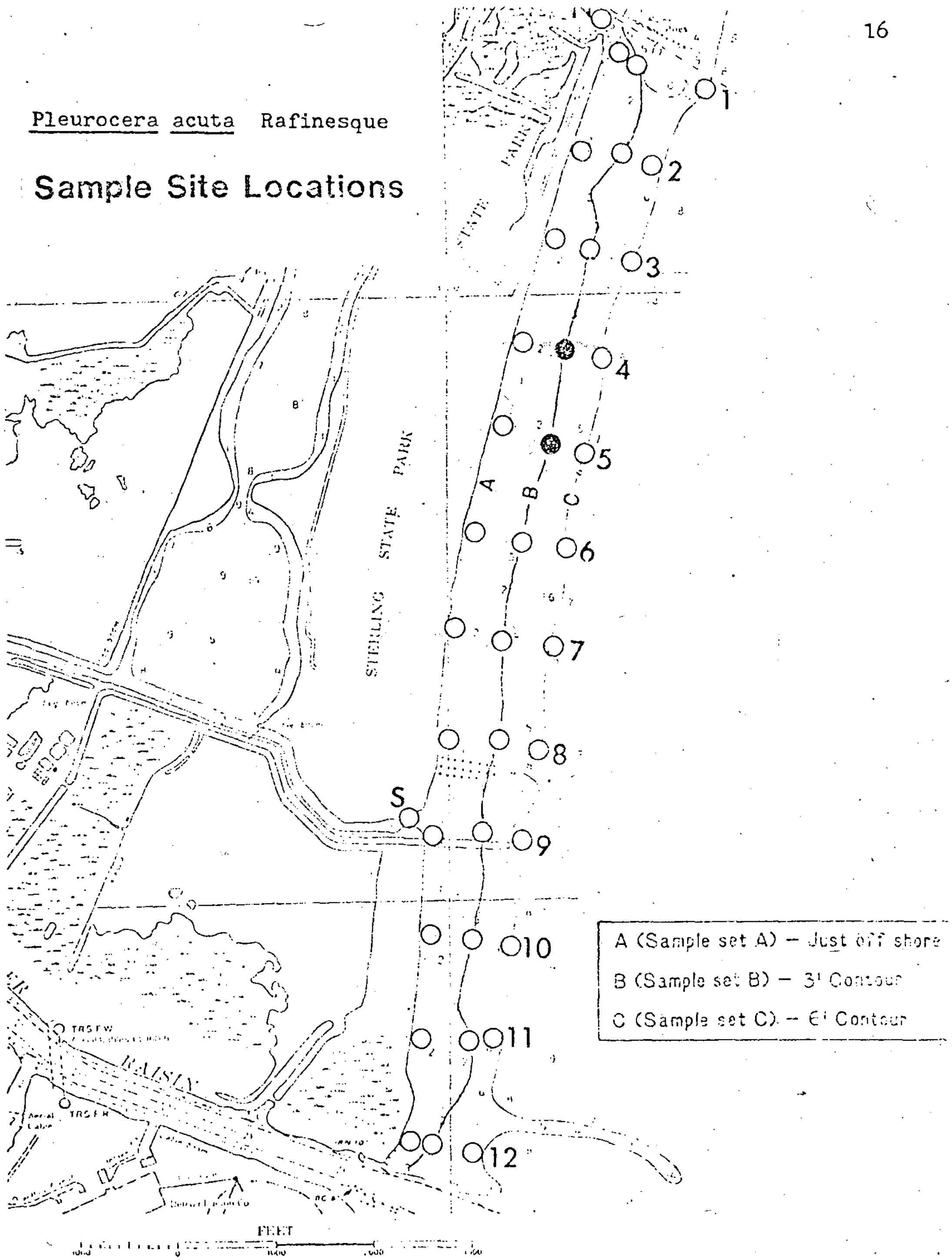
Goniobasis livescens (Menke)

Sample Site Locations



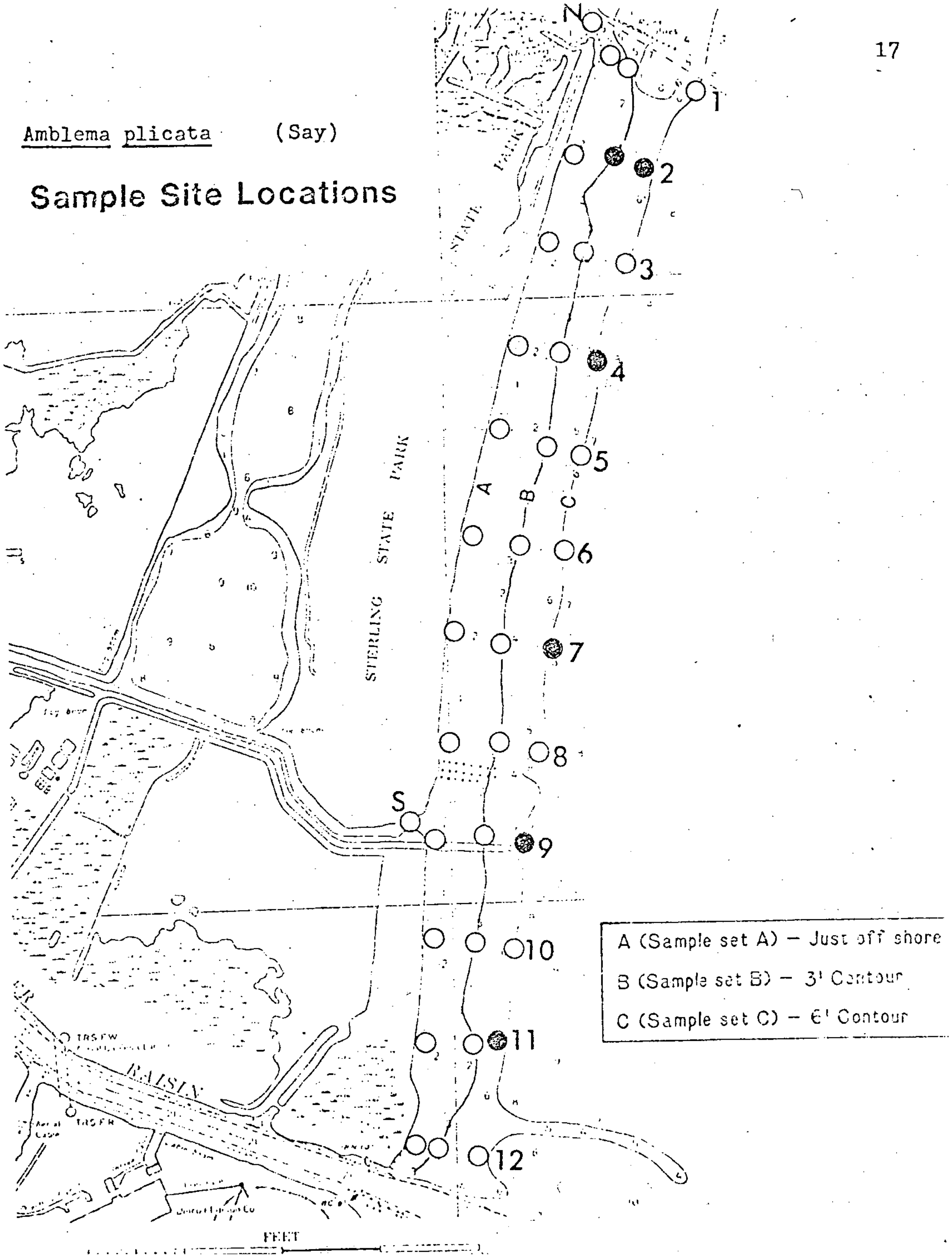
Pleurocera acuta Rafinesque

Sample Site Locations



<u>Amblema</u> <u>plicata</u> (Say)

Sample Site Locations



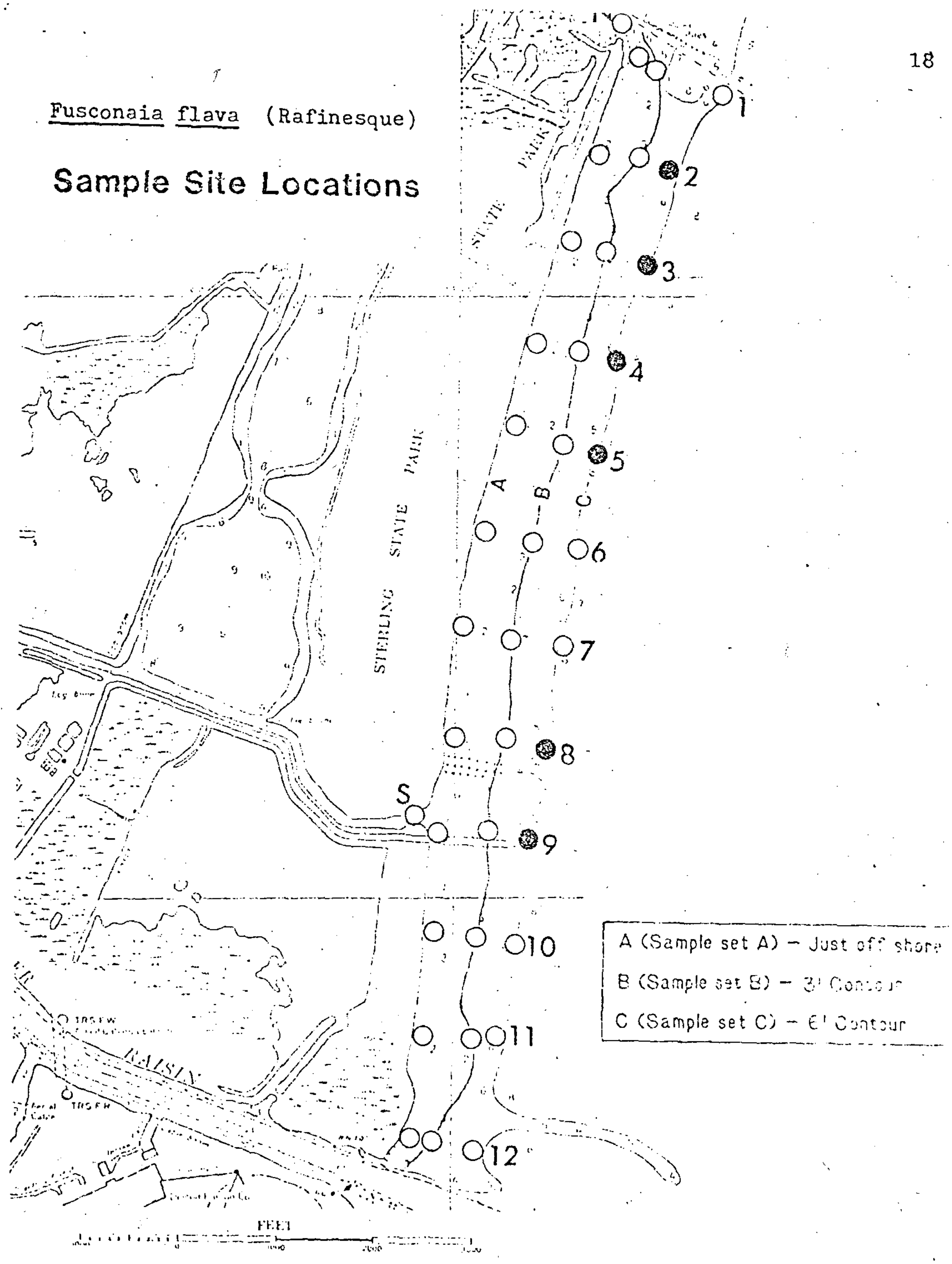
A (Sample set A) – Just off shore

B (Sample set B) – 3' Contour

C (Sample set C) – 6' Contour

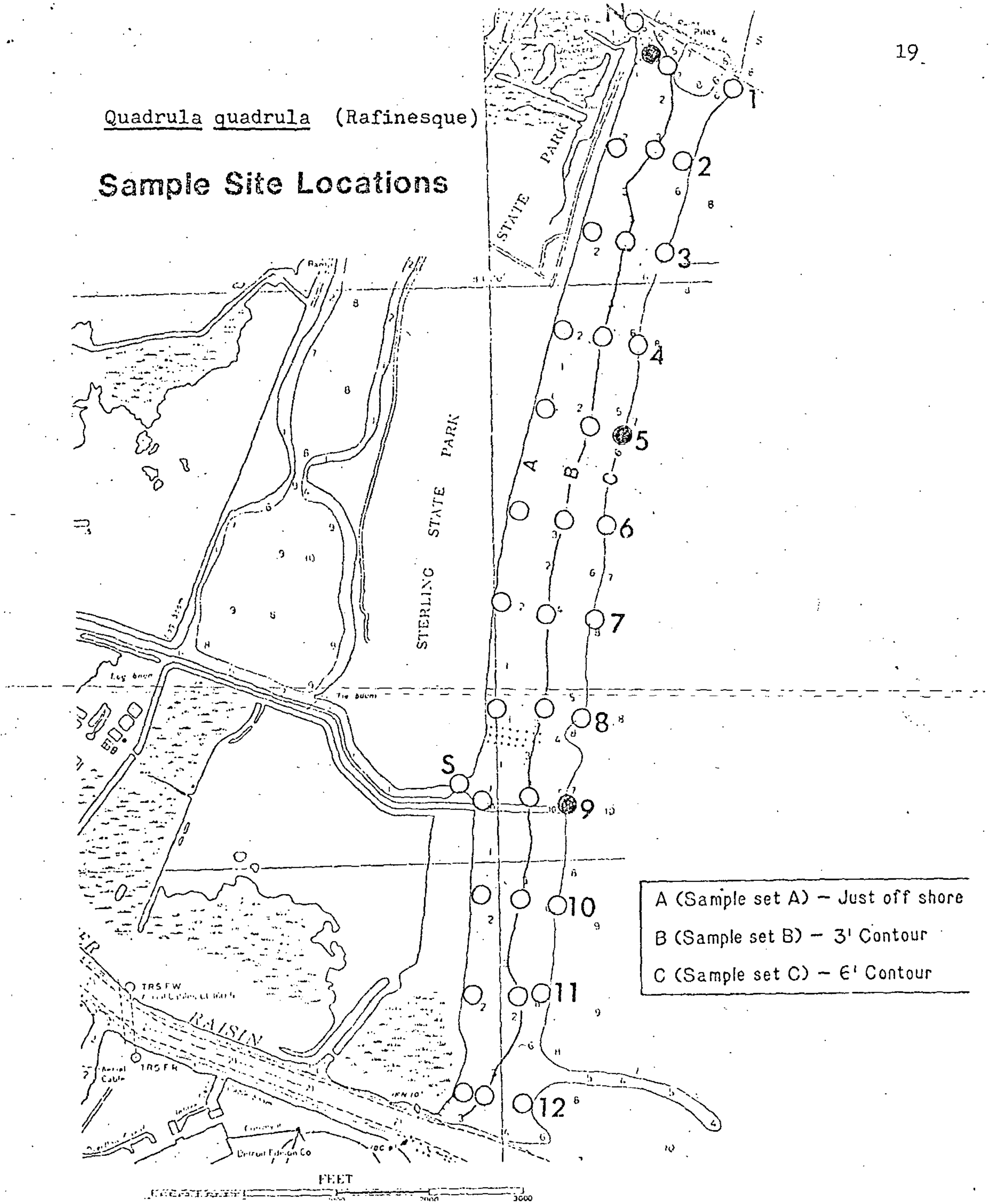
Fusconaia flava (Rafinesque)

Sample Site Locations



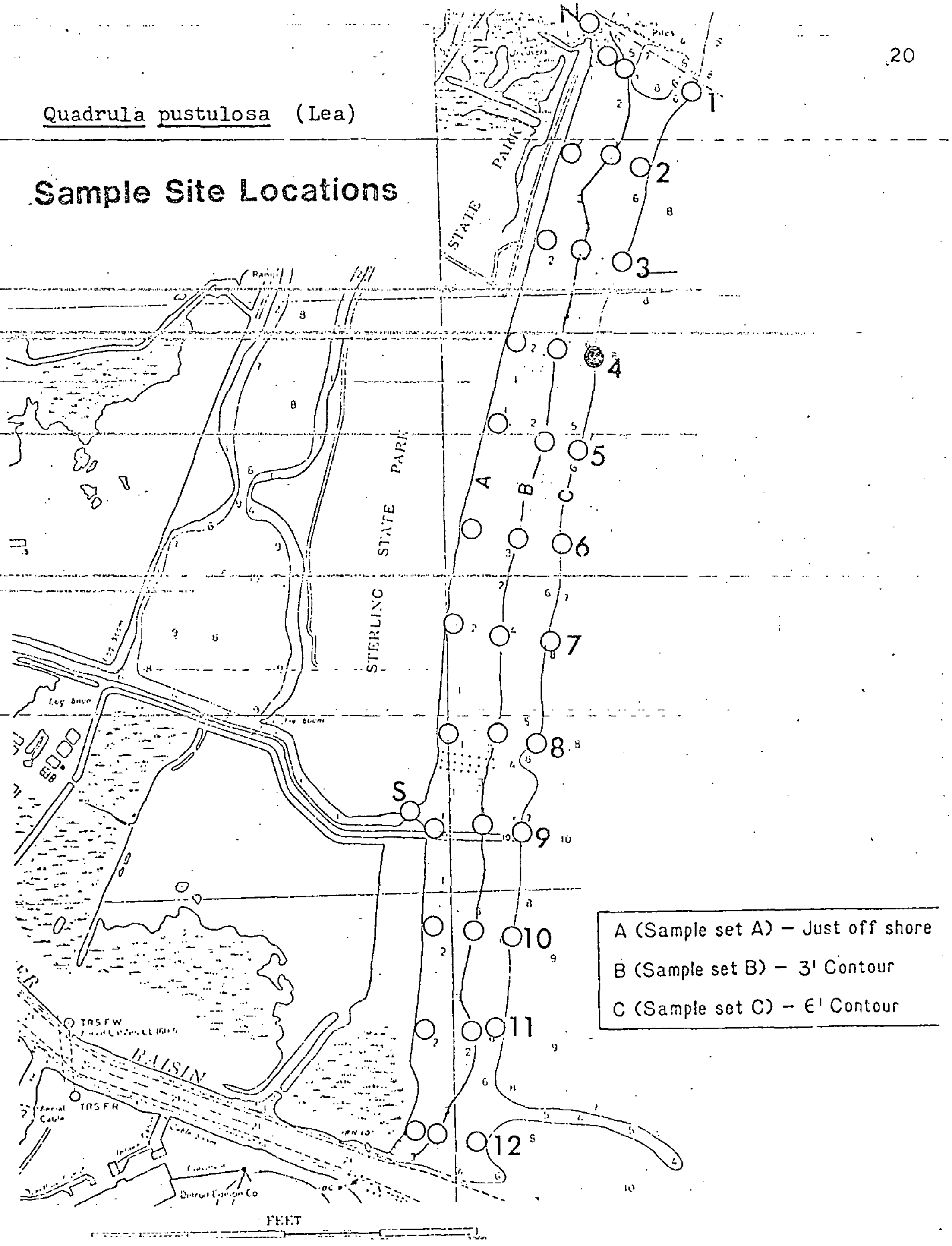
Quadrula quadrula (Rafinesque)

Sample Site Locations



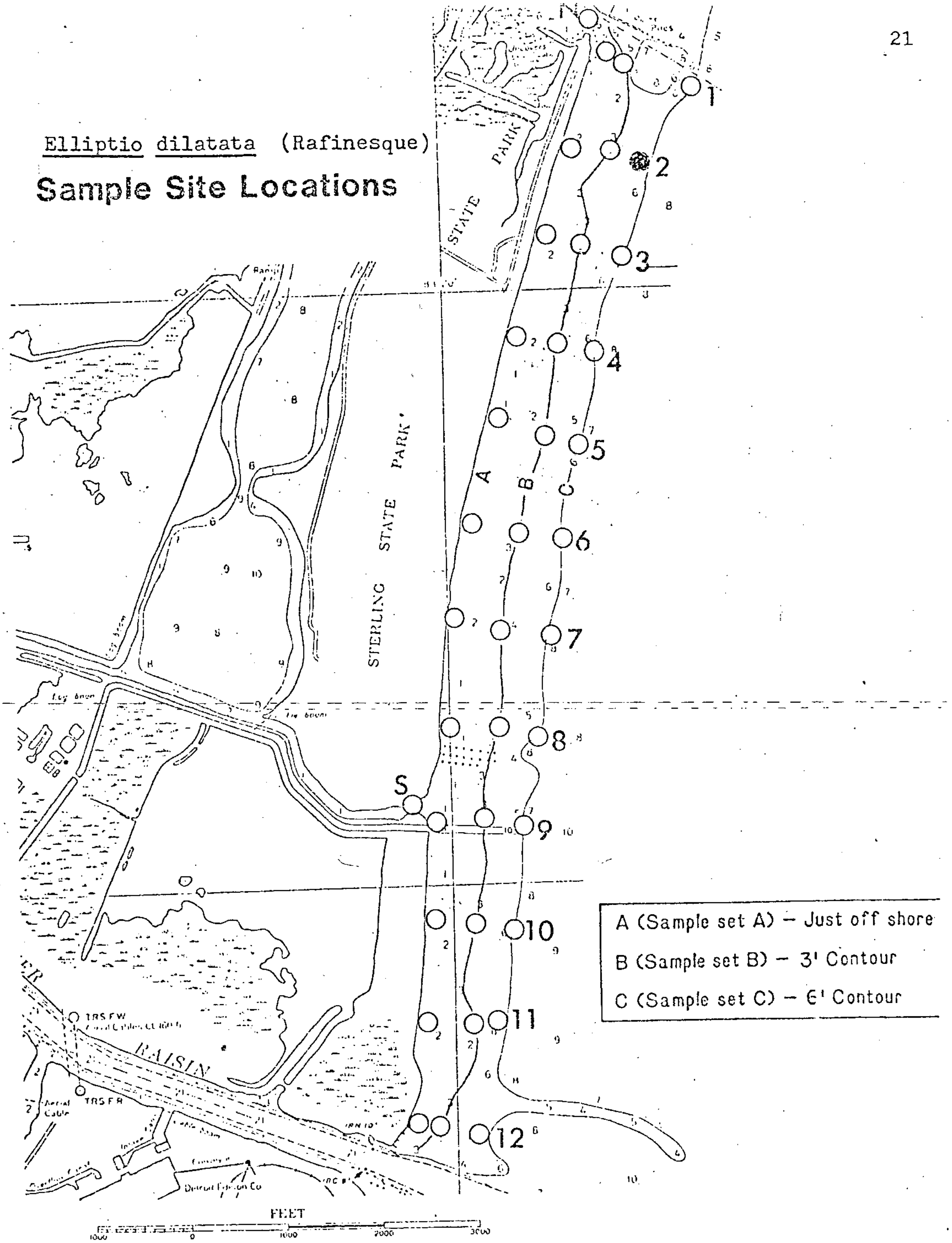
Quadrula _pustulosa_ (Lea)

Sample Site Locations



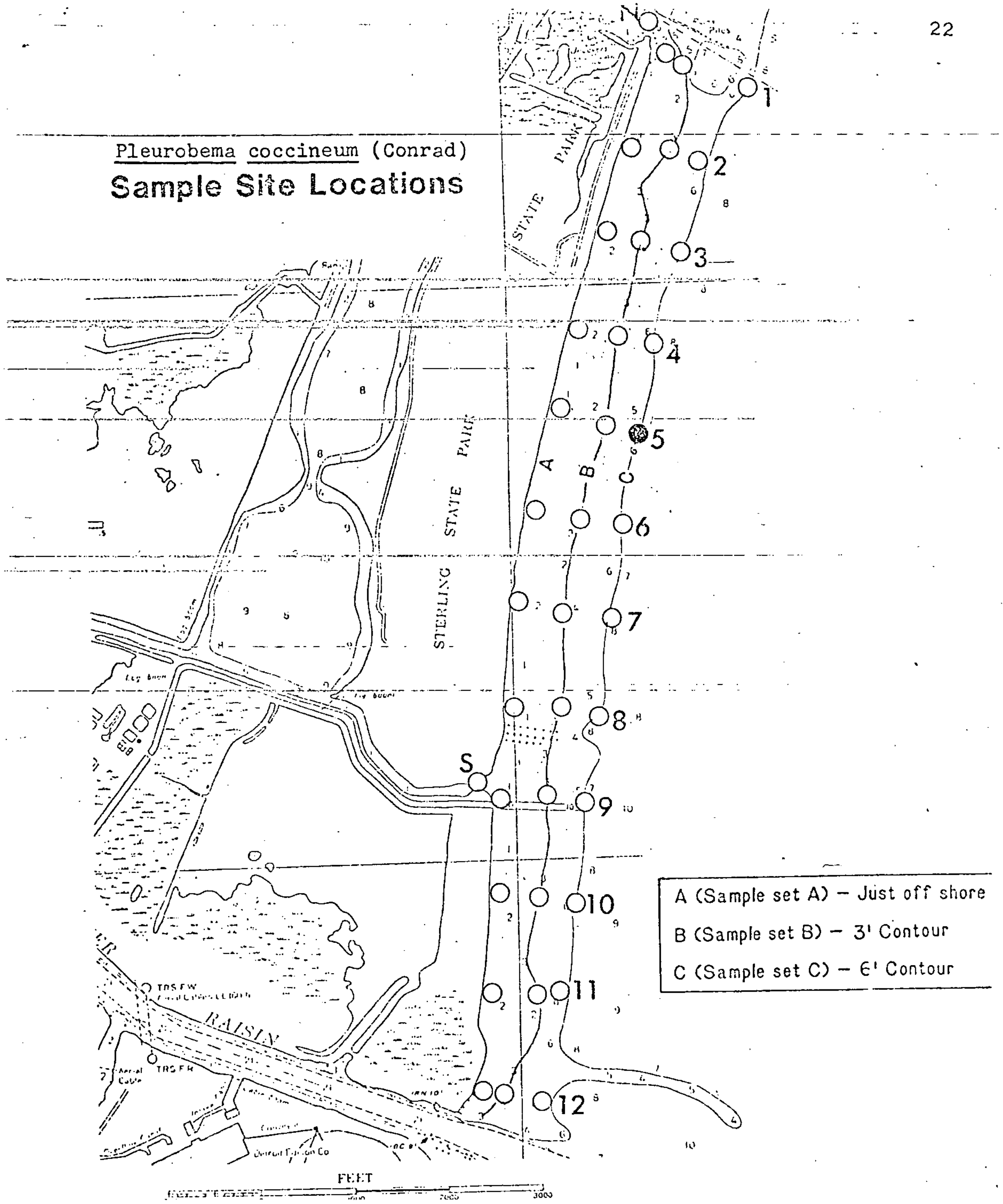
Elliptio dilatata (Rafinesque)

Sample Site Locations



Pleurobema coccineum (Conrad)

Sample Site Locations



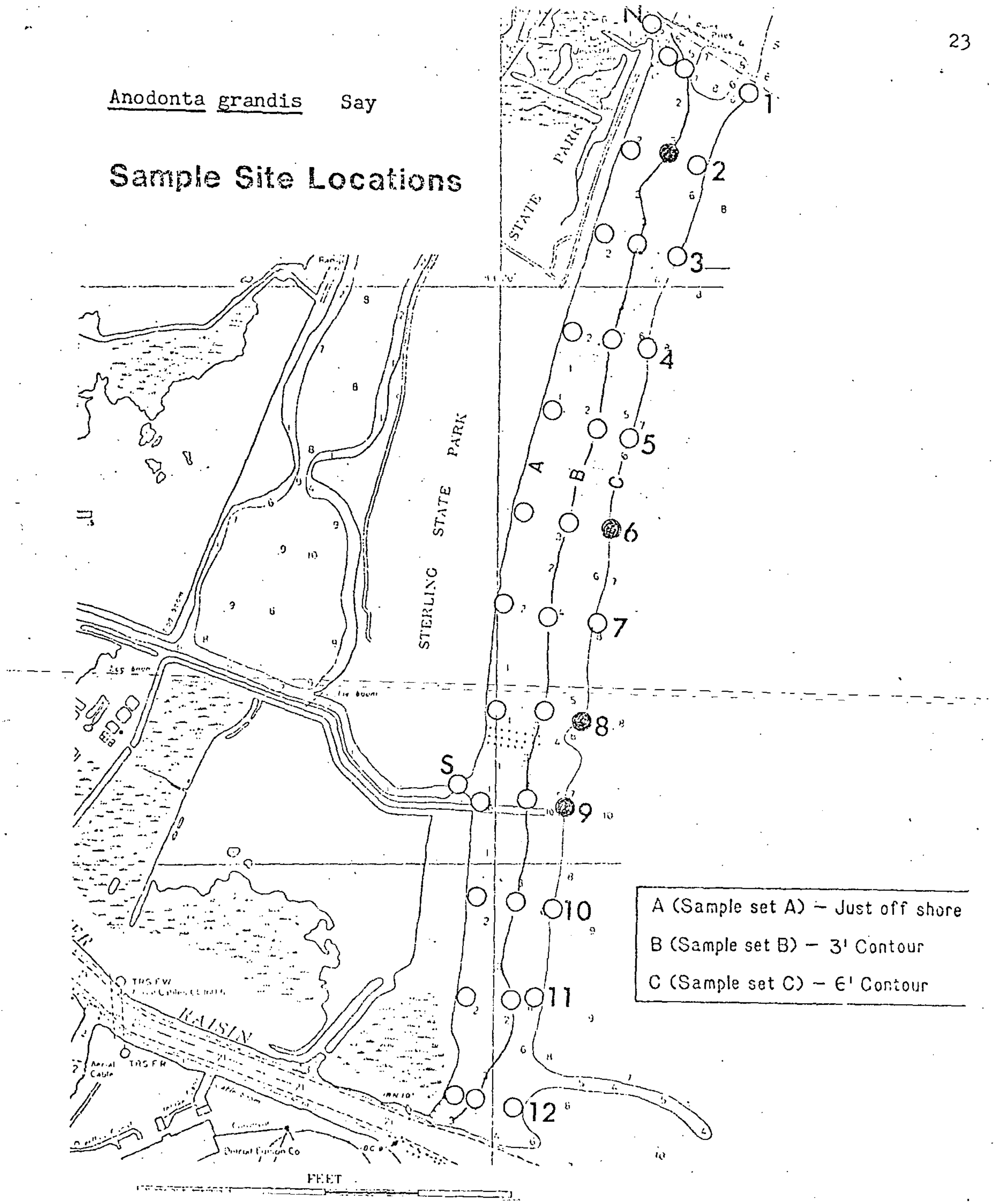
A (Sample set A) - Just off shore

B (Sample set B) - 3' Contour

C (Sample set C) - 6' Contour

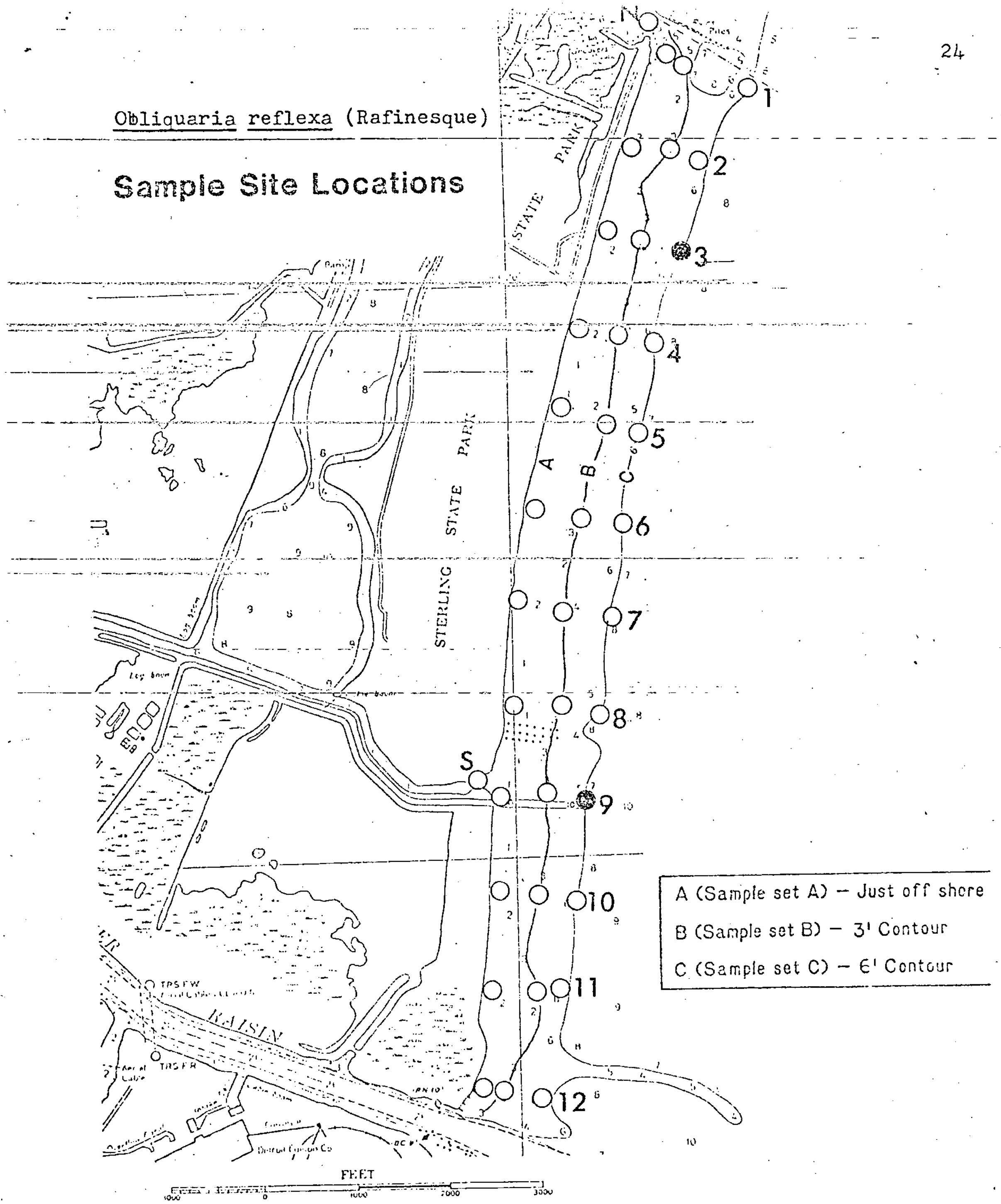
Anodonta grandis Say

Sample Site Locations



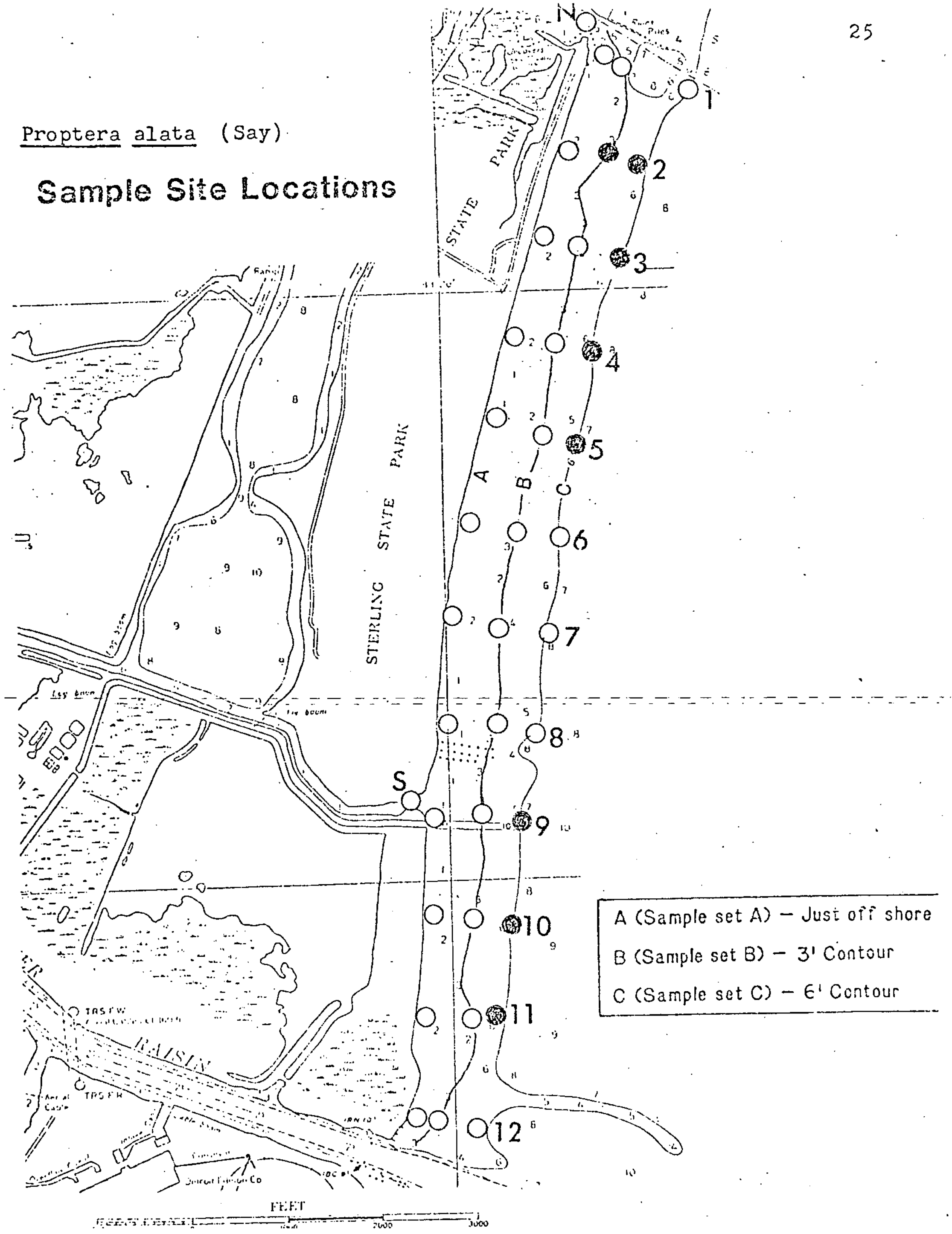
Obliquaria reflexa (Rafinesque)

Sample Site Locations



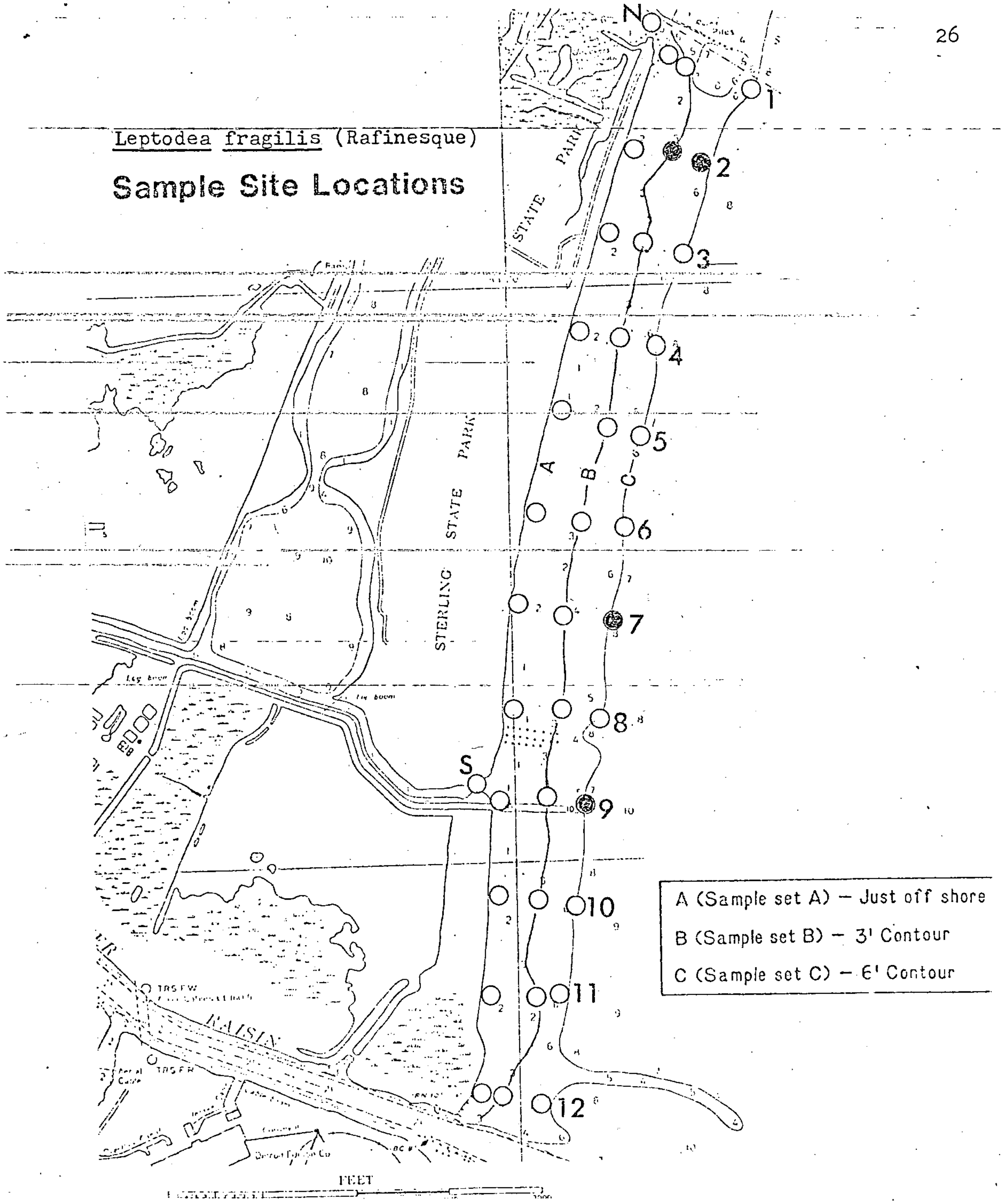
Proptera alata (Say)

Sample Site Locations



Leptodea fragilis (Rafinesque)

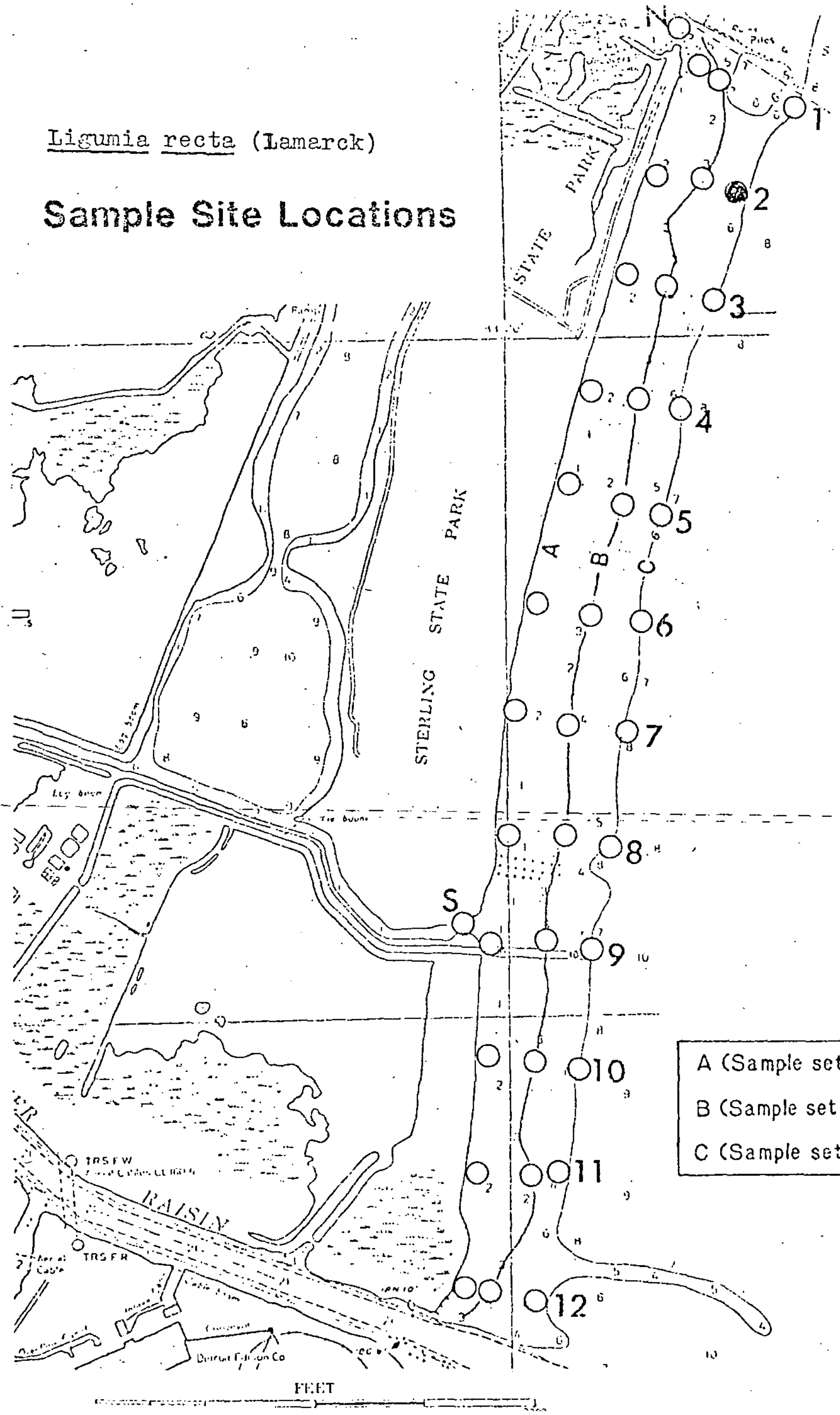
Sample Site Locations



A (Sample set A) – Just off shore
B (Sample set B) – 3' Contour
C (Sample set C) – 6' Contour

<u>Ligumia recta</u> (Lamarck)

Sample Site Locations



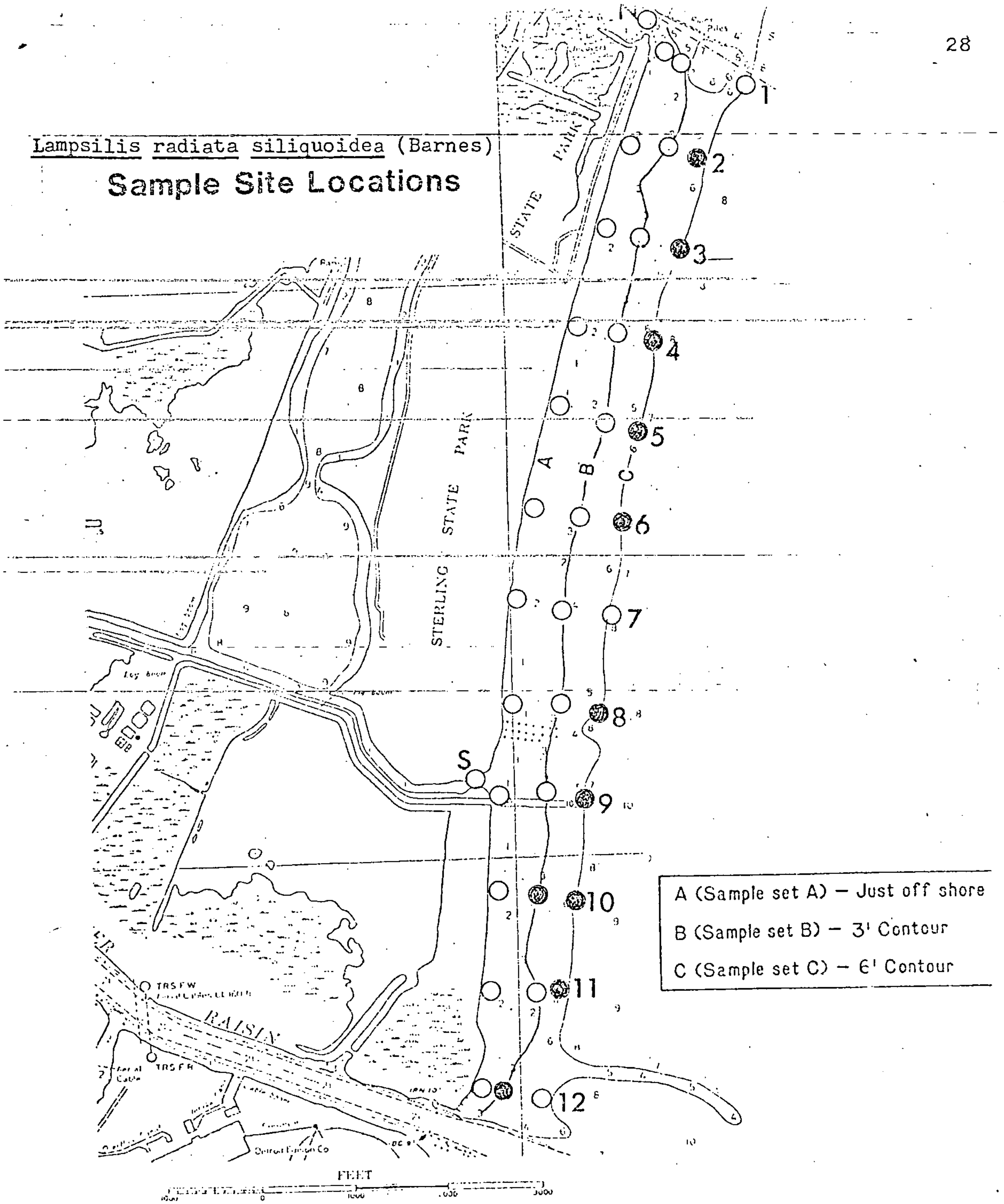
A (Sample set A) – Just off shore

B (Sample set B) – 3' Contour

C (Sample set C) – 6' Contour

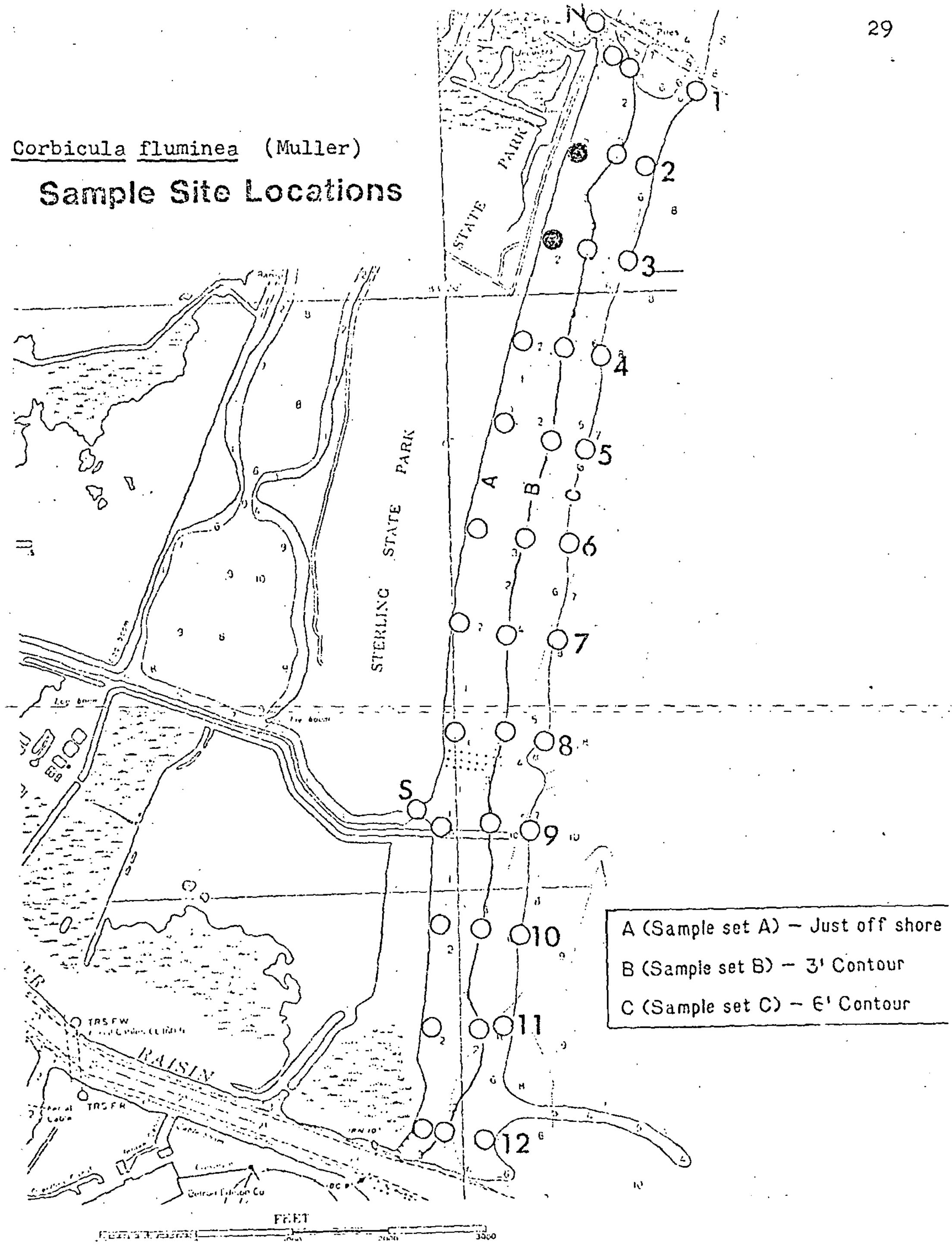
Lampsilis radiata siliquoidea (Barnes)

Sample Site Locations



Corbicula fluminea (Muller)

Sample Site Locations



Attachment 4
NRC3-10-0004

Enclosure 8

Intensive follow-up survey of the area between Sandy Creek and the Raisin River, in Lake Erie, for univalve and bivalve mollusks

(Best Available Copy)

(following 37 pages)

Project Report

For

U.S. Army Engineer District, Detroit
477 Michigan Avenue, 6th Floor
P.O. Box 1027
Detroit, Michigan 48231

Title

Intensive Follow-Up Survey of the Area Between Sandy Creek and the River Raisin, in Lake Erie, for Univalve and Bivalve Mollusks.

Contract No. DACW35-81-M-588

Submitted by Arthur H. Clarke, Ph.D., President, ECOSEARCH, INC.

Date Submitted: March 4, 1981

Contents

Introduction

A survey was conducted by ECOSEARCH, INC. on December 15-20, 1980 for freshwater mollusks in Lake Erie at and near Sterling State Park, Monroe, Monroe County, Michigan for the U.S. Army Corps of Engineers (Contract No. DACW 35-81-R-0004). We submitted our detailed report on that survey to the U.S. Army Engineer District, Detroid, on December 22, 1980.

In accordance with the requirements of that contract, sampling was carried out by divers at 12 sites located at 1000-foot intervals along the 1-foot below mean low water (MLW) contour between the mouth of Sandy Creek and the mouth of the River Raisin, at 12 sites directly offshore from the first series of sites but at the 3-foot below MLW contour, and at 12 more sites also directly offshore from the first and second series but at the 6-foot below MLW contour. A site in the mouth of Sandy Creek and a site in the mouth of the Ford Motor Company intake channel were also sampled. A bottom area of at least $3M^2$ was searched at each site. Although a census of all freshwater mollusks was carried out, freshwater mussels (Family Unionidae) were of special interest because of the possible presence of *Obovaria leibii* (Lea), a mussel species presently included on the State of Michigan Official List of Endangered Species.

A total of 23 species of freshwater mollusks were found on the beach and at sampling stations. Fifteen species occurred alive, including 12 species of freshwater mussels. Six mussel species, including *Obovaria leibii*, were found only as empty shells on the beach. More than 85% of the living mussels collected by our divers were found along the 6-foot below MLW contour. This was to be expected because our experience in similar exposed sites in other large lakes has shown that the greatest diversity and density of freshwater mussels begins at a depth of about 6 feet below MLW and extends into deeper water. Our report therefore recommended that in order to reach a reliable conclusion about the presence or absence of Obovaria leibii at or within the 6-foot below MLW contour in that area, a follow-up survey should be conducted along the 6-foot below MLW contour and that it should be much more intensive and extensive than previously called for.

reference?

The Corps of Engineers accepted our recommendations and on February 6, 1981 a contract for a follow-up survey was received and signed by ECOSEARCH. The new survey was carried out between February 9 and 14, 1981.

Materials and Methods

In early February, 1981, Lake Erie at Sterling State Park was covered with ice about 18 inches thick. South of the Park and extending to the Raisin River and beyond there was a large area of open water. Presumably this was caused by the warm water discharge from the Detroit Edison electric generating plant which flows into the River Raisin near South of Lake Erie the its mouth. of the Raisin River

Equipment for the survey was supplied by ECOSEARCH, INC. and as offered by the agency, by the Army Corps of Engineers. ECOSEARCH supplied sampling scoops, bags, other containers, labels, preservatives, surveying equipment, oars, an anchor, a pickup truck, and other gear. The Army Corps of Engineers supplied divers, support personnel, a boat, ice-cutting and diving equipment, and 2 vans as warm-up stations for the divers.

The sampling sites were selected by ECOSEARCH. First, reference points 1000 feet apart were established on the beach. Next, a series of trial holes were cut in the ice along a line directly offshore from these reference points until water of the proper depth was located. Lake level was 2.5 feet above MLW so sampling depths of 8.5 ± 0.5 feet were selected. After locating each site the ice cutters prepared a rectangular hole about 5 feet long and 3 feet wide in the ice and lowered an aluminum ladder into it. Two SCUBA divers would then decend into the water and begin work. A lifeline was attached to each diver and the ends were held by a third person standing on the ice. The divers used metal scoops and medium-mesh nylon bags with mesh small enough to retain the smallest specimens. I instructed the divers to scoop out the contents of the silt-filled depressions (described in the previous report) and to also search at random for any other specimens that could be found. I also observed the dives and immediately processed the specimens when they were brought up. At each site more than 60 minutes of work time was spent under water and a circular area about 100 feet in diameter was searched. Thus collecting effort at the sites examined during this follow-up survey was of the order of 5 to 10 times greater than was possible during the previous survey.

* area
≈7850 ft^2

50
50
2500
3.14
10000
2500
7500
785000

The specimens collected were identified by A.H. Clarke and either returned immediately to their original habitats or, if needed for other research, they were relaxed and preserved. Shortly thereafter many of these specimens were donated to the Museum of Zoology of the University of Michigan, to the Ohio State University Museum of Natural History, and to the National Museum of Natural History (Smithsonian Institution). Some specimens were also retained by ECOSEARCH for subsequent anatomical studies.

60 minutes at each site.

Results

The numbers of living specimens of each species are tabulated in Table 1. For comparison the species list is the same as that used in the previous report and includes all species found alive or (in December) as empty beach specimens. Snow cover in February precluded beach collecting. Author citations for taxonomic names are included in the previous report.

A total of two species of gastropods, fifteen species of Unionidae, and one species of Corbiculidae were found alive. With the exception of three species of unionids, viz. *Truncilla donaciformis*, *Ligumia nasuta*, and *Lampsilis ventricosa*, each represented by a single living specimen, the list of unionid species found alive is qualitatively the same as that reported previously. *Obovaria liebii* (= *O. subrotunda*, see below) was not found living.

The collection sites where each species of mollusk was found alive are shown as filled-in circles on maps 1-18.

It is significant that the introduced pest species, *Corbicula fluminea*, was encountered again and in significantly deeper water than previously. The specimens are larger (11.9-16.6mm) than previously reported and their presence at the 6 foot below MLW level, and in the warmed water at the mouth of the River Raisin, indicate that the colony is now established in western Lake Erie. Clogging of water intake systems in the area will likely occur if the population becomes large, as is to be expected at least in the warm water in the mouth of the River Raisin.

Table 1

Numbers of Living Specimens Found at Each Site

STATION NUMBER	1	2	3	4	5	6	7	8	9	10	11	12	Total
CLASS GASTROPODA													
Fam. Viviparidae													
<u>Campeloma decisum</u>	-	-	-	-	-	-	-	-	-	-	-	-	0
<u>Viviparus japonicus</u>	-	-	-	-	-	-	-	-	-	-	-	-	0
Fam. Pleuroceridae													
<u>Goniobasis livescens</u>	-	8	-	-	-	-	-	-	-	-	-	-	8
<u>Pleurocera acuta</u>	-	36	5	-	9	-	-	-	-	-	-	-	50
CLASS PELECYPODA													
Fam. Unionidae								12-13 spp					
<u>Amblema plicata</u>	-	1	2	7	10	-	-	-	-	-	-	-	20
<u>Fusconcira flava</u>	2	5	3	1	2	1	-	1	-	1	-	-	16
<u>Quadrula.quadrula</u>	-	-	-	1	1	1	-	-	-	-	-	-	3
<u>Q. pustulosa</u>	1	1	1	3	-	1	-	-	-	1	-	-	8
<u>Elliptio dilatata</u>	-	1	-	3	-	-	-	-	-	-	-	-	4
<u>Pleurobema coccineum</u>	-	-	-	1	-	-	-	-	-	-	-	-	1
<u>Lasmigona complanata</u>	-	-	-	-	-	-	-	-	-	-	-	-	0
<u>Anodonta grandis</u>	-	-	1	3	-	-	-	1	-	-	-	1	6
<u>Obliquaria reflexa</u>	-	-	-	2	1	-	-	-	-	-	-	-	3
<u>Truncilla donaciformis</u>	-	-	-	-	1	-	-	-	-	-	-	-	1
<u>T. truncata</u>	-	-	-	-	-	-	-	-	-	-	-	-	0
<u>Proptera alata</u>	-	4	2	12	2	-	-	-	-	-	-	-	20
<u>Obovaria subrotunda</u>	-	-	-	-	-	-	-	-	-	-	-	-	0
<u>Leptodea fragilis</u>	2	-	1	3	-	-	-	1	-	2	1	1	11
<u>Ligumia nasuta</u>	-	-	-	1	-	-	-	-	-	-	-	-	1
<u>L. recta</u>	-	-	-	1	2	-	-	-	-	-	-	-	3
<u>Lampsilis r. siliquoidea</u>	3	14	4	28	1	4	-	-	-	-	-	-	54
<u>L. ventricosa</u>	-	-	-	-	1	-	-	-	-	-	-	-	1
Fam. Corbiculidae													
<u>Corbicula fluminea</u>	-	1	-	-	-	-	-	-	-	-	1	2	4
Total Specimens	8	71	19	66	30	7	0	3	0	4	2	5	215
Total Species	4	9	8	13	10	4	0	3	0	3	2	4	18
	8	27	14	66	21	7	0	3	0	4	1	2	
Cum Individ	8	35	49	115	136	143		146		150	151	153	
Cum Species	4	7	8	14	15								

Discussion and Conclusions

Obovaris "*leibii*" (= *O.* *subrotunda*, see below) was not found alive during this survey nor during the previous survey. We believe, therefore, that it does not occur in the sampling area either along the 6-foot below MLW contour or in shallower water in the area. The species is relatively common on the beach, common enough to indicate a substantial population offshore. In our opinion, if that population extended into water there as shallow as 6 feet below MLW, it would have been detected. After all, *Truncilla* *donaciformis* was found alive, and that is smaller, and on the beach it is less common, than *O.* "*leibii*". Of course we cannot say with complete certainty that *O.* "*leibii*" does not occur within the sample area, but we have now sampled so extensively that I believe we can say that its occurrence there is most unlikely. At any rate, the main population of *O.* "*leibii*" must occur in deeper water and only stray specimens, if any, will likely ever be found in this area within the 6-foot below MLW contour.

Our data also indicate something about the regions of greatest density and diversity of the freshwater mussel fauna (Table 2).

Table 2

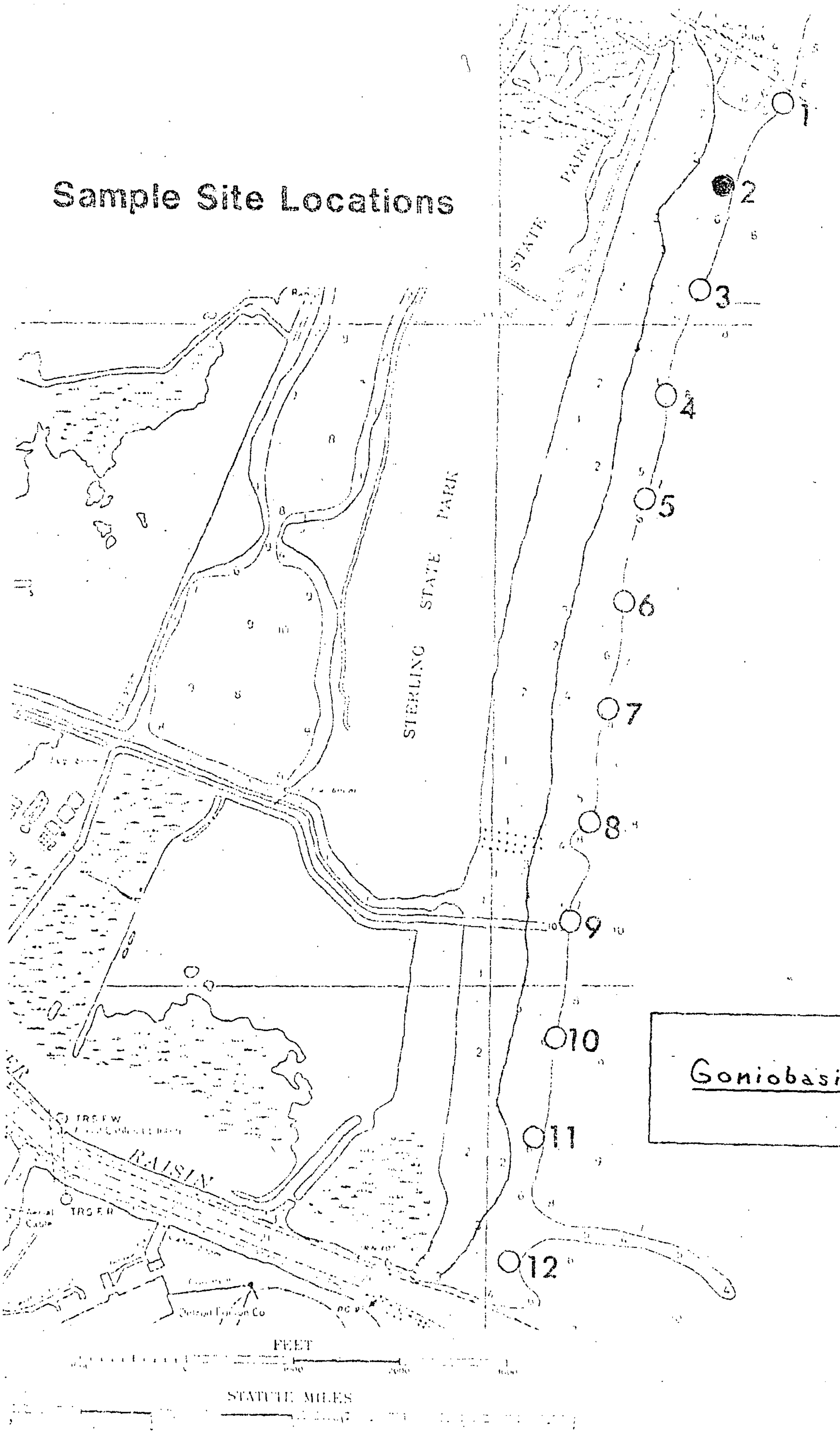
Relative Abundance of Freshwater Mussels and Faunal Diversity at Sample Sites

Sample Site	1	2	3	4	5	6	7	8	9	10	11	12
Effort (Diver Minutes)	90	174	166	96	104	114	110	70	84	66	70	72
Unionid Specimens	8	35	14	66	21	7	0	3	0	4	2	5
Specimens/Minute	.09	.20	.08	.69	.20	.06	0	.04	0	.07	.03	.07
Unionid Species	4	7	7	13	9	4	0	3	0	3	2	4
Specimens (First Survey)	0	11	4	8	8	3	3	3	9	4	5	0
Species (First Survey)	0	7	4	5	5	2	2	3	8	2	3	0

Inspection of Table 2 indicates that, except for station 9, a close correlation exists between the area of greatest richness and diversity shown by this survey and by the initial survey. The proper location of station 9 (and only that station) could not be closely approached during this survey because of thin ice there, and the results of the two surveys at station 9 may be discordant for that reason. Among the other stations, however, Stations 2, 4, and 5 showed the densest mussel population in each survey.

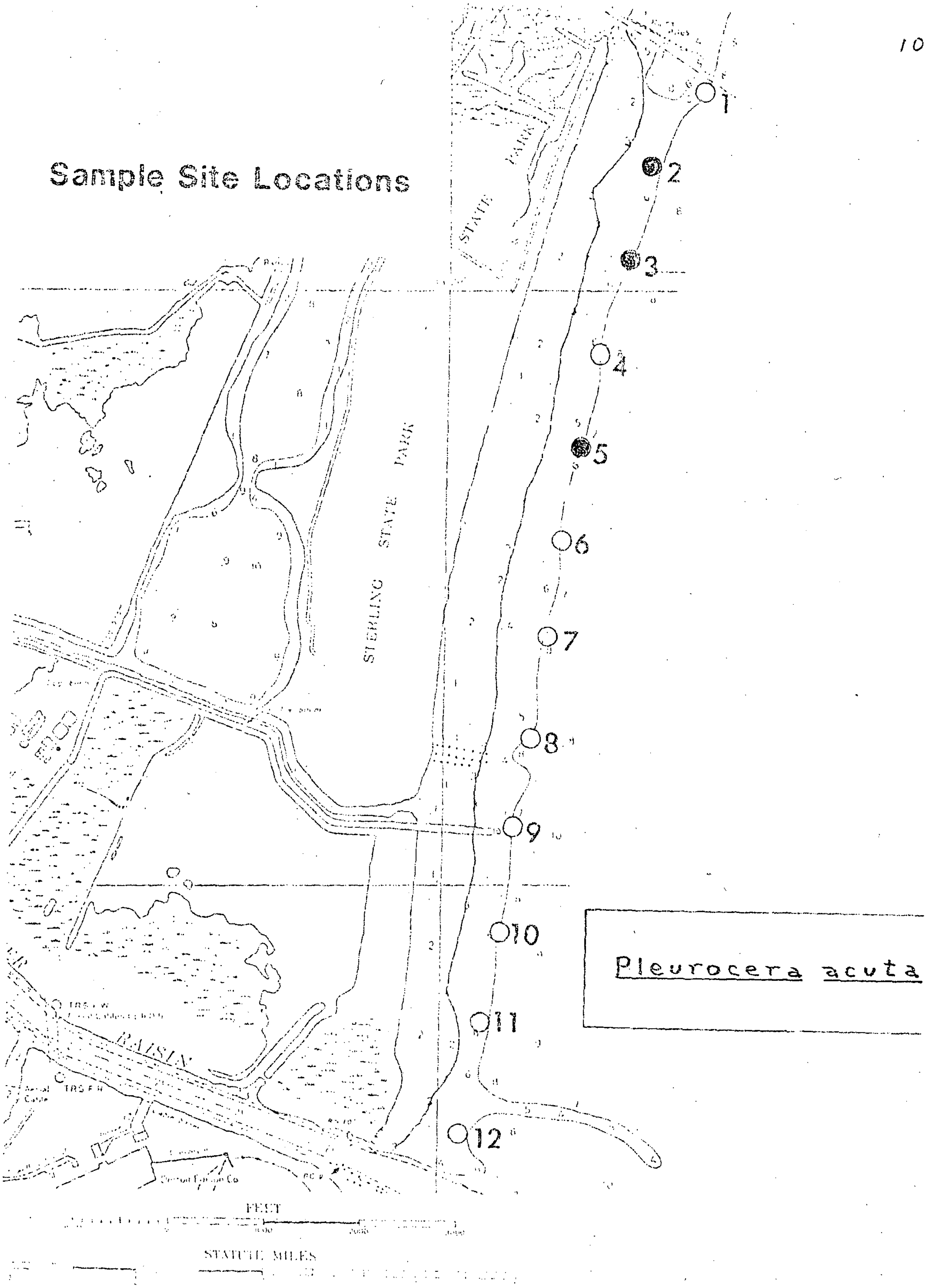
In the opinion of ECOSEARCH, INC., the presence of Obovaria "leibii" in the area is most unlikely. There is therefore no reason, on that account, to defray construction of the storage facility at Sterling State Park. If it is desired to minimize the impact of that structure on mussel beds, however, our data indicate that the area off the southern end of the park (stations 6-8) and the area between that and the River Raisin (stations 10-12) contain sparser populations of mussels than the area off the northern end of the park (stations 2-5).

Sample Site Locations



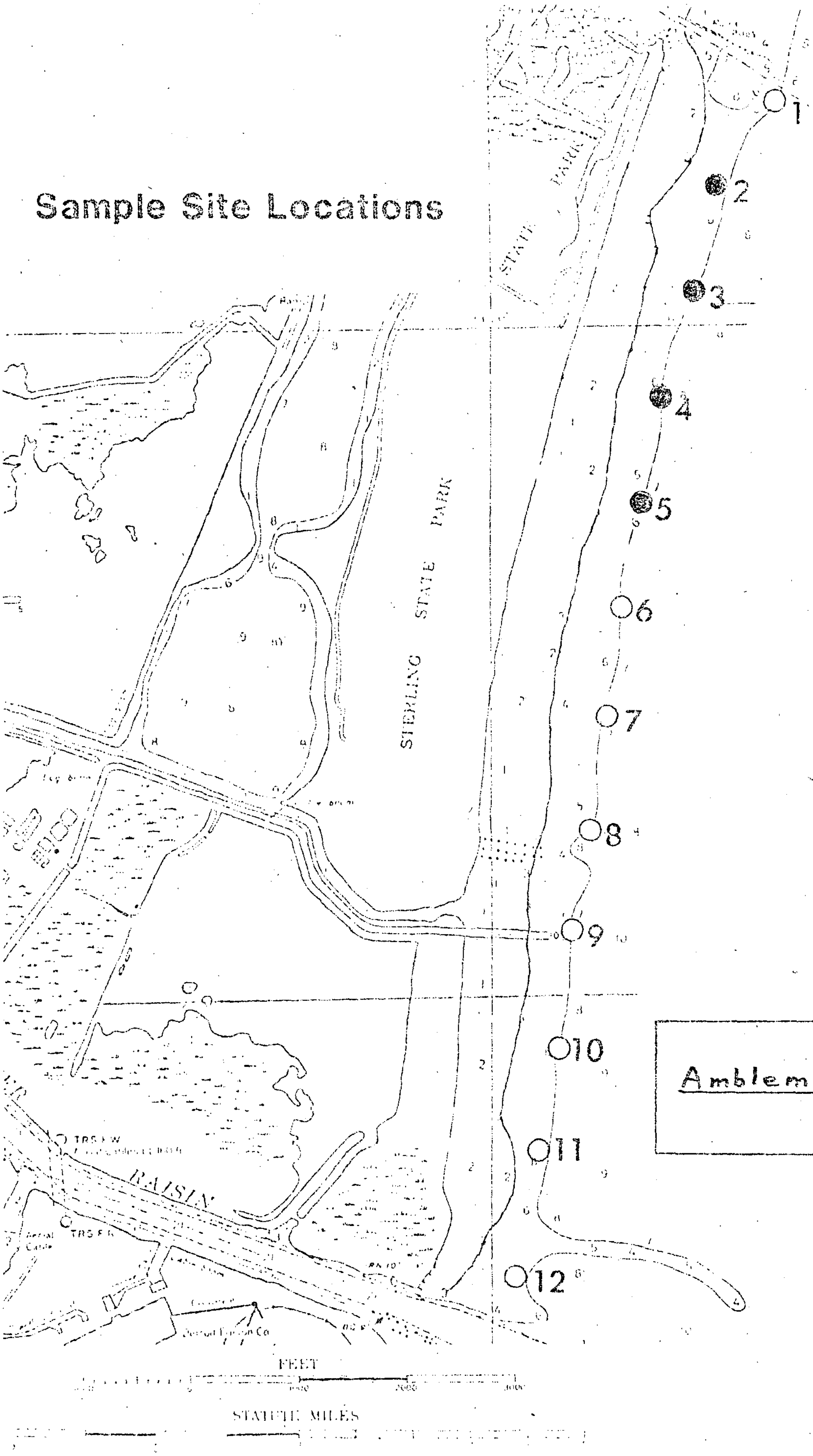
Goniobasis livescens

Sample Site Locations



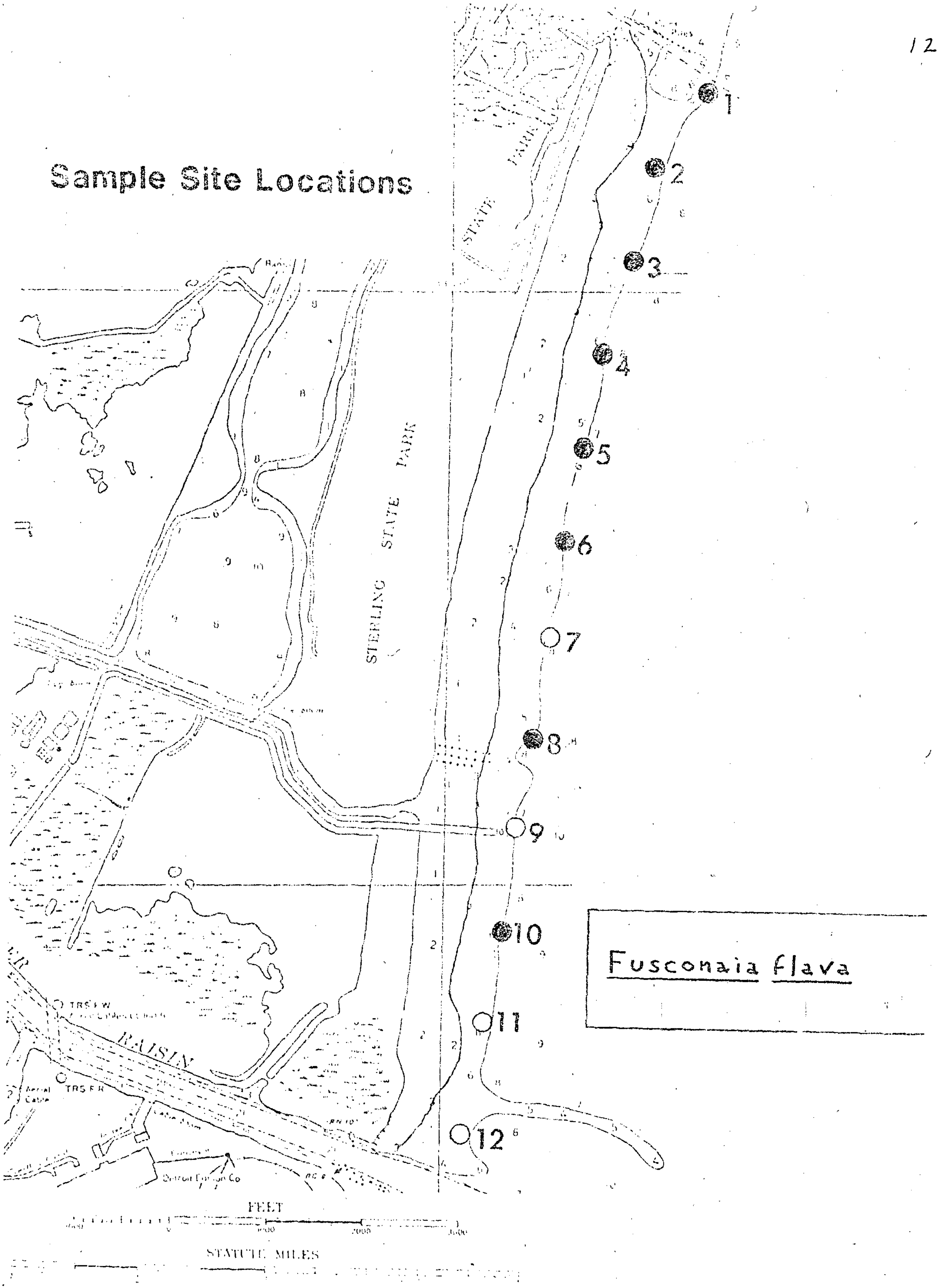
Pleurocera acuta

Sample Site Locations



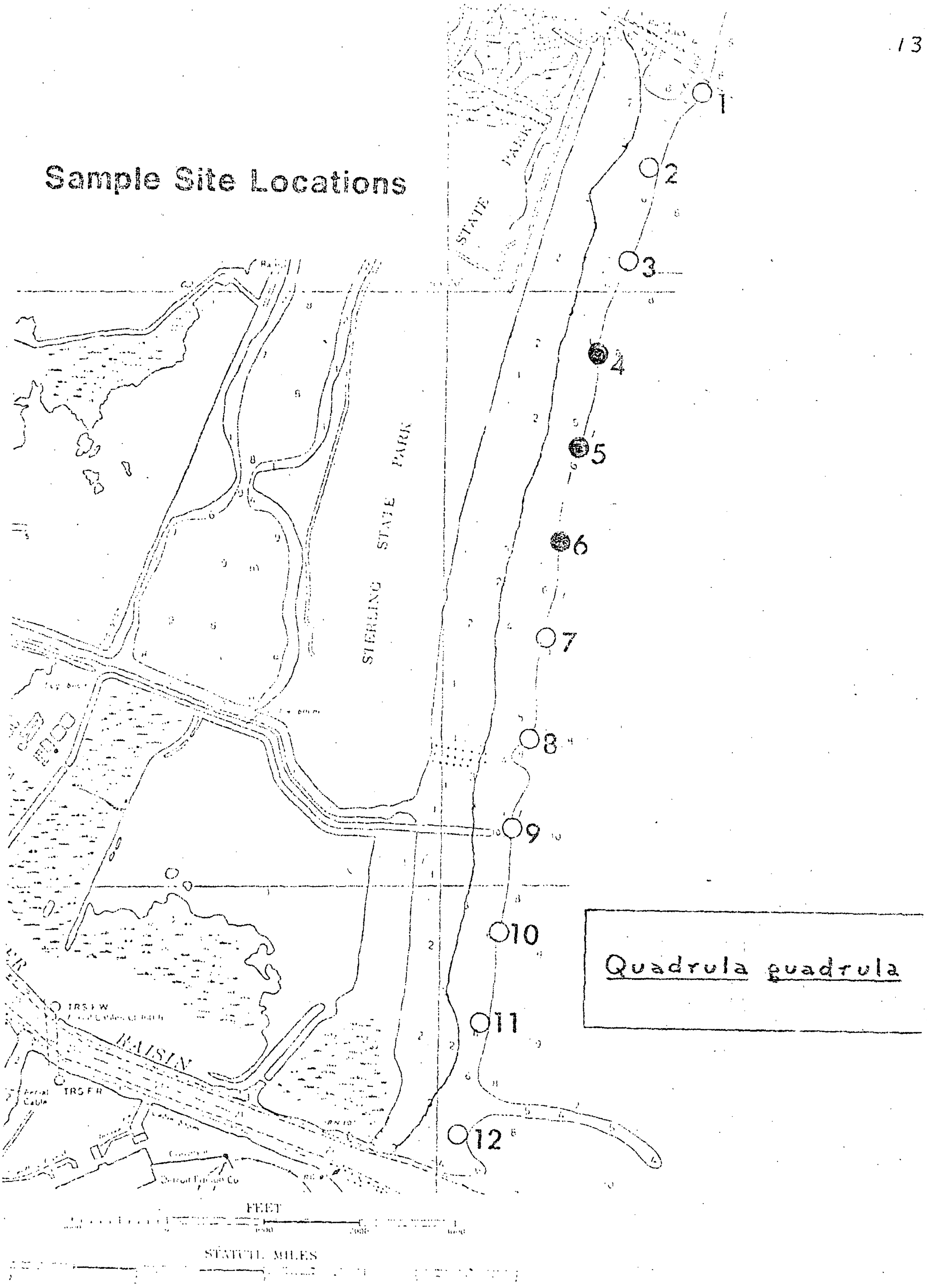
Amblema plicata

Sample Site Locations

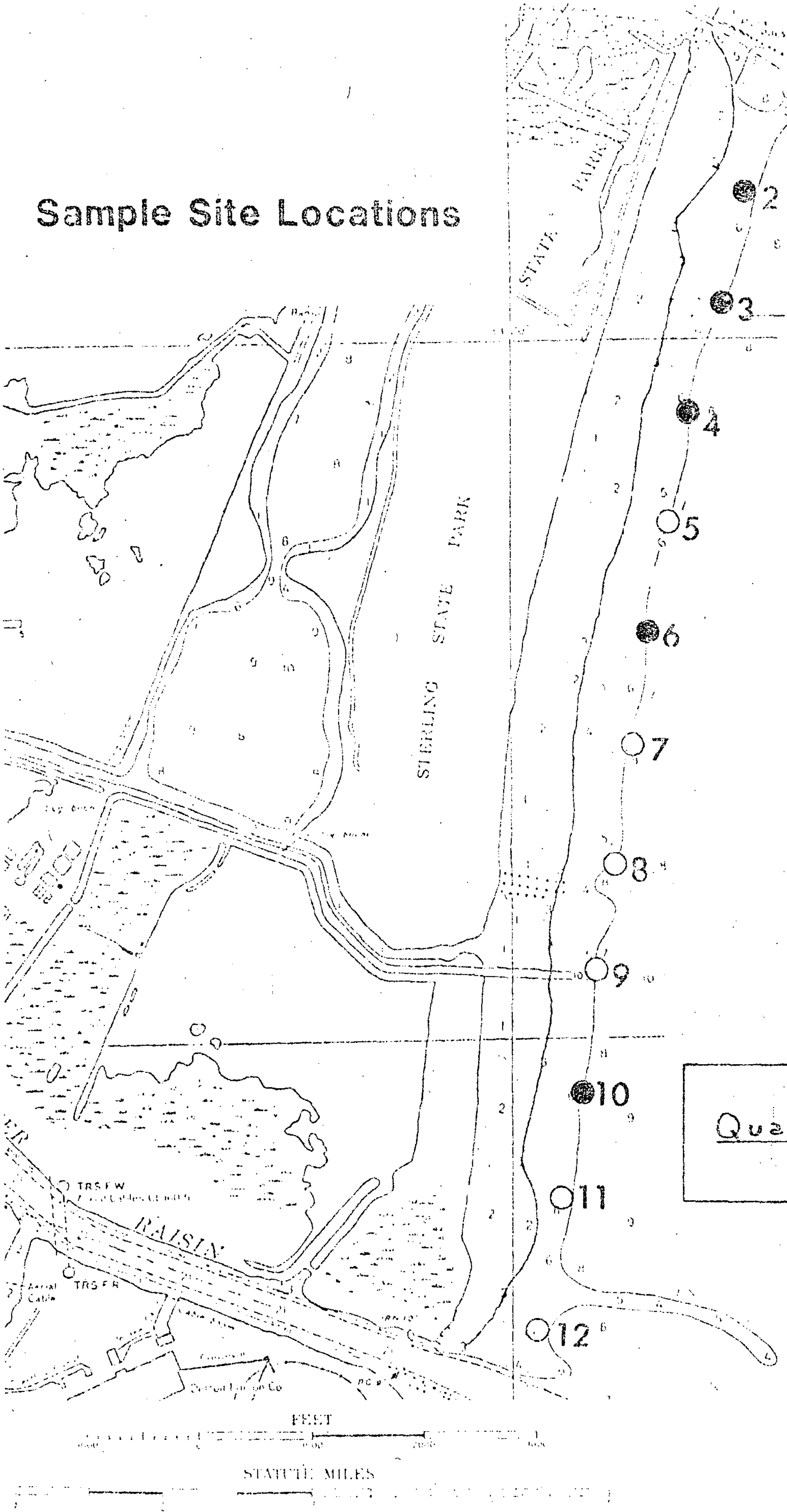


Fusconaia flava

Sample Site Locations

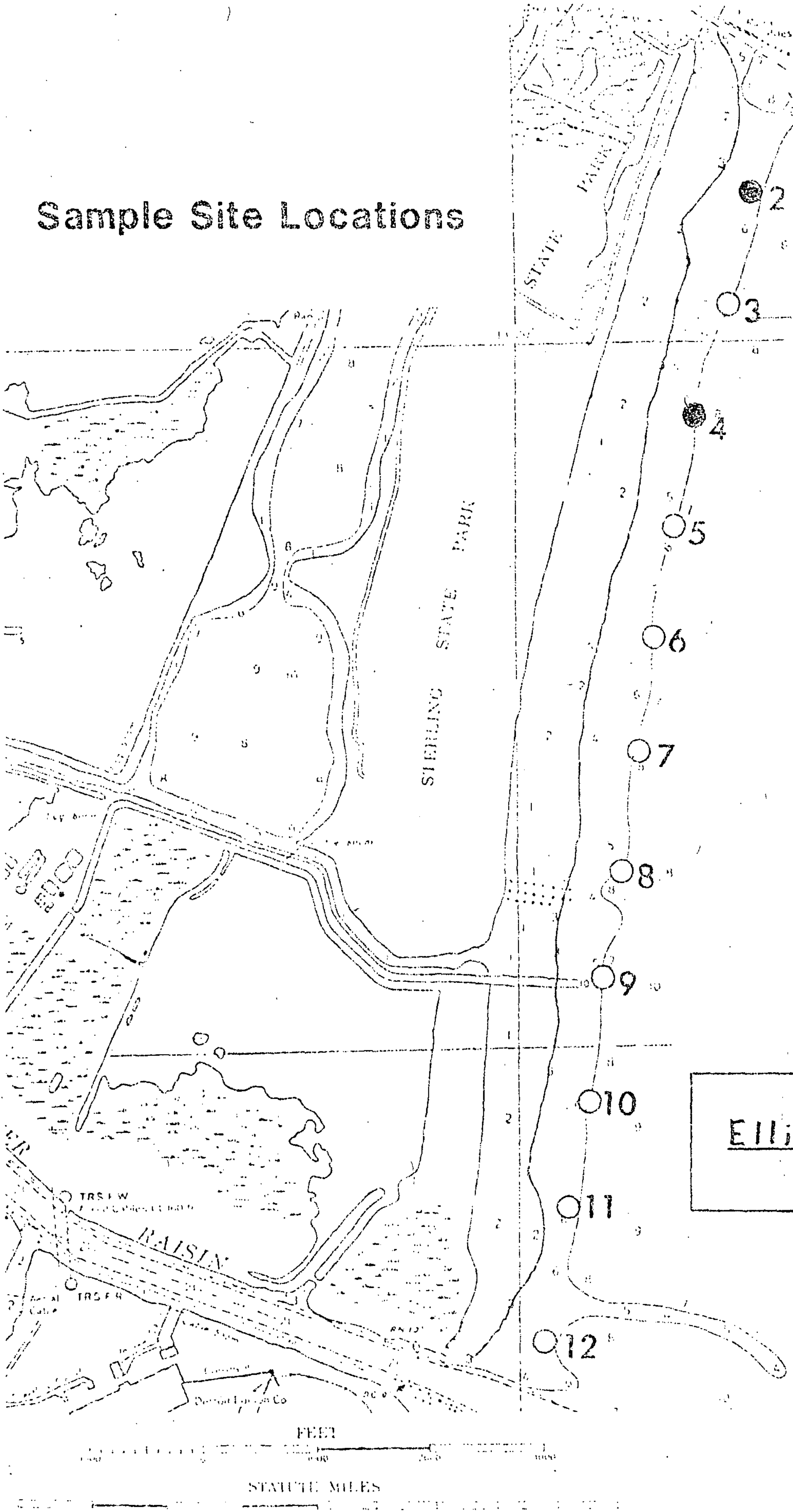


Sample Site Locations



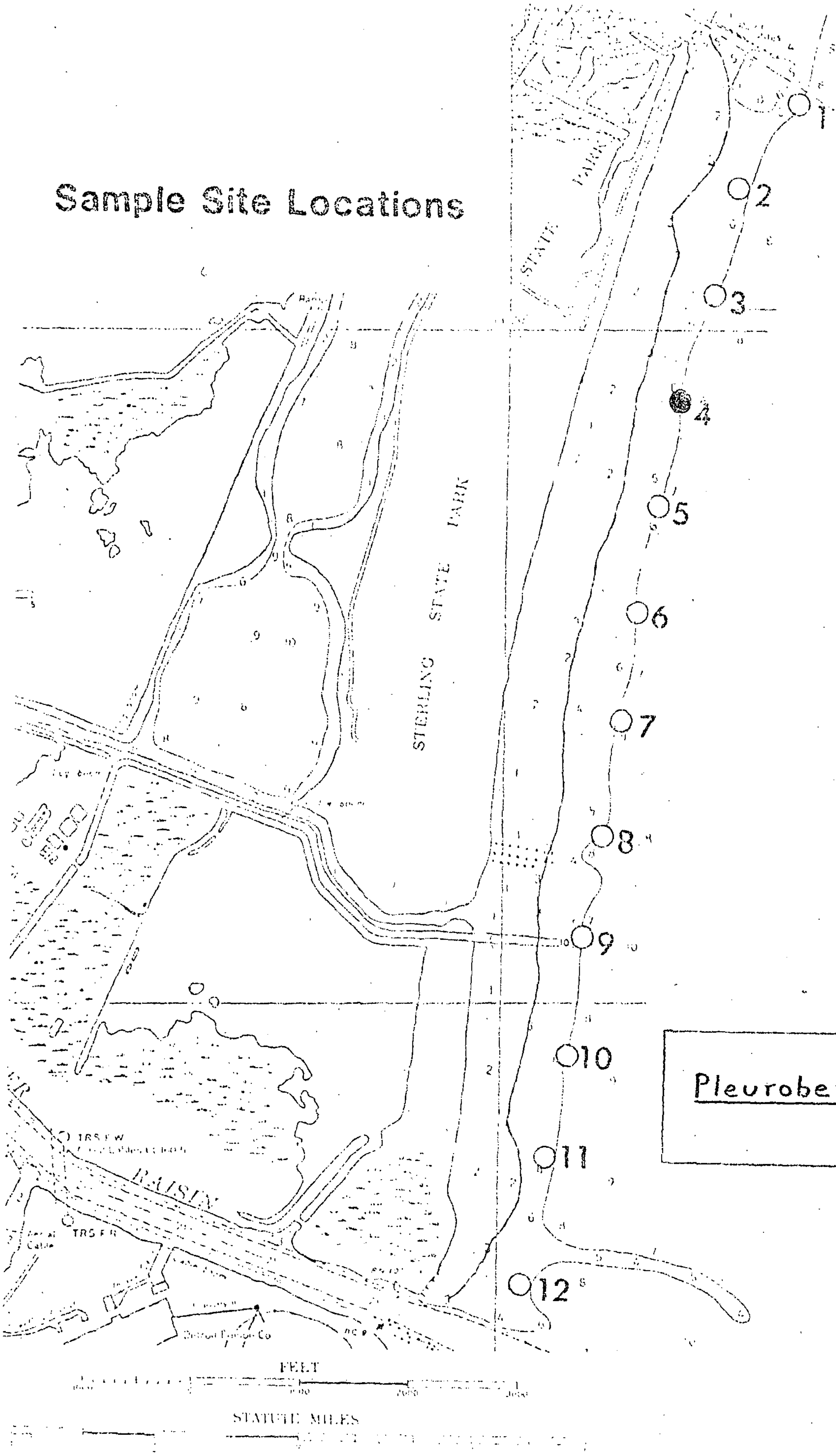
Quadrula pustulosa

Sample Site Locations



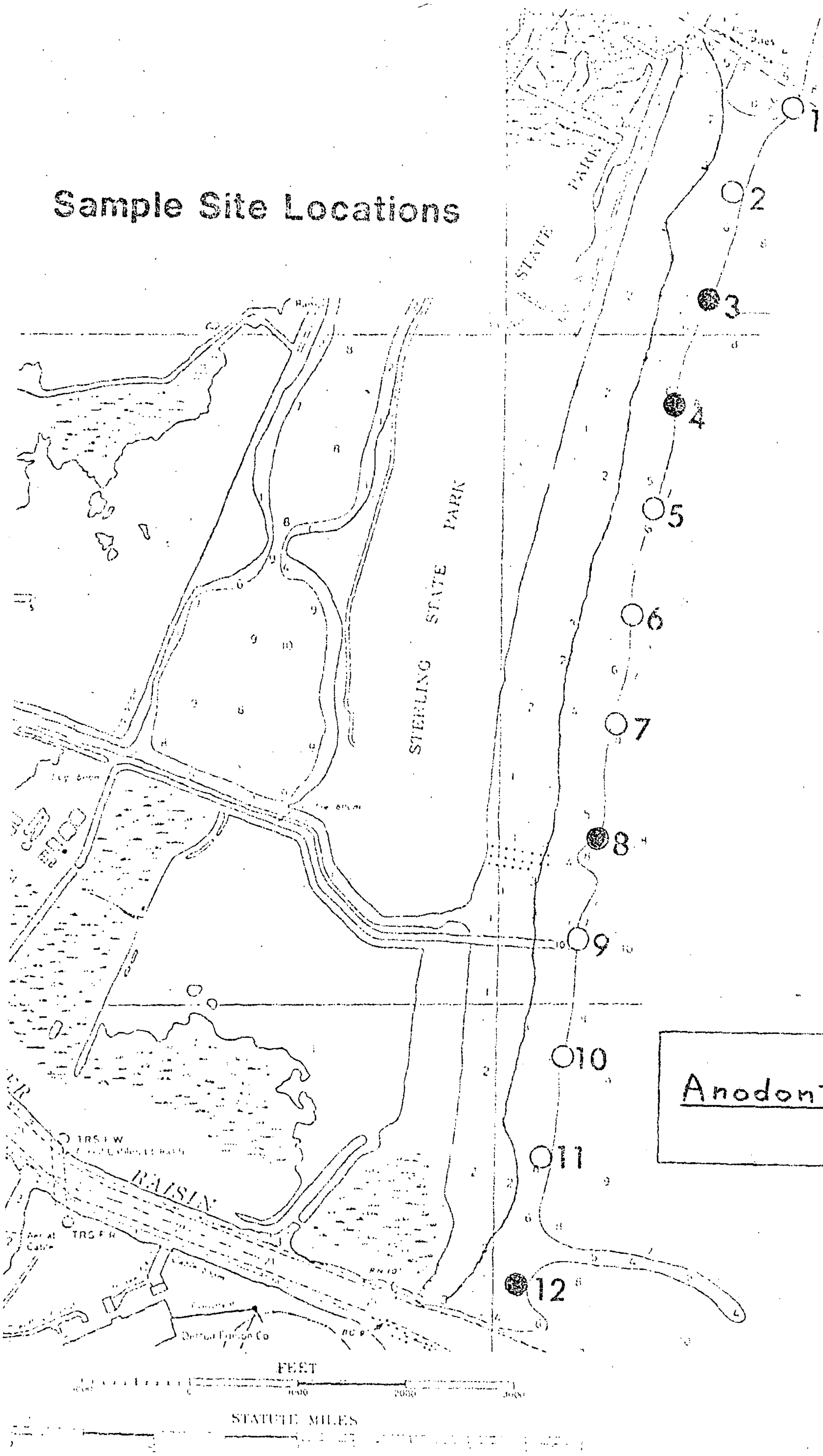
Elliptio dilatata

Sample Site Locations



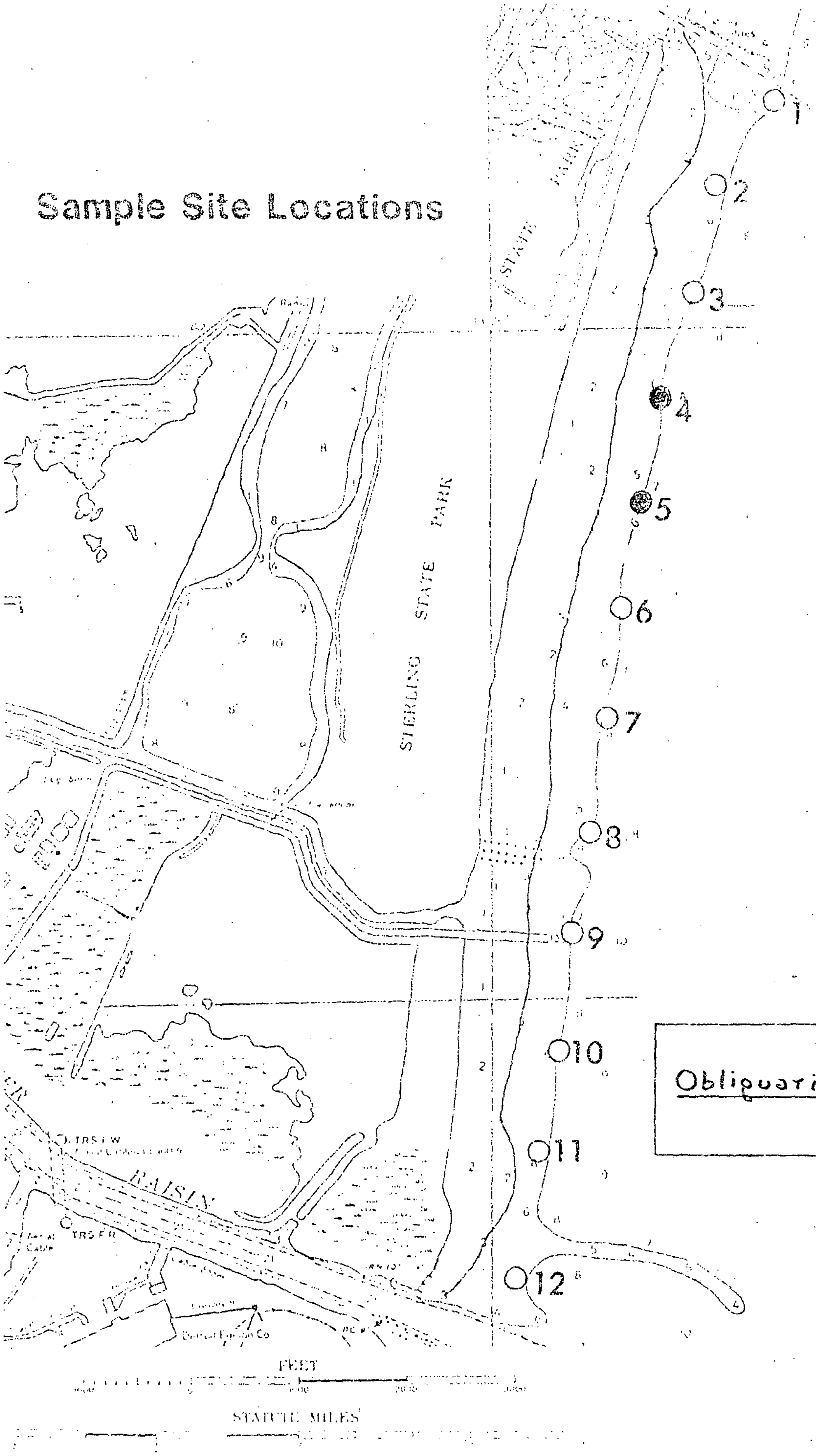
Pleurobema coccineum

Sample Site Locations



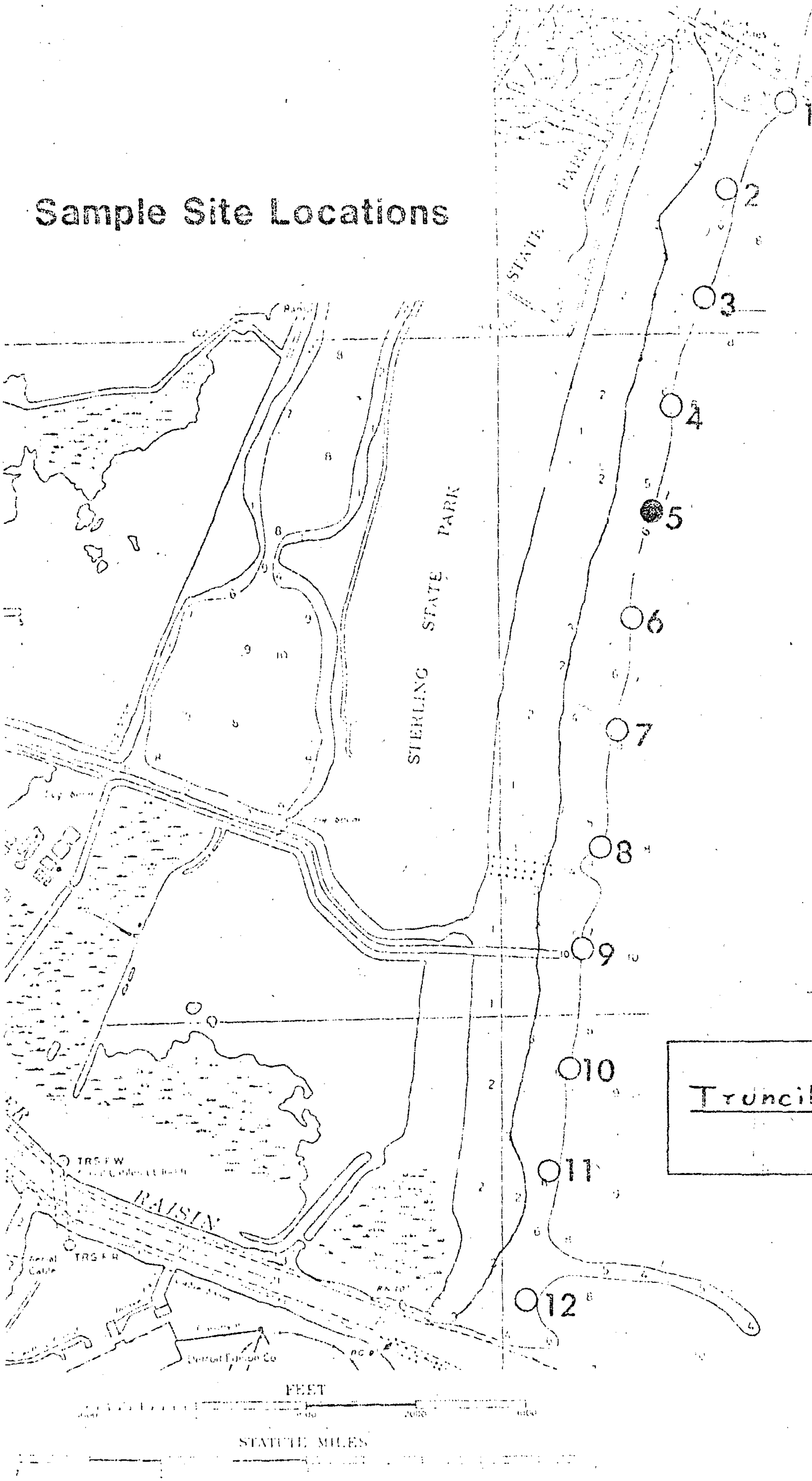
Anodonta grandis

Sample Site Locations



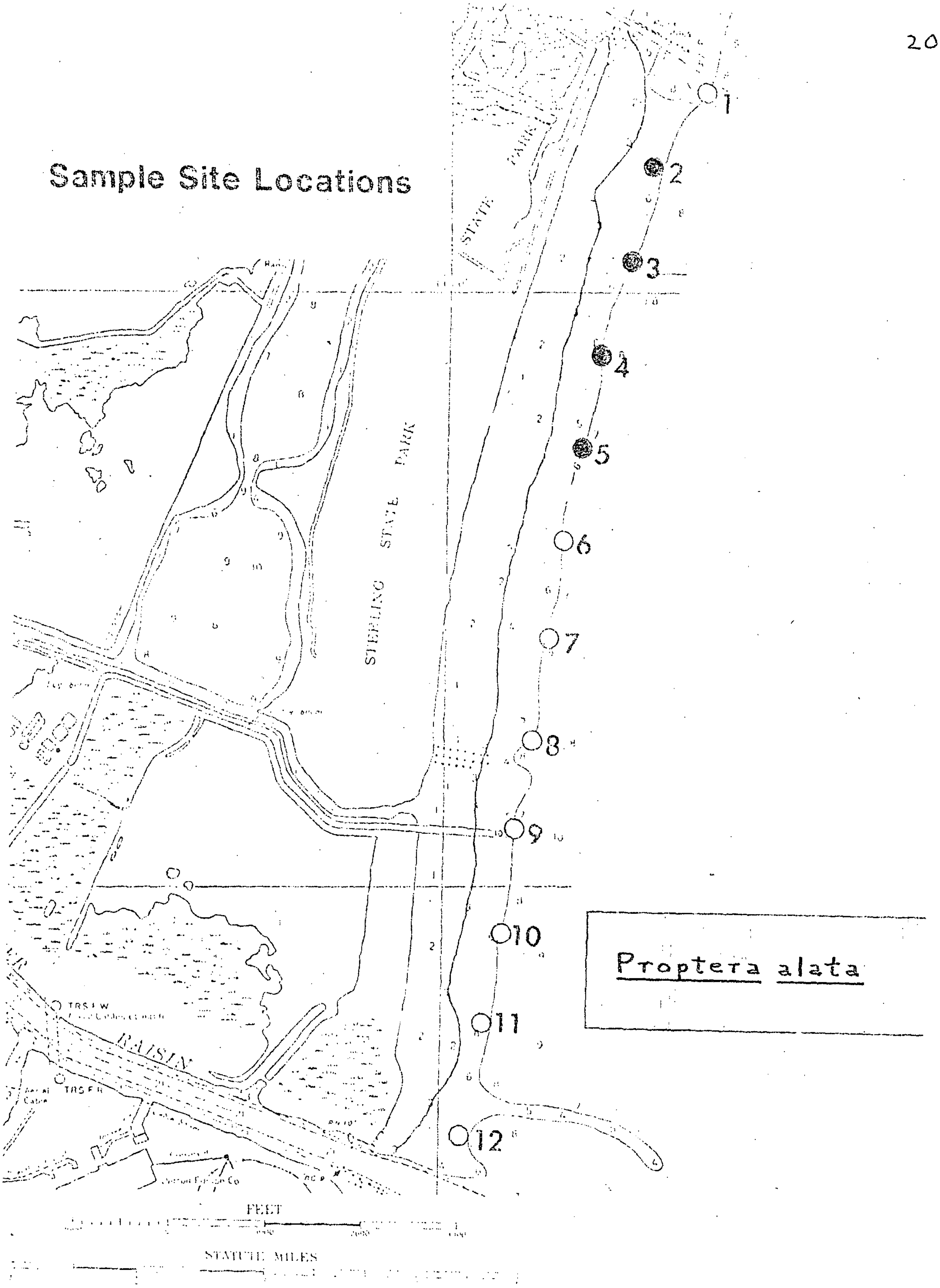
Obliquaria reflexa

Sample Site Locations

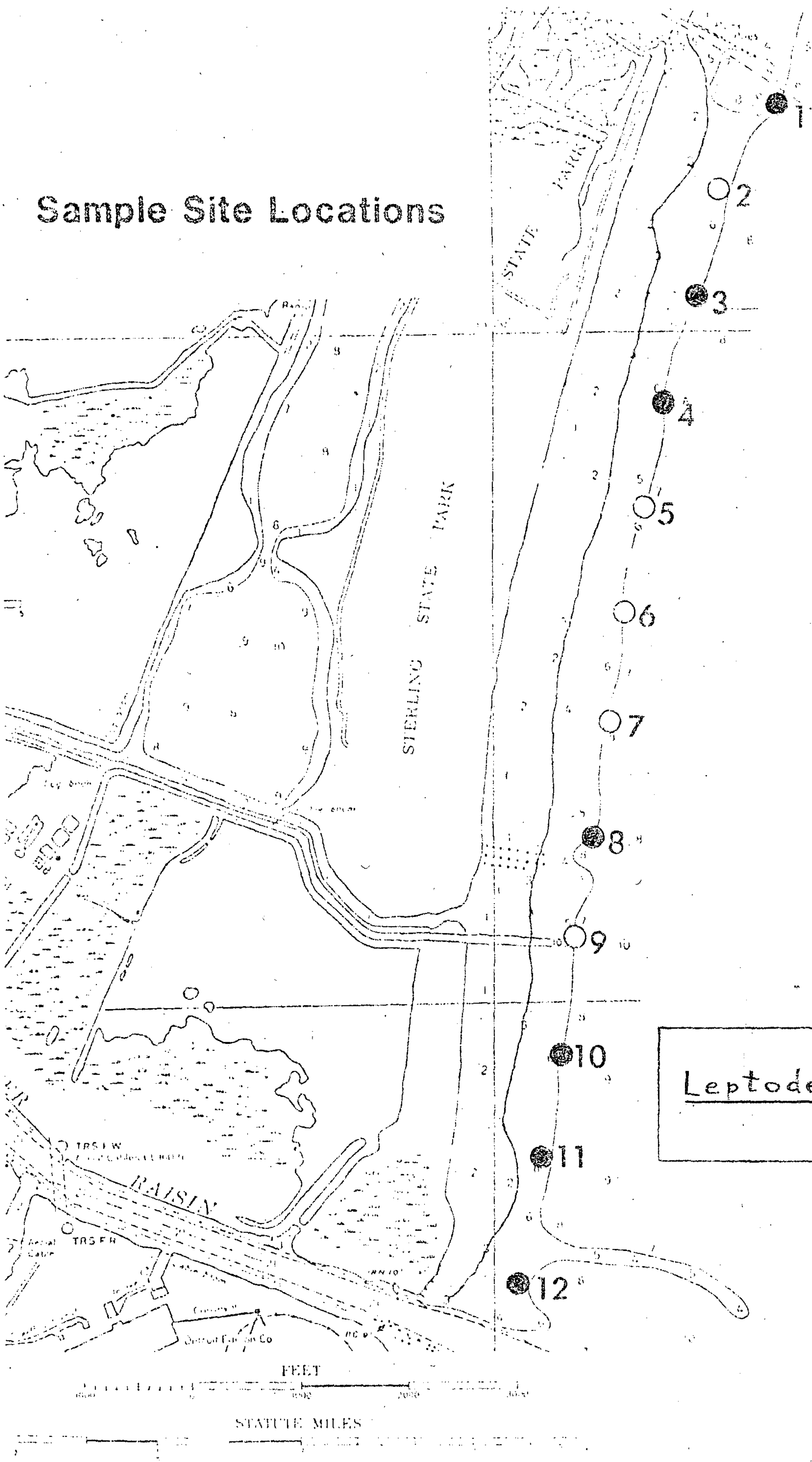


Truncilla donaciformis

Sample Site Locations

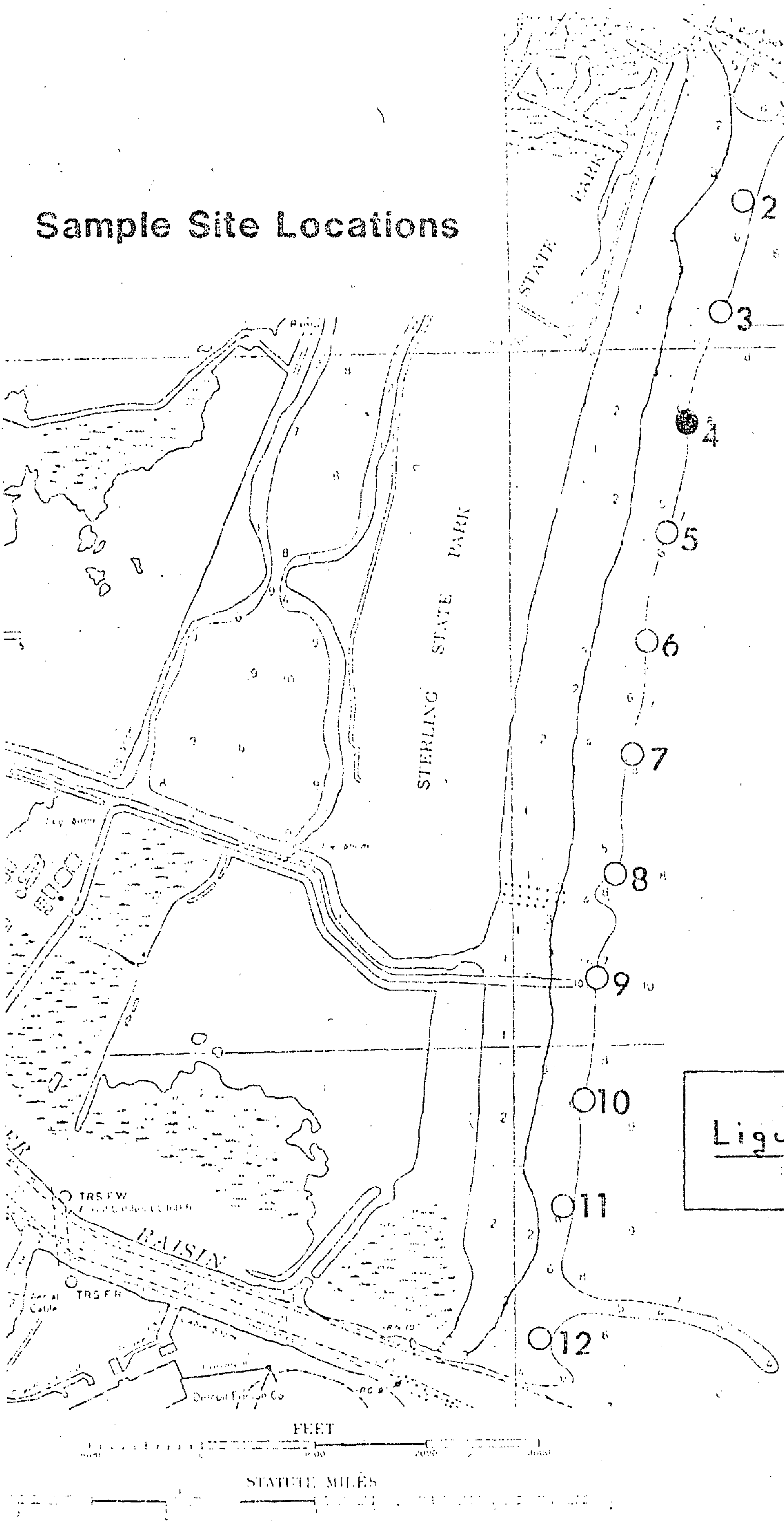


Sample Site Locations



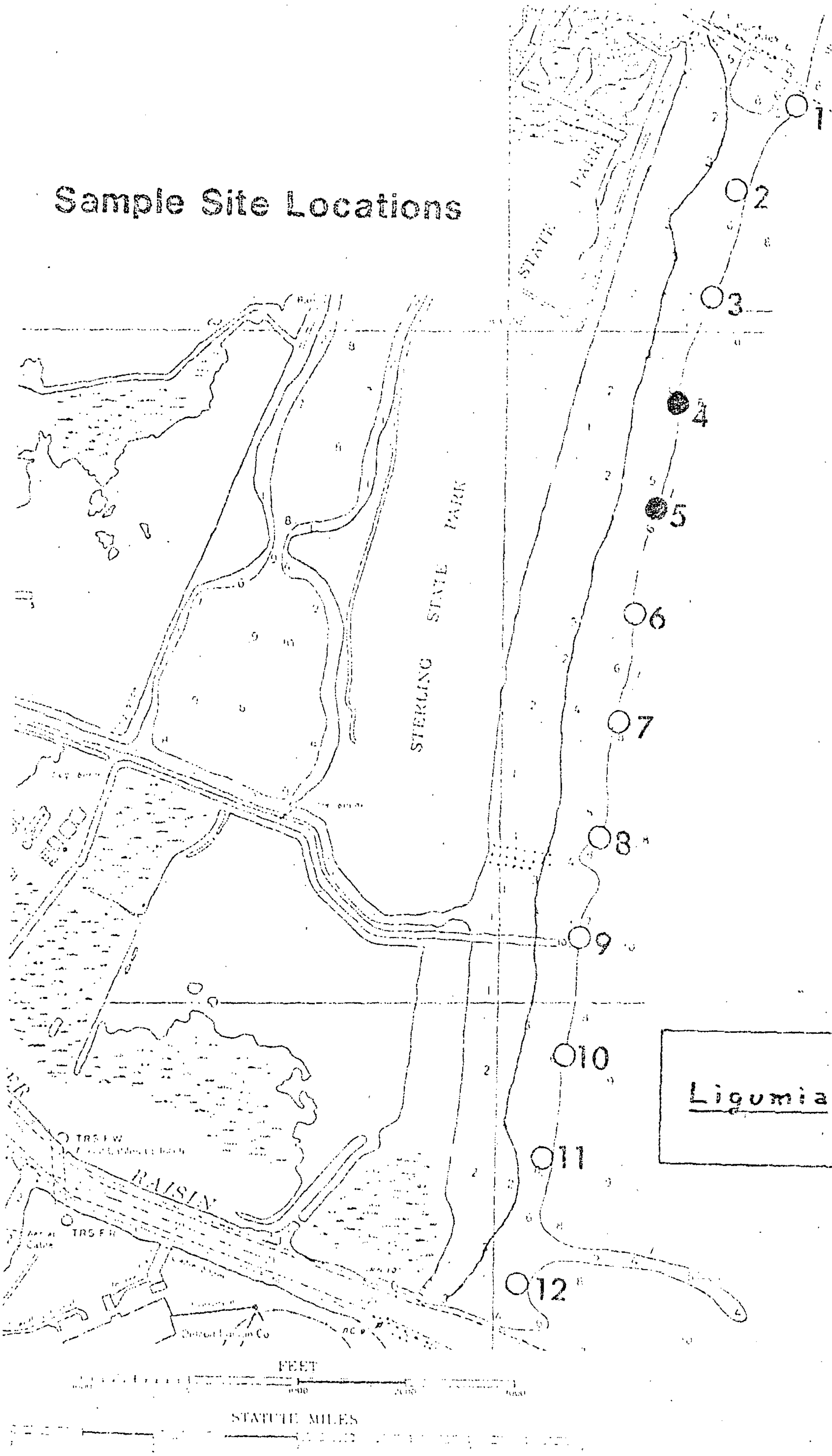
Leptodea fragilis

Sample Site Locations



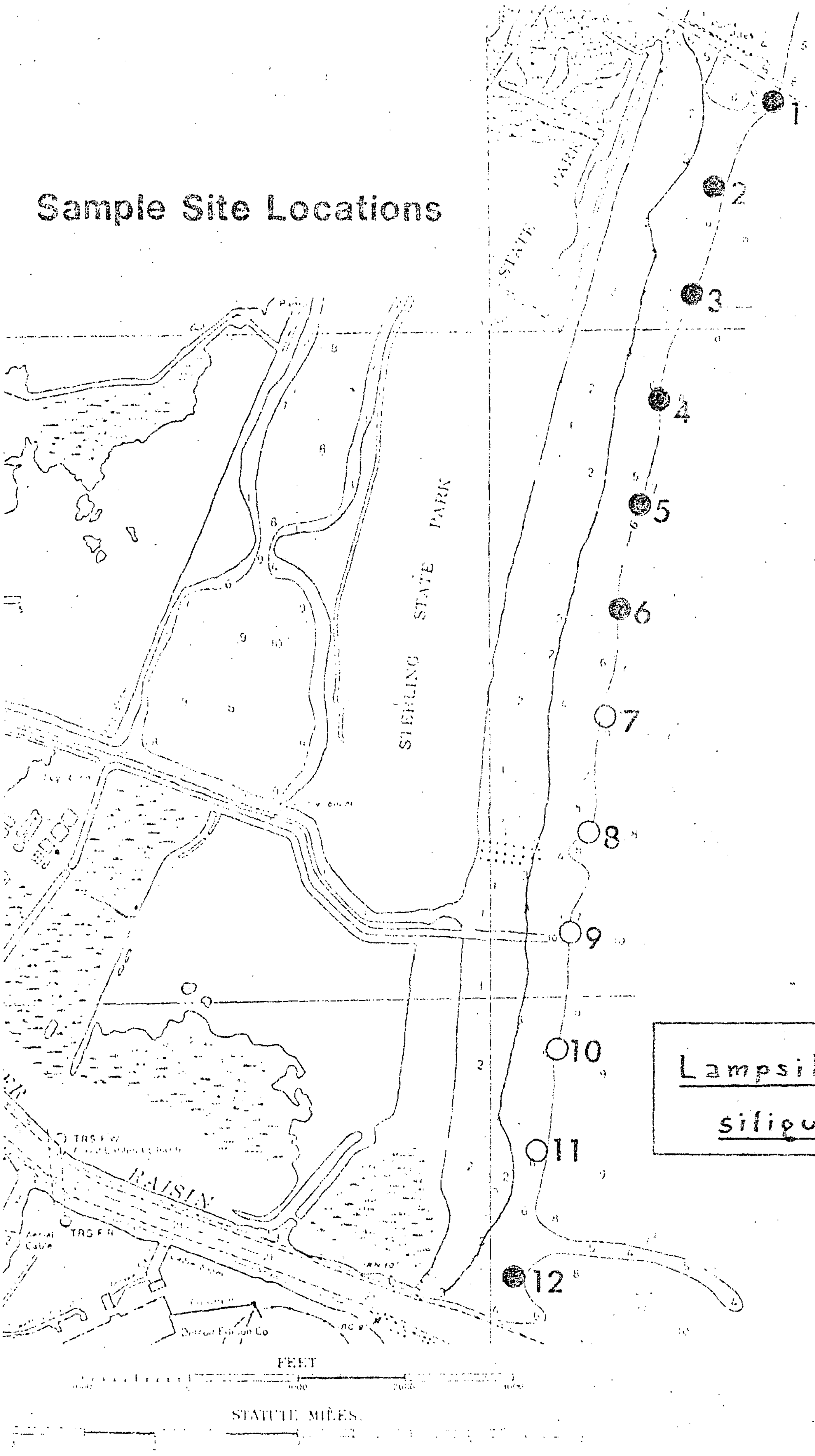
Ligumia nasuta

Sample Site Locations



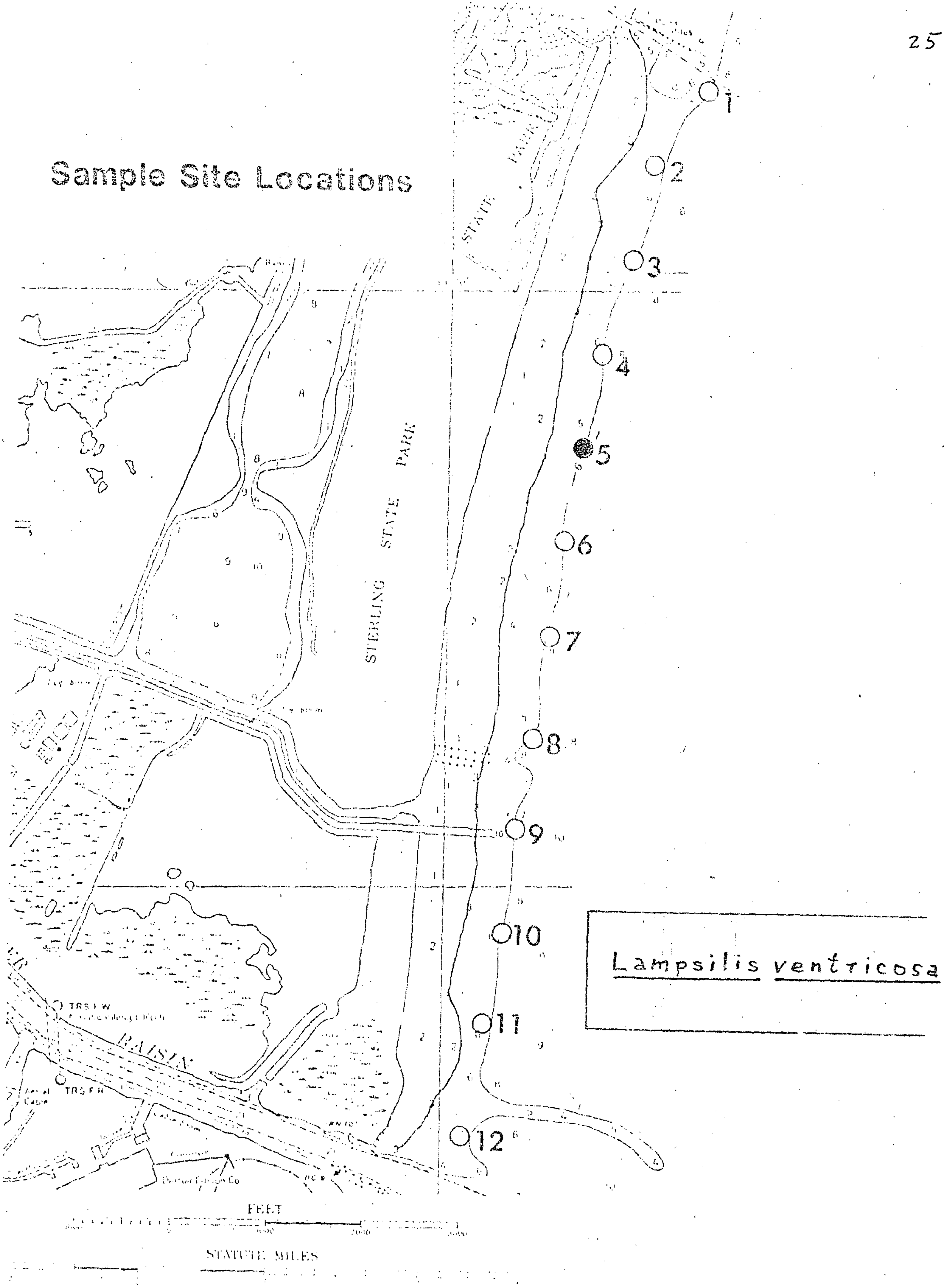
Ligumia recta

Sample Site Locations



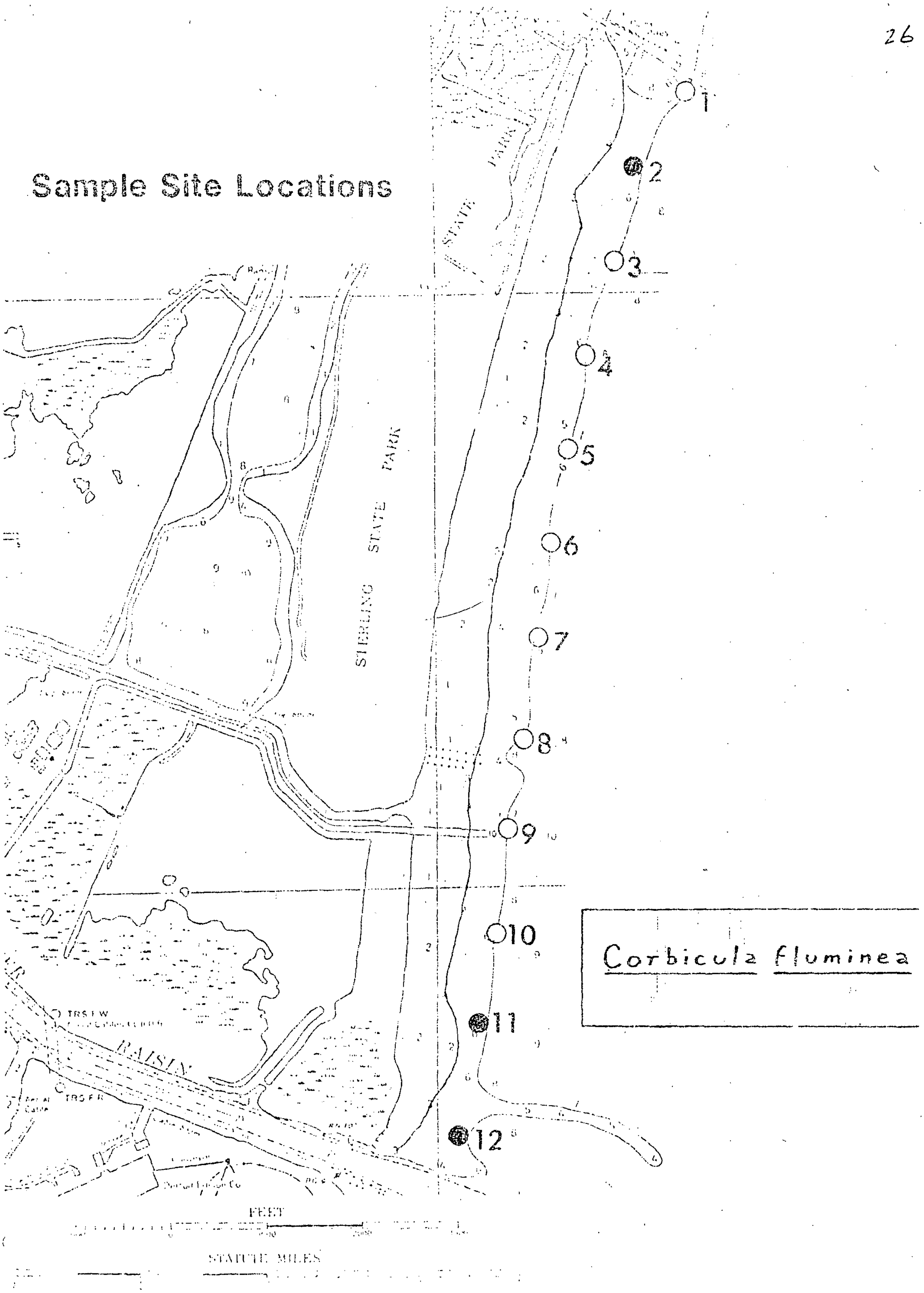
Lampsilis radiata siliquoidea

Sample Site Locations



Lampsilis ventricosa

Sample Site Locations



Appendix

Discussion of the Taxonomic Status of Obovaria leibii Lea

In 1862 Isaac Lea described an apparently new species, which he named Unio leibii. His material consisted of two unmatched valves from "Erie County, Michigan" collected by G.C. Leib, M.D. (other authors have pointed out that since there is no Erie County in Michigan, Lea must have meant Erie County, Ohio). Later Lea (1866) expanded on his original description, as follows:

> "Shell smooth, quadrate, subcompressed, very inequilateral, emarginate behind and rounded before; substance of the shell rather thick, thicker before; beaks somewhat prominent and nearly terminal; epidermis straw yellow, without rays, with numerous close lines of growth; umbonial slope slightly raised and rounded; posterior slope raised into a high carina, almost a wing, and so impressed as to form an emargination on the posterior margin; cardinal teeth rather large, erect, striate and disposed to be tripartite in the right valve; lateral teeth short, straight, thick and double in both valves; anterior cicatrices distinct, small and well impressed; posterior cicatrices confluent and very slightly impressed; dorsal cicatrices placed under the base of the cardinal tooth; cavity of the shell rather deep and round; cavity of the beaks rather shallow and angular; nacre white and slightly iridescent.
>
> Remarks.--Two odd valves only of this small species were among a number of common species from the Michigan Zoological District. It is remarkably quadrate in the outline. In these specimens the cardinal tooth is trifid in the right and double in the left valve, and the lateral teeth double in both valves. But this may not pervade all this species, as we find aberrations in the teeth of many of the species. The outline of this shell is very unusual. It is remarkably quadrate, and it is greatly to be regretted that perfect specimens of both valves were not in our possession, better to describe its characteristics. I name it after Dr. Leib, who sent it to the Smithsonian Institution."

Lea reported the size of his specimen to be: "Diam. .8, Length 1, Breadth 1.3 inches" and provided 2 illustrations of Unio leibii (see Figure 1). (In Lea's time "length" was used to mean what is now approximately equivalent to height and "breadth" was equivalent to the modern "length"). The type specimen in the Smithsonian Institution is a single right valve (USNM 84425) and exactly matches the first illustration given by Lea (our Figure 1,a).

It is useful to mention here that Obovaria subrotunda, which I believe is a senior synonym of O. leibii, is sexually dimorphic. The males are nearly circular but the females exhibit a low radial posterior depression and their posterior-ventral margins are flattened.

The next author to comment critically on Unio leibii was R.E. Call (1899:494) who, is remarks pertaining to Unio circulus Lea, wrote:

> "A very depauperate form comes from Lake Erie; under the rolling of waves and beating on the bars along the shores the conditions of life are such that the animal exhausts all its energy in maintaining life rather than in building shell material. To this shell Lea gave the name of leibii."

Thus Call considered U. leibii to be an ecophenotype of Unio circulus Lea, a decision which I believe to be correct, but not for the reasons given by Call.

Unio circulus had been described by Lea in 1829 from specimens collected in the Ohio River at Cincinnatti, the Monongahela River at Pittsburgh, and the Tennessee River at Nashville. The dimensions given were: "Diam. 1, Length 1.5, Breadth 1.5 inches". Lea's description (pp. 433-434) is as follows:

> "Shell round; posterior basal margin sometimes very slightly emarginate, very ventricose, transversely wrinkled, nearly equilateral; substance of the shell thick; beaks elevated, medial, and somewhat recurved; epidermis finely wrinkled, shining, satin-like, anterior to the umbonial slope dark brown, posterior light yellow brown; cardinal teeth oblique, thick, and disposed to be treble in both valves; lateral teeth short and thick, disposed to be double in right valve as well as left. Anterior cicatrices distinct; posterior cicatrice also distinct; the smaller one being placed against the termination of the lateral tooth; dorsal cicatrices situated on the under part of the cardinal tooth, very perceptible; cavity of the beaks deep and sub-angular; nacre white, pearly, and iridescent, rarely tinted with rose in the centre."

Under "Remarks" (p. 434) Lea offers other useful information, viz:

> "The margin of the circulus is more perfectly round than any other species; it is sometimes disposed to be subangular posteriorly. The division of the colour on the umbonial slope is very peculiar. When the posterior slope is looked on, this view of the shell is heart shaped, and the dark brown colour is seen entirely to surround the light yellow brown. The epidermis is more satin-like than any other species, and the teeth are peculiarly disposed to be double."

Lea's illustrations of U. circulus are also given in Figure 1.

After Call, the next worker to consider U. leibii was Simpson (1900) who recognized that the hundreds of species of freshwater mussels in the world-wide fauna which had been placed under the genus Unio belonged to many different genera. He assigned Unio leibii to the genus Obovaris Rafinesque (1819). He also recognized O. retusa (Lamarck), O. tinkeri (Wright), O. lens (Lea), O. lens var. depygis (Conrad), O. unicolor (Lea), O. rotulata Lea, O. ellipsis (Lea) and O. castanea (Lea). Simpson expanded on his "Synopsis" in 1914. Under O. leibii (p. 296) he wrote:

> "I am inclined now to believe this is a valid species, certainly as good as most of those of this puzzling group. It is always small and longer than high, it is comparatively thin, and its female shells are more produced in the marsupial region than those of O. circulus."

Although the genus name *Obovaria* Rafinesque is still used by modern authors for this group, more than half of the "species" recognized by Simpson are now considered invalid.

Vanatta (1915) next pointed out that *Unio circulus* Lea, 1829 had been described previously by Rafinesque (1820) as *Obliquaria subrotunda*. We will not quote Rafinesque's brief description because, unlike Lea's detailed descriptions, it does not assist in recognizing the species. The name change of *Obovaria circulus* (Lea, 1829) to *Obovaria subrotunda* (Rafinesque, 1820) was followed by all other authors, however, and that name is still used today.

In 1919, in his important monograph on the mussels of Pennsylvania, A.E. Ortmann wrote (p. 225, under *O. subrotunda*) as follows:

> "Another "species"," distinguished by Lea (and Simpson), *O. leibi* (Lea), is nothing but the form from Lake Erie of *O. subrotunda*. It differs merely in its smaller size (largest at hand: L. 42, H. 38, D. 26 mm), and has, like many lake-forms, more regular and more distinct growth-rests. It is also sometimes lighter in color."

Frierson (1927:90) followed Ortmann in synonymizing *Obovaria liebii* (Lea) under *Obovaria subrotunda* (Rafinesque) and, except for its continued appearance in some faunal lists for the State of Michigan (e.g. Winslow, 1926:22) the name *Obovaria liebii* has disappeared from the roster of valid names used in the molluscan literature.

Most of the species of mussels of Lake Erie have long been known to be stunted, i.e. the maximum sizes which they achieve in Lake Erie are significantly smaller than those achieved by populations in rivers. Grier (1918:9) described new "varieties" of these species from Lake Erie, i.e. *Elliptio dilatatus* var. *sterkii*, *Lasmigona costata* var. *ereganensis*, and *Fusconaia flava* var. *parvula*. The mussel fauna of Lake Erie has been further studied by Grier (1919), Grier and Mueller (1926), Brown, Clark, and Gleissner (1938), Stansbery (1961), and by Clarke (1981).

Grier, Grier and Mueller, and Brown *et al* compare measurements of many populations of unionids from Lake Erie with those from rivers and amply demonstrate that stunting occurs in many Lake Erie species. Brown *et al* make the further point that Lake Erie has both exposed and semi-exposed habitats and (p. 700) that "the degree of stunting in Lake Erie for all species studied is definitely correlated with the degree of exposure found in the habitats. The more stunted individuals are found in the more exposed lake habitats."

None of those authors have given comparative measurements for lake morphs and river morphs of *Obovaria subrotunda*, probably because the species is usually uncommon and statistically significant population samples are difficult to acquire. The National Museum of Natural History (Smithsonian Institution) has several lots of *Obovaria subrotunda* from Lake Erie and the specimens are all less than 40 mm in length. Many specimens of *O. subrotunda* from river habitats exceed 60 mm, however. This difference is of the same order of magnitude that one normally sees when comparing Lake Erie populations of many other species with river populations of the same species.

Stansbery (1961:5) has thoroughly described several aspects of the Lake Erie mussel fauna. His general statement (p. 5) is certainly applicable here, i.e. "The naiad fauna of Lake Erie is unusual in several ways. Most, if not all, of the species found there are markedly smaller than their counterparts in streams tributary to the lake." *Obovaria subrotunda* appears to be no exception to this rule. *O. leibii* is therefore considered to be the Lake Erie ecophenotype of *O. subrotunda* and as such it does not deserve separate taxonomic status.

Literature Cited

Brown, C.J.D., C. Clark, and B. Gleissner

1938. The Size of Certain Naiades from Western Lake Erie (etc.). The American Midland Naturalist 19:682-701.

Call, R.E.

1899. A Descriptive Illustrated Catalogue of the Mollusca of Indiana. 24th Annual Report of the Department of Geology and Natural Resources of Indiana. Pp. 193-194.

Clarke, A.H.

1981. The Freshwater Molluscs of Canada, Special Publications, National Museums of Canada, 450 pages.

Frierson, L.S.

1927. A Classified and Annotated Check List of the North American Naiades. Waco: Baylor University Press.

Grier, N.M.

1918. New Varieties of Naiades from Lake Erie. The Nautilus 32:9-12.

1919. Morphological Features of Certain Mussel Shells Found in Lake Erie (etc.). Annals of the Carnegie Museum 13:145-182.

_____ and Mueller, J.F.

1926. Further Studies in Correlation of Shape and Station in Fresh Water Mussels. Wagner Free Institute of Science of Philadelphia 1: 11-28.

Lea, Isaac

1829. Description of a New Genus of the Family of Naiades (etc.). Transactions of the American Philosophical Society 3(NS): 403-457.

1862. (descriptions of new species) Proceedings of the Academy of Natural Sciences, p. 168.

1866. New Unionidae, Melanidae, etc. Journal of the Academy of Natural Sciences, 4:5-65.

Rafinesque, C.S.

1820. Monographie des Coquilles Bivalves (etc.). Annales Générales des Sciences Physiques, Brussels. Pp. 287-322.

Simpson, C.T.

1900. Synopsis of the Naiades or Pearly Fresh-Water Mussels. Proceedings of the United States National Museum, 22:501-1044.

1914. A Descriptive Catalogue of the Naiades (etc.). 3 volumes. Detroit: B. Walker.

Stansbery, D.H.

1961. The Naiades (Mollusca, Pelecypoda, Unionacea) of Fishery Bay, South Bass Island, Lake Erie. Part 1. Sterkiana, No. 5, pp. 1-37.

Vanatta, E.G.

1915. Rafinesque's Types of Unio. Proceedings of the Academy of Natural Sciences of Philadelphia, pp. 549-559.

Winslow, Mina L.

1926. A Revised Check List of Michigan Mollusca. Occasional Papers of the Museum of Zoology, University of Michigan, No. 181.

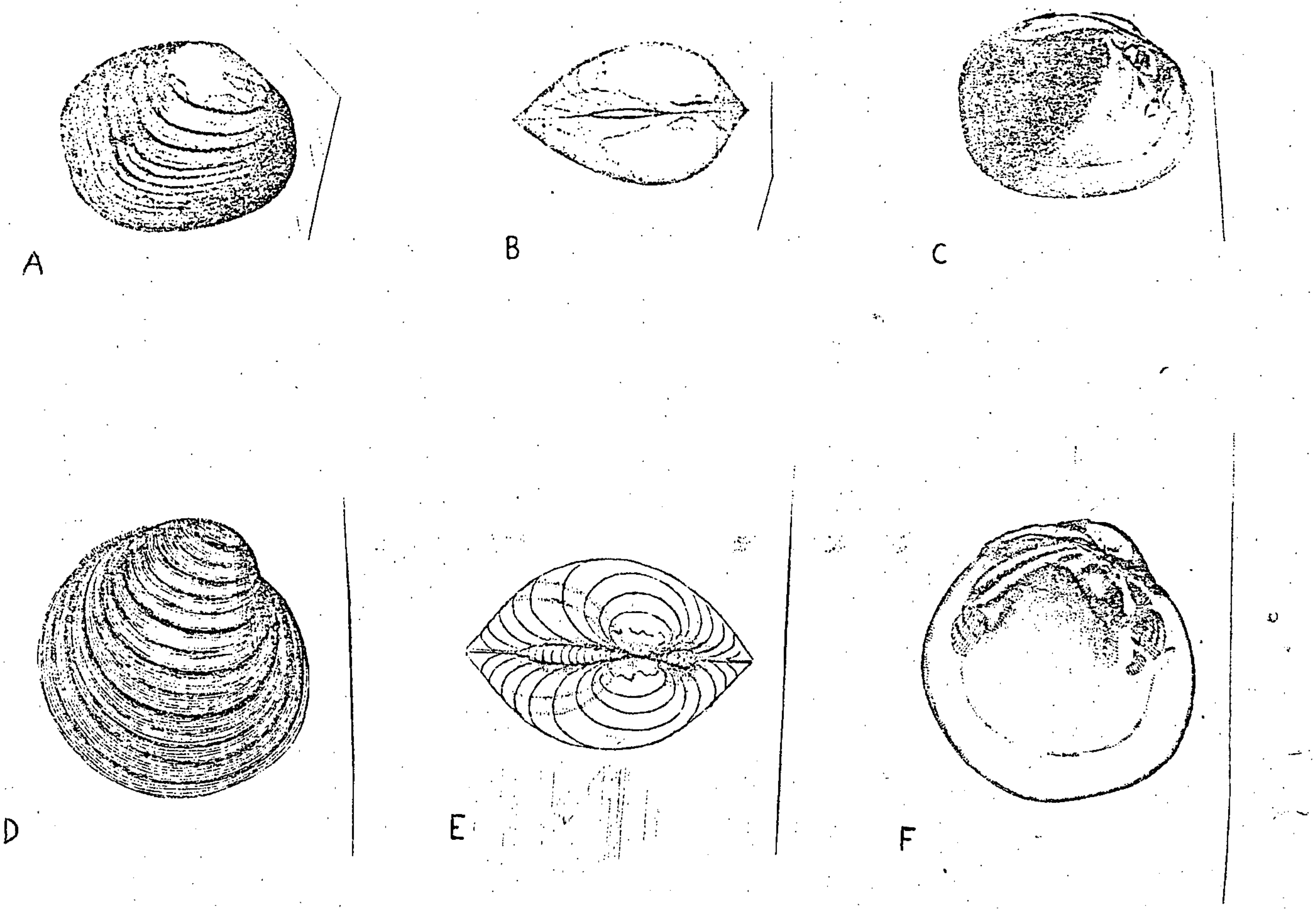


Figure 1, photocopies of Lea's original figures: a-c, *Unio leibii*; d-f, *Unio circulus*.

Attachment 4
NRC3-10-0004

Enclosure 9

Supplement to Intensive follow-up survey of the area between Sandy Creek and the Raisin River, in Lake Erie, for univalve and bivalve mollusks

(Best Available Copy)

(following 11 pages)

Supplement
To
Project Report
For
U.S. Army Engineer District. Detroit
477 Michigan Avenue, 6th. Floor
P.O. Box 1027
Detroit, Michigan 48231

From
ECOSEARCH. INC.
9 Mechanic Street
Mattapoisett, Massachusetts 02739

Title

Intensive Follow-Up Survey of the Area Between Sandy Creek and the River Raisin, in Lake Erie, for Univalve and Bivalve Mollusks.

Supplement. The Geographical Distribution of *Obovaria subrotunda* (Rafinesque, 1820).

Contract No. DACW 35-81-M-588

Submitted by Arthur H. Clarke, Ph.D., President
ECOSEARCH, INC.

Date Submitted - April 2, 1981

Introduction

During March of 1981 visits were made to the University of Michigan Museum of Zoology (abbreviated UMMZ), at Ann Arbor; the Ohio State University Museum of Natural History (OSUM) at Columbus; the Smithsonian Institution (USNM) in Washington; and Harvard University's Museum of Comparative Zoology (MCZ) at Cambridge, Mass. All of the specimens of _Obovaria subrotunda_ from Michigan or from Lake Erie or Lake St. Clair in those museums were examined and listed. It is believed that this is the most accurate method for determining the known distribution of the species in Michigan. In addition, in order to provide a comprehensive view of its overall distribution, all of the specimens of _O. subrotunda_ collected from elsewhere and housed in the Smithsonian Institution or in the Museum of Comparative Zoology were also listed. Additional records from my files, based on specimens in the National Museum of Canada (NMC) in Ottawa, were also tabulated.

These records are listed on the following pages. They are arranged in geographical order by river system and by river drainage. Records based on specimens collected before 1950 are identified by institutional source only, but since recent records are more likely to represent currently living populations, records based on specimens collected in 1950 or later are also identified by data and by collector.

Geographical Records
Of
Obovaria subrotunda

Great Lakes - St. Lawrence System

Lake Michigan Drainage. Grand River, Mich.(UMMZ). Lake Michigan(USNM). Both records doubtful.

Lake St Clair Drainage. Black River, 1½ mi W of Amadore, Sanilac Co., Mich. Black River, Port Huron, St. Clair Co., Mich.(both UMMZ). Belle River, 4 mi above Marine City, St. Clair Co., Mich. (1951, H.D. Athearn!, MCZ). Clinton River, 1 mi above mouth of Middle Branch, Macomb Co., Mich., and Mt. Clemens, Macomb Co.(both UMMZ). Sydenham River at 10 mi SW of Strathroy; 3.0 mi NE of Alvinston, both Middlesex Co., Ont. (1971, A.H. and L.R.Clarke!, NMC); and 3.7 mi S of Alvinston, Middlesex Co., Ont. (1963, H.D.Athearn!, NMC). Lake St. Clair, Mich. (UMMZ).

Lake Erie Drainage. Middle River Rouge 4 mi N of Dearborn, Wayne Co., Mich. (UMMZ). Rouge River, Mich. (USNM). Detroit River, Fighting Isle, Mich. Huron River, Rockwood, Monroe Co., Mich. (all UMMZ). River Raisin, S of Tecumseh, Lenawee Co., Mich. River Raisin, 2½ mi W of Blissfield, Lenawee Co., Mich. (all UMMZ). River Raisin, Petersburg, Monroe Co., Mich. (MCZ and USNM) and at Lake Erie (MCZ). Maumee River System at Blanchard River, Ohio (USNM) and West Branch St. Joseph River, Sec. 30, Bridgewater Twp., Williams Co., Ohio (MCZ). Sandusky River at McCutchensville, Wyandot Co., Ohio (MCZ). Cuyahoga River, Summit Co.,Ohio (MCZ).

Grand River, Painsville, Lake Co., Ohio (MCZ). Grand River, Ontario, Canada. (1971-2, B.T. Kidd!, NMC). Lake Erie at the following locations: near mouth of Detroit River (USNM); La Plaisance Bay, Monroe Co., Mich. (MCZ and UMMZ); Toledo Beach, 4 mi E of La Salle, Monroe Co., Mich. (MCZ); beach at Locust Point, 9 mi NW of Port Clinton, Ottawa Co., Ohio (empty valves) (1977, B.D.Valentine!, OSUM); Fishery Bay, South Bass Island, 0.4 mi NW of Put-In-Bay, Ottawa Co., Ohio (1970, F. Kokai!, OSUM); Fishers Pond, Middle Bass Island, Ottawa Co., Ohio (1966. B.O. Valentine and J.R. Hubschman!, OSUM); Sandusky, Ohio (USNM); Kingsville, Essex Co., Ontario (MCZ): Pelee Island, Ontario (several localities) (1977. 1978, B.D. Valentine!, (OSUM).

OHIO RIVER SYSTEM

Upper Ohio River Drainage. Monongahela River at Charlerio, Washington Co., Pa. (USNM). Crooked Creek, Rosston, Armstrong Co., Pa. Allegheny River, Natrona, Allegheny Co., Pa., Pymatuning Creek, Pymatuning twp., Mercer Co., Pa. Shenango River at Harbor Bridge, at Pulaski, Lawrence Co., and at Clarksville, Mercer Co. (all Ortmann, 1919). Beaver River, Wampum, Lawrence Co., Pa. (MCZ, USNM). West Branch, Mahoning River, Portage Co., Ohio (MCZ). Mahoning River, Mahoningtown, Lawrence Co., Pa. Ohio River, Nevill Island, Allegheny Co., Pa. (both Ortmann, 1919).

Muskingum River Drainage. Tuscarawas River at New Philadelphia (MCZ,USNM) and 4 mi N of Gnadenhütten (MCZ), both Tuscarawas Co., Ohio. Mohican River just above confluence with Kokosing River, Newcastle Twp., Coshocton Co., Ohio (1965, C.B. Stein, R.I. Johnson, J.J.Jenkinson!, MCZ) and 10 mi above its mouth, 1.0 mi NNW of Walhonding, Coshocton Co., Ohio (1966, D.H. Stansbery!, MCZ, OSUM). Muskingum River, Lowell, Washington Co., Ohio (1978, R.E. Winters!, MCZ).

Middle Island Creek Drainage. Middle Island Creek, West Union, Doddridge Co., W. Va. (MCZ).

Big-Sandy River Drainage. Big Sandy River, Willard, Charter Co., Ky. (USNM). Big Sandy River, Va. (MCZ)

Kanawha River Drainage. Elk River at Gassaway, Braxton Co., W. Va. (MCZ); between Sutton, Braxton Co. and Clendenin, Clay Co., W.Va. (1979, R.C. Hughart!, MCZ); and about 1 mi W of Procius, Clay Co. (1965, S.L.H. Fuller!, MCZ). Meeting House Fork, Richie Co., W. Va. (MCZ). Kanawha River immediately below Kanawha Falls, 0.6 mi below Kanawha Falls, and 1.2 mi below Gauley Bridge, all Fayette Co., W. va. (all 1969 and 1970, W.S. Clench and D.H. Stansbery!, MCZ).

Scioto River Drainage. Big Darby Creek, Borror Riffle, 4 mi S of Orient, Pickaway Co., Ohio (1965, R.I. Johnson & D.H. Stansbery!, MCZ). Alum Creek near Orange Twp., Delaware Co., Ohio (1965, D.H. Stansbery!, MCZ). and near Africa, Delaware Co., Ohio (1959, D.H. Stansbery!, MCZ). Whetstone River, Delaware Co., Ohio (MCZ). Olentangy River at Olentangy, Franklin Co., and at Delaware, Delare Co., Ohio (both MCZ). Scioto River, Ohio (MCZ, Usnm).

Little Miami River Drainage. Little Miami River, Ohio (MCZ).

Licking River Drainage. Licking River, 5.3 mi WNW of Index, Morgan Co., Ky. (1966. H.D. Athearn!, MCZ) and 5 mi WNW of W. Liberty, Morgan Co. (1965, H.D. Athearn!., MCZ).

Great Miami River Drainage, Great Miami River, Miami, Hamilton Co., Ohio. (MCZ).

Kentucky River Drainage. Middle Fork Kentucky River at Rio, Breathitt Co., Ky, and 1 mi W of Tallega, Lee Co. Ky, (both 1958, W.J. Clench & J. Rosewater!, MCZ). Redbird Creek, 1 mi W of Big Creek, Clay Co., Ky. (1953, H.D. Athearn!, MCZ). South Fork Kentucky River, Rt. 30 bridge, Booneville, Owsley Co., Ky. (1958, W.J. Clench & J.Rosewater!., MCZ)

Wabash River Drainage. East Fork White River at Rockford, Ind. and Brownstone, Ind. (both MCZ). Eel River, Clay Co., Ind. (MCZ). West Fork White River at Worthington, Green Co. Ind. (MCZ); Indianapolis, Ind. (USNM); and 2 mi E of Wheatland, Ind. (MCZ). White River at Giro, Ind. (USNM). Mississinewa River, 1 mi below Somerset, Wabash Co., Ind. (USNM). Wabash River at Delphi, Carroll Co., Ind. (MCZ, USNM); Lafayette, Tippecanoe Co., Ind. (MCZ); Independence, Warren Co., Ind. (MCZ); near N end of Juno Island, New Harmony, Posey Co., Ind. (MCZ); and Old River, Posey Co., Ind. (MCZ).

Main Ohio River. Ohio River at Shanghai, Jefferson Co., Ohio and at Cincinnati, Hamilton Co., Ohio (both MCZ).

GREEN RIVER SYSTEM

Green River Drainage. Barren River, Bowling Green, Warren Co., Ky, (MCZ). Green River at ½ mi above bridge, Rio, Hart Co., Ky. (MCZ); near Wilson's Park, Hart Co.; Mumfordville, Hart Co. (both 1964, D.H. Stansbery & D. Bickel!, (MCZ); Mammoth Cave, Edmonson Co. (MCZ,USNM); 12 mi N of Bowling Green, Warren Co. (1972, D.H. Stansbery, et al!, MCZ); Rochester, Butler Co. (MCZ,USNM); ½-2 mi below dam at,Rochester, in Muhlenberg Co., Ky. (1965, S.L.H. Fuller, MCZ); and Calhoun, McLean Co., Ky. (USNM).

CUMBERLAND RIVER SYSTEM

Cumberland River Drainage. Beaver Creek, E of Rowena Ferry, Russell Co., Ky. (MCZ,USNM). Wolf River, 2 mi above its mouth, Clinton Co., Ky. (MCZ). Obey River, 9 localities between Spurrier, Pickett Co., Tenn. and Lillydale, Clay Co., Tenn, (MCZ,USNM). Caney Fork River, 5 mi SE of Carthage, Smith Co., Tenn. (MCZ). East Fork Stone's River, Walterhall, Rutherford Co., Tenn. (1967, W.J. Clench & D.H. Stansbery!, MCZ). Stone's River, 7 mi NNE of Murfreesboro, Rutherford Co., Tenn. (MCZ) and 1.2 mi W of Couchville, Davidson Co., Tenn. (1965, D.H. Stansbery & J.J.Jenkinson!, MCZ) Cumberland River 1 mi E of Horseshoe Bottom, Russell Co. Ky. (MCZ); Neeley's Ford, Cumberland Co. Ky. (MCZ,USNM): and Nashville, Davidson Co., Tenn. (MCZ,USNM).

TENNESSEE RIVER SYSTEM

Tennessee River Drainage. Powell River, Bryant's Shoals, Tenn. Clinch River, Union Co., Tenn. Holston River near Knoxville, Knox Co., Tenn. (all USNM). Sequatchie River, Lee Station, 5 mi S of Pikeville, Bledsoe Co., Tenn. (1958, W.J. Clench & D.H. Stansbery!, MCZ) and at Princeton, Holly Tree, Trenton, and Paint Rock, all Jackson Co., Ala. (all MCZ). Elk River at 1 mi S of Estill Springs, Franklin Co., Tenn.;Winchester, Franklin Co., (both MCZ); Lexie Crossroads Bridge, 12 mi W of Winchester, Franklin Co. (1955, J.R. Hood!, MCZ); Fayetteville, Lincoln Co. (MCZ); and US Rt 64 bridge, 4 mi ESE of Fayetteville, Lincoln Co. (old empty valves, 1967. W.J. Clench & D.H. Stansbery!, MCZ). Bear Creek, Franklin Co., Ala. (MCZ). Buffalo Creek, 5 mi N of Lobelville, Perry Co., Tenn. (MCZ). Duck River at 6 mi ESE of Shelbyville, Bedford Co., Tenn. (1967, W.J. Clench & D.H. Stansbery!, MCZ); Shelbyville, Bedford Co.;Wilhoite, Marshall Co., Tenn.; and Hardinson's Mill, 12 mi NW of Lewisburg, Marshall Co. (all MCZ); Clay Hill, Marshall Co. (1953, H.D. Athearn!, MCZ); 10 mi ESE of Columbia, Maury Co., Tenn. (1965, B. Isom & P. Yokley!, MCZ); and Columbia, Maury Co. (USNM). Tennessee River, Knoxville, Davidson Co., Tenn. (MCZ).

UPPER MISSISSIPPI RIVER SYSTEM

Illinois River Drainage. Fox River, Granville, Ill. (USNM).

White River Drainage. Canal at Indianapolis, Ind. White River, Rockford, Ill. (both MCZ).

<u>Main Mississippi River.</u> Davenport, Iowa (MCZ,USNM) and Hickman, Hickman Co., Ky. (MCZ).

Summary and Conclusions

The above records demonstrate that Obovaria subrotunda occurs in the Great Lakes System in Lake St. Clair and Lake Erie and in their tributaries. (The two Lake Michigan records are considered doubtful). It also occurs throughout the Ohio, Green, Cumberland, and Tennessee river systems, in some other major tributaries of the Mississippi River (Illinois River and White River in Illinois), and in the main Mississippi River.

Other closely-related species occur in the Gulf of Mexico drainage and west of the Mississippi River. Obovaria unicolor (Lea) is represented in MCZ and USNM collections from numerous localities in Alabama, Mississippi, and Louisiana. Obovaria jacksoniana Frierson is recorded at the USNM from a number of localities in Arkansas and Texas. It is possible that O.unicolor and O. jacksoniana are the same species.

It will be seen from the above listings that although numerous records exist of Michigan collections of O. subrotunda, almost all of these records are old. Most are based on work by Calvin Goodrich and Henry van der Schalie in the 1920's and 1930's. Only one collection of living specimens from Michigan made since 1950 has been seen by me, i.e. a 1951 colleciton from Belle River, 4 mi above Marine City, St Clair Co. by H.D. Athearn. It is probable that a very few other recent Michigan collections are in private hands or in institutions, but even if such exist it is certain that they do not provide adequate documentation of the present distribution of O. subrotunda in Michigan.

The University of Michigan is one of the leading centers for molluscan research in North America and during this century it has been the only institution in Michigan to sponser significant taxonomic or zoogeographic research on the freshwater mollusks of Michigan. Van der Schalie has recently summarized the past molluscan research activities of that institution (Bulletin of the American Malacological Union for 1980, pp.1-5). With the exception of a thesis by Louise A. Kraemer in 1966 on physiological behavior in Lampsilis, none of the numerous University of Michigan students since 1946 have used freshwater mussels as subjects for graduate theses. This lack of recent activity in unionid research is amply reflected in museum collections.

It is therefore impossible, at this time, to discuss with confidence the status of endangerment of Obovaria subrotunda in Michigan. In order to do so a new and comprehensive survey is necessary. If such a survey is conducted, the probability appears great that several species of freshwater mussels which were formerly abundant or common in the State will now be found to be rare and perhaps endangered. ECOSEARCH, INC. stands ready to do such a survey, or to assist in such an activity, if a mussel survey is to be carried out in Michigan.

Attachment 5
NRC3-10-0004

Supplemental Response to RAI letter related to Fermi 3 ER

RAI Question HH5.4.3-1

NRC RAI HH5.4.3-1

Provide occupational dose calculations from normal operation of Fermi Unit 3 (The occupational dose should also include dose from existing Fermi 1 and Fermi 2 sources.)

Supporting Information

Provide occupational doses from normal operations. ESRP Section 5.4.3.III(3) recommends inclusion of "an estimate of the collective occupational dose using the format of Table 5.4.3-2." Provide collective occupational doses, or justify their exclusion.

Supplemental Response

In the original response to RAI HH5.4.3-1 submitted in Detroit Edison letter NRC3-09-0016 (ML093380331), dated November 23, 2009, Fermi 3 occupational dose estimates were presented. Based on discussions with the NRC on December 16, 2009, it was determined that the Fermi 3 occupational dose analysis should be simplified to reduce complexity and incorporate recent revisions related to the ESBWR DCD. Additionally, GEH has presented updated occupational dose estimates associated with GEH RAI 12.4-40. This supplemental response amends the response submitted in Detroit Edison letter NRC3-09-0016 (ML093380331), dated November 23, 2009, and updates the occupational dose estimates to the latest ESBWR data.

Occupational dose estimates presented in ESBWR DCD Revision 6, Section 12.4, indicate that the projected annual collective occupational dose for the ESBWR is 80.82 man-rem/year. GEH revised that estimate to 84.52 man-rem/year in response to GEH RAI 12.4-40, in letter MFN 09-774 (ML093450064) dated December 10, 2009.

The GEH projected annual collective occupational dose for the ESBWR, accurately approximates Fermi 3 collective occupational dose. Contributions from the decommissioned Fermi 1 site, Fermi 2 and the planned Fermi 2 ISFSI are insignificant relative to the 84.52 man-rem/year ESBWR estimate. The shielding from the exterior walls of Fermi 3 buildings, and interior shielding from systems, structures and components within the Fermi 3 buildings will reduce the contribution to individuals working in radiological controlled areas from sources other than the ESBWR to insignificant levels. Contributions to Fermi 3 individuals working outside of radiological controlled areas will be very small incremental additions, and will be governed by standards in 10 CFR Part 20. Thus Fermi Unit 3 projected annual collective occupational dose is 84.52 man-rem/year.

Proposed COLA Revision

ER Section 5.4.3 will be revised to include a discussion of occupational dose as shown in the attached markups. The markups reference the GEH occupational dose estimates as presented in DCD section 12.4 and remain unchanged from the DTE response to RAI HH5.4.3-1 in Detroit Edison letter NRC3-09-0016 (ML093380331), dated November 23, 2009. Reference to DCD section 12.4 will appropriately incorporate the GEH estimate noted above, as the DCD is revised to incorporate the response to GEH RAI 12.4-40 (ML093450064).

Markup of Detroit Edison COLA
(following 3 pages)

The following markup represents how Detroit Edison intends to reflect this RAI response in a future submittal of the Fermi 3 COLA. However, the same COLA content may be impacted by revisions to the ESBWR DCD, responses to other COLA RAIs, other COLA changes, plant design changes, editorial or typographical corrections, etc. As a result, the final COLA content that appears in a future submittal may be different than presented here.

5.4.2.2 Gaseous Pathway Doses

Based on the parameters in Table 5.4-3, the GASPAR II computer program was used to calculate doses to the MEI child, who represents the bounding age group for total body and all organs. GASPAR determined that a child was the MEI because of the greater sensitivity of that age group to internal exposure from vegetables and meat. The gaseous activity releases (source terms) for each radionuclide are described in Subsection 3.5.1. The annual pathway components for the total body, thyroid, and other organ doses calculated by the GASPAR computer program for this individual are presented in Table 5.4-5.

As part of the analysis, several sensitivities were performed to account for potentially limiting combinations of atmospheric dispersion, deposition and ingestion pathways. The SSE direction provides the limiting plume dose. The WNW direction at the site boundary provides the limiting dose for non-milk iodine and particulate sources. This is conservative relative to the doses at the actual residences, vegetable gardens and meat cows. The WNW direction at the actual locations provides the dose contribution due to milk consumption. In this case the cow and goat milk both included for conservatism. The total dose is the sum of these individual contributions.

As shown in Table 5.4-5, the annual total body dose to the MEI is 0.66 mrem to a child, and the maximum annual thyroid dose of 14.2 mrem to a child. Experience at Fermi 2 (Reference 5.4-6) indicates that these calculations are likely very conservative.

5.4.2.3 Summary

The maximum doses due to the liquid and gaseous effluents are summarized in Table 5.4-5. As shown, all results are well within the 10 CFR 50, Appendix I limits. Therefore, the impacts are SMALL and no mitigation actions are necessary.

5.4.3 Impacts to Members of the Public (Individual and Collective Dose to the Public and Comparison with Regulations)

The radiological impacts to individuals and population groups from liquid and gaseous effluents are presented using the methodologies and parameters specified in Subsection 5.4.1. Table 5.4-5 estimates the total body and organ doses to the MEI from liquid effluents and gaseous releases from Fermi 3 for analytical endpoints prescribed in 10 CFR 50, Appendix I. The MEI receptor age group and location are those described in Subsection 5.4.2. As Table 5.4-5 indicates, the predicted doses are below Appendix I limits. These results are discussed in Subsection 5.4.2.3, above.

The total site liquid and gaseous effluent doses from Fermi 2 plus Fermi 3 would be well within the regulatory limits of 40 CFR 190 (Table 5.4-8). As indicated in NUREG-1555, demonstration of compliance with the limits of 40 CFR 190 is considered to be in compliance with the 0.1 rem limit of 10 CFR 20.1301.

Table 5.4-6 and Table 5.4-7 show the total body dose to the population within 50 miles that would be attributable to Fermi 3. Based on the information in these tables, the total whole body dose due to liquid and gaseous effluents from Fermi 3 is 22.2 person-rem/year. As discussed above, the average annual radiation exposure from natural sources to an individual in the United States is about 300 mrem (Reference 5.4-3). Multiplying this by the population of 7,713,709 (Table 5.4-1), results in 2,300,000 person-rem/year. Thus, the dose from Fermi 3 is less than 0.001 percent of that received by the population from natural causes. Impacts to members of the public from operation of Fermi 3 would be SMALL and would not warrant mitigation.

Insert 1 Here.

5.4.4 Impacts to Biota Other than Members of the Public

Subsection 2.4.1 and Subsection 2.4.2 identify the relevant species within the site area. Radiation exposure pathways to biota are expected to be the same as those to humans, i.e., inhalation, external (from ground, airborne plume, water submersion, and shoreline), drinking water and ingestion. These pathways were examined to determine if they could result in doses to biota significantly greater than those predicted for humans from operation of Fermi 3. This assessment used surrogate species that provide representative information about the various dose pathways potentially affecting broader classes of living organisms. The gaseous pathway doses for muskrats, raccoons, herons and ducks were taken as equivalent to human doses for the inhalation (child), plume (adult), and twice the ground (adult) pathways. The doubling of doses from ground deposition reflects the closer proximity of these organisms to the ground. Doses to those same species plus fish, invertebrate and algae are calculated by the LADTAP II computer program.

Doses to biota from liquid and gaseous effluents from Fermi 3 are shown in Table 5.4-9. The total dose is taken as the sum of the internal and external dose. Annual doses to all of the surrogates meet the requirements of 40 CFR 190.

Use of exposure guidelines, such as 40 CFR 190, which apply to members of the public in unrestricted areas, is considered very conservative when evaluating calculated doses to biota. The International Council on Radiation Protection states that "...if man is adequately protected then other living things are also likely to be sufficiently protected," and uses human protection to infer environmental protection from the effects of ionizing radiation (Reference 5.4-7 and Reference 5.4-8). This assumption is appropriate in cases where humans and other biota inhabit the same environment and have common routes of exposure. It is less appropriate in cases where human access is restricted or pathways exist that are much more important for biota than for humans.

Species in most ecosystems experience dramatically higher mortality rates from natural causes than man, as witnessed by their lesser life spans. From an ecological viewpoint, population stability is considered more important to the survival of the species than the survival of individual organisms. Thus, higher dose limits could be permitted. In addition, no biota has been discovered that show significant changes in morbidity or mortality due to radiation exposures predicted from nuclear power plants.

An international consensus has been developing with respect to permissible dose exposures to biota. The International Atomic Energy Agency (IAEA) (Reference 5.4-9) evaluated available evidence including the "Recommendations of the International Commission on Radiological Protection" (Reference 5.4-7). The IAEA found that appreciable effects in aquatic populations will not be expected at doses lower than 1 rad per day and that limiting the dose to the maximally exposed individual organisms to less than 1 rad per day will provide adequate protection of the

Insert 1

Occupational exposure to Fermi 3 workers from Fermi 3 sources are described in the ESBWR DCD (Reference 5.4-12), Section 12.4. After consideration of shielding provided by the Fermi 3 facilities, occupational exposure from other sources on-site are relatively insignificant. As described in the Fermi 3 FSAR, Appendix 12AA, occupational exposure at Fermi 3 will be maintained as low as reasonably achievable (ALARA).

Attachment 6
NRC3-10-0004

Response to RAI letter related to Fermi 3 ER

RAI Question HY2.3.1-16

NRC RAI HY2.3.1-16

Provide a report or reports detailing the laboratory results of the distribution coefficient measurements of onsite samples from the bedrock. Include a description of laboratory methods used to determine distribution coefficient values; sample locations, depths, rock types, and quantities; and quality control results. Also, describe the calculation method for the values presented in Table 2.4-234 of Detroit Edison's September 1, 2009 safety-related RAI response letter.

Supporting Information

Contaminant transport in the ER is limited to a discussion of advective transport (Section 2.3.1.2.3.2). The staff intends to include a more thorough discussion in the EIS of the environmental impacts of a potential release of radioactive materials to groundwater. Detroit Edison presented a discussion of a potential release of radioactive material to groundwater in Section 2.4.13 of the FSAR. That discussion will form the basis of the staff's discussion of contaminant transport in the EIS. Incorporating site specific distribution coefficient (Kd) values would allow estimation of the transport rate of radioactive constituents to receptors.

The staff filed safety-related RAIs corresponding to Section 2.4.13 of the Final Safety Analysis Report (FSAR) on January 14, 2009. Detroit Edison's September 1, 2009 RAI letter response to these RAIs, which included transport analysis, methodology, and references, provided a conservative basis for calculating concentrations at receptors (nearest well and Lake Erie). The response included Kd values from onsite bedrock samples. Review of the Kd investigation report is needed to verify the basis for the transport analysis.

Response

The report contained in Enclosure 1 of this response details the laboratory results of the distribution coefficient measurements of onsite samples from the bedrock. The report includes a description of the laboratory methods used to determine distribution coefficient values; sample locations, depths, rock types, and quantities, and quality control results.

The values used in Table 2.4-234 of Detroit Edison letter NRC3-09-0026 (ML092470230), dated September 1, 2009 represent the input values used in the RESRAD-OFFSITE computer modeling of the radionuclide groundwater transport analysis. The following table summarizes the bases for the values provided in Table 2.4-234. Input values used in the RESRAD-OFFSITE were conservatively selected to maximize the predicted nuclide concentrations at the receptor (either the off-site well or Lake Erie).

Parameter	Value	Bases
Nuclide K_d values	Varies by Nuclide	K_d values are based on tested results determined in the laboratory. The laboratory report is provided as part of this response. As noted in the laboratory report K_d values were determined at several different locations. The locations selected were based on the postulated flow path either to the off-site well or to Lake Erie. As shown in the laboratory report, there is a range of K_d values for each nuclide. The K_d values used for each nuclide in the analysis represent the minimum value determined for that nuclide.
Total Porosity	0.25	Conservatively selected based on information available for Bass Islands rock formations in the State of Michigan.
Effective Porosity	0.01	Selected based on published report for similar type of material (dolomite).
Hydraulic Conductivity	197,719 m/yr	Hydraulic conductivity is representative of the Rock Fill at the site. The release is actually to the Bass Islands Group; which has a much lower hydraulic conductivity (on the order of 767 m/yr). Using the hydraulic conductivity for the Rock Fill provides bounding analytical results.
Hydraulic Gradient	0.002	Hydraulic gradient is based on site groundwater conditions, described in more detail in FSAR Section 2.4.12.
Distance to nearest off-site well	1333 m	Determined based on minimum distance from Radwaste Building to receptor location.
Distance to nearest surface water body (Lake Erie)	474 m	Determined based on minimum distance from Radwaste Building to receptor location.
Precipitation	0.892 m/yr	Based on meteorological information presented in FSAR Section 2.3.
Dry bulk density	1.68 – 2.4 gm/cm^3	Based on sub-surface conditions presented in FSAR Section 2.5.4. 1.68 gm/cm^3 represents the Rock Fill. 2.4 gm/cm^3 represents the Bass Islands formation.
Dispersivity values	Varies by horizontal and longitudinal and receptor location	Determined based on equations in Boulding, J.R. and Ginn, J.S., "Practical Handbook of Soil, Vadose Zone, and Ground-water Contamination, Assessment and Prevention," CRC Press Boca Raton, Florida, 2004; and EPRI RP2485-05, "Estimation of Hydrodynamic Dispersivity in Selected Subsurface Materials."

Proposed COLA Revision

None

Attachment 6
NRC3-10-0004

Enclosure 1

Distribution Coefficient (K_d) Measurements with Soil and Groundwater from the DTE ENSR Monroe MI site

(following 18 pages)

Distribution Coefficient (K_d) Measurements with Soil and Groundwater from the DTE ENSR Monroe MI site.

For Black and Veatch Corporation
11401 Lamar Avenue
Overland Park, KS 66211
913-458-7512

Black and Veatch Corporation, Project 163696

Under ACL Job No. 09-0104

Prepared By:
Analytical Chemistry Laboratory
Chemical Sciences and Engineering Division
Argonne National Laboratory

Report
July 10, 2009

ACL Manager: Vivian S. Sullivan
Dr. Vivian S. Sullivan

ACL QA/QC Coordinator: Susan J.
Susan J. Lopykinski

Contents

Sections and Tables

Appendices

Introduction

The Analytical Chemistry Laboratory (ACL) in Argonne National Laboratory's Chemical Sciences and Engineering Division was contracted by Black and Veatch Corporation to conduct measurements to determine distribution coefficients (K_d values) between groundwater and rock. Rock and groundwater samples were provided to the Analytical Chemistry Laboratory for testing. Black and Veatch provided rock samples from subsurface borehole locations specially selected by them during Combined License (COL) site characterization in April of 2009, as well as groundwater samples collected from monitoring wells. Groundwater was provided in one liter high density polyethylene bottles. The rock was crushed before being provided for analysis; individual rock pieces were approximately 1 centimeter long.

The rock and groundwater samples were formally received at Argonne in April 2009. Table 1 provides a summary of the ACL identification numbers assigned to the samples upon receipt and rock/water sample pairs for the K_d determination. All solid samples were designated with S; all groundwater samples were designated with W. Black and Veatch requested 9 sample sets for the K_d determination. There were nine unique rock samples and 5 unique water samples. Four of the rock samples were paired with four water samples for the K_d determination. The other five rock samples were paired with a composite of two water samples.

Analysis of the samples began on May 13, 2009. Quality oversight was provided in accordance with the Analytical Chemistry Laboratories Quality Assurance (QA) Program. The isotopes of interest were as follows:

manganese (Mn)
iron (Fe)
cobalt (Co)
zinc (Zn)
strontium (Sr)
yttrium (Y)
ruthenium (Ru)
silver (Ag)
cesium (Cs)
cerium (Ce)

Natural elemental standards were used in the determination of the K_d.

Procedures for the K_d measurement were as follows: ACL Standard Operating Procedure SOP-264 "Determination of the Distribution Coefficient (Kd) in Soil Samples" and ACL SOP-271 "Procedure for the Determination of Trace Elements/Isotopes in Solution by Inductively Coupled Plasma Mass Spectrometry Using the Perkin Elmer SCIEX DRC II."

Table 1: Sample Identification

SOIL SAMPLES RECEIVED

Submitters Sample ID	ACL Sample ID
MW-381D-KD	09-0104-01S
MW-383D-KD	09-0104-02S
MW-384D-KD	09-0104-03S
MW-386D-KD	09-0104-04S
RW-C3-KD	09-0104-05S
CB-C1-KD	09-0104-06S
EB/TSC-C2-KD	09-0104-07S
RB-C7-KD	09-0104-08S
RB-C4-KD	09-0104-09S

WATER SAMPLES RECEIVED

Submitters Sample ID	ACL Sample ID
MW-381D	09-0104-01W
MW-383D	09-0104-02W
MW-384D	09-0104-03W
MW-386D #1 of 3	09-0104-04WA
MW-386D #2 of 3	09-0104-04WB
MW-386D #3 of 3	09-0104-04WC
MW-387D #1 of 2	09-0104-05WA
MW-387D #2 of 2	09-0104-05WB

K_d ANALYSIS SAMPLE COMBINATION

Submitters Sample ID		ACL Sample ID		
Soil/Rock	**Water**	**Soil/Rock**	**Water**	**Kd ID**
MW-381D-KD	MW-381D	09-0104-01S	09-0104-01W	09-0104-01
MW-383D-KD	MW-383D	09-0104-02S	09-0104-02W	09-0104-02
MW-384D-KD	MW-384D	09-0104-03S	09-0104-03W	09-0104-03
MW-386D-KD	MW-386D	09-0104-04S	09-0104-04WA	09-0104-04
RW-C3-KD	MW-386D/MW-387D	09-0104-05S	Composite	09-0104-05
CB-C1-KD	MW-386D/MW-387D	09-0104-06S	Composite	09-0104-06
EB/TSC-C2-KD	MW-386D/MW-387D	09-0104-07S	Composite	09-0104-07
RB-C7-KD	MW-386D/MW-387D	09-0104-08S	Composite	09-0104-08
RB-C4-KD	MW-386D/MW-387D	09-0104-09S	Composite	09-0104-09

NOTE: A composite was made with equal volumes of MW-386D & MW-387D water samples ACL ID #'s 09-0104-04WB, 09-0104-04WC, 09-0104-05WA & 09-0104-05WB.

Analysis and Results

Laboratory analyses of samples were performed with ICP-MS. The concentration of the elements of interest was measured in micrograms per liter (μg/L) in the groundwater before and after contact with the soil. Contact time was 20 days. Calculations were carried out in a Microsoft Excel spreadsheet. All Excel equations were confirmed by manual calculation by calculator.

The elements of interest for the K_d measurement were added to 120 mL of groundwater sample provided by Black and Veatch. The isotopes added were natural Mn, Fe, Co, Zn, Sr, Y, Ru, Ag, Cs and Ce. Natural elemental standards were substituted for the radioactive isotope to make the K_d determination. These substitutions allow the determination of the K_d to be made using ICP-MS and reduces the radiological exposure from the analysis.

First, the groundwater samples were spiked with the elements of interest, and ten milliliter aliquots were analyzed for the initial concentration value, A_L^o. The pH of the spiked groundwater was also measured after the addition of the tracer solution. The spiked groundwater was combined with site core samples. The core samples were matched with the spiked groundwater sample corresponding to the solid matrix, as indicated in Table 1. The rock and groundwater mixture was rotated in a tumbling sample rotation apparatus for 19 days to equilibrate the rock and groundwater concentrations of the tracer elements. On day 19 the samples were removed from the tumbler and allowed to settle. On the 20th day of the test, the groundwater portion was centrifuged and filtered to remove the sediment. The filtered water was acidified and analyzed by ICP-MS for the final analyte concentration values, A_L^f. In a separate analysis, 2 grams of rock were leached overnight with 1-molar potassium nitrate. The leach solution was filtered and analyzed and used in the K_d calculation as the term A_S^o. ICP-MS data collected in the course of operations to complete this analysis and the pH and sample size information are summarized in tables in Appendix A of this report.

The tracer solution was prepared using single element stock solutions of the elements to be added. The stock solutions were combined, taken to a damp salt using gentle heating in a beaker, and then brought up in the de-ionized water. This led to a slightly acidic solution with a trace nitric acid present. The pH of the groundwater samples did not change significantly upon addition of this tracer solution. When the initial measurements of the site water were made, there was a decrease in the concentration of many of the elements relative to the LCS. Y, Ru, Ag, and Ce were affected. This is most likely due to an interaction of the spiking elements with chemical constituents of the site water. The effect was detected across the water samples.

A blank sample was prepared using reverse osmosis de-ionized (RODI) water. A laboratory control sample (LCS) was prepared by adding tracer elements to a solution of RODI water and a drop of 0.05M nitric acid. One reference sample (09-0104-05REF) was prepared by adding the tracer elements to a sample of site water without solid. The Blank, LCS and Reference samples were shaken similarly to the solid/water samples for 20 days and analyzed with the site samples.

Table 2 presents the K_d values for the 9 groundwater-rock pairs analyzed as well as the Reference, Blank, and LCS samples. Equations used for the determination of the K_d are given in Appendix B.

Table 2: Distribution Coefficients (K_d) in cm^3/g

Solid Sample ID	Mn cm3/g	Fe cm3/g	Co cm3/g	Zn cm3/g	Sr cm3/g	Y cm3/g	Ru cm3/g	Ag cm3/g	Cs cm3/g	Ce cm3/g
MW-381D-KD	605	2.99	2,074	76.9	58.6	> 19329	509	3.28	1,536	> 5092
MW-381D-KD (D)	799	2.88	1,795	40.0	56.0	> 18119	373	2.58	1,579	> 4575
MW-383D-KD	423	2.93	1,319	56.8	14.5	11,535	197	0.41	1,323	> 5289
MW-384D-KD	394	3.02	640	45.1	0.44	> 3183	42.9	960	1,518	> 10422
MW-386D-KD	823	10.1	2,472	146	188	> 21946	574	2.12	1,951	> 9666
RW-C3-KD	971	7.00	3,134	165	107	18,762	530	10.8	1,152	> 6821
CB-C1-KD	869	6.36	2,919	26.1	397	7,366	449	> 579	1,422	> 6666
CB-C1-KD (D)	751	6.28	3,128	101	376	> 19418	730	> 582	1,715	> 6867
EB/TSC-C2-KD	588	4.20	2,089	16.7	72.6	> 18698	265	348	1,862	> 6528
RB-C7-KD	681	4.40	1,513	105	33.1	17,519	303	> 624	1,238	5,894
RB-C4-KD	651	4.65	2,238	51.5	53.6	> 19455	301	> 625	1,078	6,389
Blank	< 1.00	< 1.00	< 1.00	4.72	< 1.00	< 1.00	< 1.00	< 1.00	< 1.00	< 1.00
Lab Control	< 1.00	< 1.00	< 1.00	< 1.00	< 1.00	< 1.00	< 1.00	< 1.00	< 1.00	< 1.00
Reference	< 1.00	< 1.00	< 1.00	< 1.00	< 1.00	1.41	20.8	< 1.00	< 1.00	5.99

(D) indicates a duplicate sample

The 2-sigma uncertainties are 14 percent. The uncertainty for the distribution coefficients, K_d, were calculated by propagation of uncertainty from the ICP-MS data. The uncertainty reported is a 95 percent confidence level value. The uncertainty from the mass and volume measurements was calculated to be < 0.03 percent and was not included in the propagation of uncertainty as it is a negligible factor. The percent uncertainty is determined from ACL SOP-271 as a measured uncertainty from QC samples, with a minimum uncertainty of 10 percent.

The limits of quantitation are determined for each set of samples measured by using 10X the standard deviation of the QA blank run before that sample set. The reporting limit is listed below each table of data in Appendix A for reference.

A "negative" K_d value will result for elements where no adsorption occurs, and the final water measurement was higher than the initial measurement. 'Greater than' values were calculated from the non-detect reporting limits for elements that were so strongly adsorbed that they could not be detected in the final sample.

ICP-MS data and other supporting information are presented in Appendix A as follows:

Table A1	Measured pH values and the rock and groundwater sample weights.
Table A2	Groundwater measurements. The site groundwater data were collected for reference to determine the amount of spike to be added and are not used in the calculations.
Table A3	Leachable elements present in the site samples. (A_S^o)
Table A4	Initial spiked groundwater ICP-MS measurements. (A_L^o)
Table A5	Final groundwater measurements (A_L^f) measured after the 20-day contact between the groundwater and the site samples.

Quality Assurance

Quality oversight was provided in accordance with Black and Veatch's QA Program.

A2LA-certified weights were used to confirm the balance calibration. QA checks were done according to SOP ACL-271 "Procedure for the Determination of Trace Elements in Solution by Inductively Coupled Plasma Mass Spectrometry." All daily QA checks for the ICP-MS were satisfactory.

A copy of the original chain-of-custody (COC) forms and ACL sample receipt forms were provided to Black and Veatch when the samples were received. A copy of the COC forms and ACL forms are attached as Appendix D.

As specified in the supplemental QA Plan, the ICP-MS QA data were verified by the ACL QA/QC coordinator. Internal standards were monitored and were well within the acceptability limits of 70 percent. No interference from molecular ions was detected that interfered with the K_d measurements.

Laboratory Control Standard and Reference Sample

A LCS sample was prepared from the tracer solutions to confirm that all elements of interest in the tracer solution were transferred to the water samples. The LCS sample was prepared by adding tracer elements to RODI water with one drop of 0.05M nitric acid instead of site groundwater, using the same volume solution and same volume tracer aliquot that were used for the samples.

One reference sample (REF) was prepared using site water provided by Black and Veatch. This reference sample was prepared to give a more accurate representation of the interaction between the tracer elements and the site water. Results and sample information for the LCS and reference samples are included in Table 2 and Appendix A.

The reference sample gave a K_d of <1 for all elements except Y, Ru and Ce. This means no interactions occurred between the groundwater and elements of interest except for Y, Ru and Ce during the 20-day contact period. These elements showed a slight precipitation during the contact time. The effect for Y and Ce shown in the reference sample is small compared with the actual Kd of the solid samples.

Replicate Analysis

The QC duplicate samples were prepared by the ACL by preparing two samples from one provided solid sample and water sample. The leach test and dry weight test were performed in triplicate.

The highest relative percent deviations were seen for Zn. Variation was seen in both the leach test and the K_d test. The high percent deviation for Y in sample CB-C1-KD is a reflection of the strong adsorption of Y by the sample. In the ICP-MS analysis of one sample the value was below the detection limit (0.01 µg/kg); the duplicate was less than five times the reporting limit at 0.03 µg/kg. A small absolute difference in these small values gives a large relative difference as it is the denominator of the equation for calculating K_d (Equation 3 in Appendix B).

The relative percent deviation (RPD) is given below for these replicate samples.

Table 3: Replicate Analysis Results

Relative Percent Deviation (RPD) of the K_d Analysis:

Solid Sample ID	Mn	Fe	Co	Zn	Sr	Y	Ru	Ag	Cs	Ce
MW-381D-KD	28%	3.8%	14%	63%	4.7%	6.5%	31%	24%	2.8%	11%
CB-C1-KD	15%	1.3%	6.9%	118%	5.4%	90%	48%	0.5%	19%	3.0%

Percent Relative Standard Deviation (%RSD) of ICP-MS data for Initial Analyte Concentration:

Solid Sample ID	Mn	Fe	Co	Zn	Sr	Y	Ru	Ag	Cs	Ce
MW-381D-KD	1.7%	2.0%	2.1%	4.9%	2.4%	6.6%	15%	9.4%	2.3%	1.7%
CB-C1-KD	0.6%	3.0%	0.0%	1.6%	0.6%	3.8%	12%	0.6%	3.9%	0.6%

Relative Percent Deviation (RPD) of ICP-MS data for the Final Analyte Concentration:

Solid Sample ID	Mn	Fe	Co	Zn	Sr	Y	Ru	Ag	Cs	Ce
MW-381D-KD	15%	1.0%	10%	69%	5.8%	N/A	16%	8.5%	5.0%	N/A
CB-C1-KD	3.8%	1.9%	4.5%	71%	7.3%	N/A	59%	N/A	15%	N/A

N/A- No analyte was detected. RPD is Not Applicable – For sample CB-C1-KD only one sample had detected analyte, the other was detected at a concentration less than five times the reporting limit.

Relative Percent Deviation (RPD) of ICP-MS Data for the Leach Analysis of the Solid:

Solid Sample ID	Mn	Fe	Co	Zn	Sr	Y	Ru	Ag	Cs	Ce
MW-381D-KD	35%	N/A	N/A	33%*	19%	N/A	N/A	N/A	N/A	N/A
CB-C1-KD	43%	N/A	N/A	104%*	2.8%	N/A	N/A	N/A	N/A	N/A

N/A- No analyte was detected. RPD is Not Applicable
* Analyte detected at a concentration that was less than five times the reporting limit.

Appendix A: Data Tables

Table A1: Sample Information

Weights are in g with uncertainty of ± 0.01g.

		pH					
Rock Sample ID	Water Sample ID	Water	Initial	Final	% dry weight	g solid for Kd	mL water for Kd
MW-381D-KD	MW-381D	7.8	7.6	8.3	99.9	100.14	100.0
MW-381D-KD (D)	MW-381D	7.8	7.6	8.5	99.9	100.05	100.0
MW-381D-KD (T)					99.9		
MW-383D-KD	MW-383D	7.7	7.7	8.6	99.9	100.00	100.0
MW-384D-KD	MW-384D	7.3	8.0	8.5	99.9	100.04	100.0
MW-386D-KD	MW-386D	7.5	7.5	8.4	99.9	100.23	100.0
RW-C3-KD	MW-386D/MW-378D		7.8	8.7	100.0	100.27	100.0
CB-C1-KD	MW-386D/MW-378D		8.3	8.7	100.0	100.01	100.0
CB-C1-KD (D)	MW-386D/MW-378D		7.7	8.5	100.0	100.04	100.0
CB-C1-KD (T)					100.0		
EB/TSC-C2-KD	MW-386D/MW-378D		8.2	8.4	100.0	100.07	100.0
RB-C7-KD	MW-386D/MW-378D		8.2	8.4	100.0	100.49	100.0
RB-C4-KD	MW-386D/MW-378D		7.6	8.3	100.0	100.34	100.0
Blank			5.1	6.0		0.00	100.0
Lab Control			3.4	3.3	100.0	0.00	100.0
Reference	MW-386D/MW-378D	8.0	7.4	8.4		0.00	100.0

(D) indicates a duplicate sample; (T) indicates a triplicate sample

Table A2: Site Groundwater ICP-MS Measurement Data

Un-spiked groundwater sample analysis for reference only.
ug/L, uncertainty of 10%

Solid Sample ID	Mn µg/L	Fe µg/L	Co µg/L	Zn µg/L	Sr µg/L	Y µg/L	Ru µg/L	Ag µg/L	Cs µg/L	Ce µg/L
MW-381D	6.29	355	0.16	12.4	20,094	0.17	1.93	ND	ND	0.05
MW-381D (D)	5.50	345	0.15	16.7	21,114	0.14	1.83	ND	ND	ND
MW-381D (T)	5.53	350	0.15	9.04	21,114	0.14	1.91	ND	ND	ND
MW-383D	13.2	434	0.20	11.5	14,484	0.10	1.24	ND	ND	ND
MW-384D	0.34	920	0.38	12.8	11,526	0.09	0.94	ND	0.03	ND
MW-386D	9.46	785	0.33	20.2	11,118	0.12	0.82	ND	ND	ND
MW-386D /MW-378D	3.12	482	0.22	9.53	16,728	0.11	1.18	ND	ND	ND
Blank	0.06	ND	ND	10.2	0.13	ND	ND	ND	ND	ND

(D) indicates a duplicate sample; (T) indicates a triplicate sample

Table A3: Leached Solid ICP-MS Measurement Data (A_S^0)

Separate aliquot of rock, analysis for leachable contribution.
μg/kg, uncertainty of 10%

Solid Sample ID	Mn µg/kg	Fe µg/kg	Co µg/kg	Zn µg/kg	Sr µg/kg	Y µg/kg	Ru µg/kg	Ag µg/kg	Cs µg/kg	Ce µg/kg
MW-381D-KD	210	ND	11.6	112	12,883	ND	ND	ND	ND	ND
MW-381D-KD (D)	310	ND	ND	181	9,962	ND	ND	ND	ND	ND
MW-381D-KD (T)	435	ND	ND	ND	9,001	ND	ND	ND	ND	ND
MW-383D-KD	420	ND	41.9	292	4,817	1.75	ND	26.1	48.6	3.76
MW-384D-KD	375	ND	24.3	595	3,555	ND	ND	5.20	ND	ND
MW-386D-KD	177	ND	15.2	630	1,924	ND	ND	ND	ND	ND
RW-C3-KD	336	ND	ND	ND	2,559	ND	ND	ND	ND	ND
CB-C1-KD	194	ND	12.0	349	2,828	ND	ND	ND	ND	ND
CB-C1-KD (D)	300	ND	ND	11.5	2,714	ND	ND	ND	ND	ND
CB-C1-KD (T)	468	ND	ND	844	2,866	ND	ND	ND	ND	ND
EB/TSC-C2-KD	289	ND	ND	487	2,484	ND	ND	ND	ND	ND
RB-C7-KD	379	ND	13.3	ND	3,326	ND	ND	ND	ND	ND
RB-C4-KD	347	ND	ND	379	2,620	ND	ND	ND	ND	ND
Blank	666	ND	ND	1,400	25.3	3.75	ND	16.3	49.5	3.75
Reporting Limit	32.2	7,230	11.8	292	18.7	3.45	10.6	15.9	7.55	3.45

(D) indicates a duplicate sample; (T) indicates a triplicate sample

Calculations were applied to correct for dry weight factor, sample mass and dilution of sample when submitted for analysis.

ND is Not Detected – detection limit was set as Dilution factor times the LOQ.

When elements were detected in the Blank it is assumed that these are present in the leach solution. The sample values listed above have had the Blank subtracted from the original values. Where the sample value is less than the Blank value and less than the reporting limit, it is reported as ND.

Table A4: Initial Groundwater ICP-MS Measurement Data (A_L^0)

After addition of spike, before contact with rock – µg/L

Solid Sample ID	Mn µg/L	Fe µg/L	Co µg/L	Zn µg/L	Sr µg/L	Y µg/L	Ru µg/L	Ag µg/L	Cs µg/L	Ce µg/L
MW-381D-KD	481	418	487	471	21,726	193	51.8	24.0	452	50.8
MW-381D-KD (D)	473	410	476	449	21,216	181	44.5	21.8	442	45.6
MW-383D-KD	489	537	480	447	16,524	188	50.0	22.7	446	52.7
MW-384D-KD	478	1,132	481	458	11,220	235	63.4	16.1	446	100
MW-386D-KD	490	986	477	463	11,016	219	43.0	14.0	440	96.6
RW-C3-KD	485	625	477	444	16,830	188	30.7	18.3	439	68.2
CB-C1-KD	486	592	475	444	16,728	187	32.4	18.4	439	66.5
CB-C1-KD (D)	489	574	475	451	16,830	194	28.9	18.5	456	68.5
EB/TSC-C2-KD	487	556	468	447	16,014	187	28.5	18.8	446	65.2
RB-C7-KD	487	569	469	443	16,116	192	31.4	19.9	444	68.7
RB-C4-KD	490	555	473	456	17,238	195	32.4	19.9	441	70.5
Blank	0.05	5.88	0.02	16.1	0.20	ND	ND	0.02	0.02	ND
Lab Control	495	984	511	502	476	490	488	81.4	459	470
Reference	503	629	494	466	16,728	227	57.7	19.8	472	89.1
Reporting Limit	0.02	3.29	0.01	0.12	0.01	0.01	0.01	0.02	0.01	0.01

(D) indicates a duplicate sample

Table A5: Final Groundwater ICP-MS Measurement Data (A_L^F)

Groundwater after 20 day contact with rock
µg/L, uncertainty of 10%

Solid Sample ID	Mn µg/kg	Fe µg/kg	Co µg/kg	Zn µg/kg	Sr µg/kg	Y µg/kg	Ru µg/kg	Ag µg/kg	Cs µg/kg	Ce µg/kg
MW-381D-KD	1.14	105	0.24	7.51	581	ND	0.10	5.61	0.29	ND
MW-381D-KD (D)	0.98	106	0.27	15.4	549	ND	0.12	6.11	0.28	ND
MW-383D-KD	2.18	137	0.37	7.75	1652	0.02	0.25	16.1	0.34	ND
MW-384D-KD	2.27	283	0.82	16.3	11118	0.07	1.45	0.04	0.33	ND
MW-386D-KD	1.05	89.1	0.20	7.22	77.1	ND	0.07	6.15	0.23	ND
RW-C3-KD	0.68	78.1	0.16	6.48	173	ND	0.06	1.55	0.38	ND
CB-C1-KD	0.95	80.6	0.16	16.4	48.6	0.03	0.07	ND	0.31	ND
CB-C1-KD (D)	0.91	79.1	0.16	7.81	52.2	ND	0.04	ND	0.27	ND
EB/TSC-C2-KD	1.34	107	0.22	25.9	255	ND	0.11	0.05	0.24	ND
RB-C7-KD	1.40	105	0.31	12.1	555	0.01	0.10	ND	0.36	0.01
RB-C4-KD	1.19	98.0	0.21	18.0	361	ND	0.11	ND	0.41	0.01
Blank	5.85	ND	2.82	0.13	ND	ND	ND	ND	ND	5.85
Lab Control	615	516	488	473	496	252	48	462	494	615
Reference	665	473	379	15198	94.4	2.65	26.5	443	12.8	665
Reporting Limit	0.12	5.66	0.02	0.62	0.05	0.01	0.01	0.03	0.01	0.01

(D) indicates a duplicate sample

Appendix B: Underlying Principles and Method of Measurement

The solid/liquid distribution coefficient, K_d, is, by definition, an equilibrium constant that describes the process wherein a species, A, is partitioned by adsorption between a solid phase (soil or rock) and a liquid phase (groundwater). The process may be represented by the equilibrium: A(solid) $\leftrightarrows$ A(liquid)

The K_d defines the relationship between concentrations of A on the solid and in the liquid when the system is at equilibrium and is given by the ratio of the concentration of A adsorbed on the solid to the concentration of A in the liquid. By convention, the concentration on the solid is tendered in units of mass per unit mass (for example, milligram per kilogram [mg/kg]) and the solution concentration is in units of mass per unit volume (for example, milligram per liter [mg/L]) with Kd expressed in units of liter per kilogram (L/kg) or equivalent units, such as milliliter per gram (mL/g). Thus, for the soil-water system, one may express Kd as

$$Kd = [A]soil/[A]water \qquad (1)$$

where [A]soil is the microgram per gram (μg/g) concentration of A adsorbed on the soil, and [A]water is the microgram per milliliter (μg/mL) concentration of A in the water.

Argonne's methodology to determine the value for K_d is a "batch" process in which a measured mass of solid material (soil or rock) having a concentration A_S^o is contacted with a measured volume of water having a concentration A_L^o. Argonne's tests to determine the distribution coefficients are patterned after the guidelines provided in American Society for Testing and Materials (ASTM) Designation D 4319-93, "Standard Test Method for Distribution Ratios by the Short Term Batch Method." Differences between the ASTM method and the test performed are summarized in a separate section below.

The two phases are mixed and allowed to come to equilibrium. When equilibrium is attained, the species A will distribute in such a way as to satisfy Equation 1. Moreover, the system must satisfy the mass-balance relationship that says the total quantity of A in the system is the same at the beginning and at the end of the test. Thus,

$$M^* A_S^o + V^* A_L^o = M^* A_S^f + V^* A_L^f \qquad (2)$$

where M is the mass of solid, V the volume of groundwater, and the superscripts o and f indicate values at the beginning and end of the test.

Using the definition of K_d allows one to substitute for A_S^f in this relationship, thereby obtaining an expression for K_d that requires knowledge only of the initial concentrations in the solid and groundwater and the final concentration in the groundwater.

$$K_d = A_S^o / A_L^f + (V/M)^*(A_L^o / A_L^f - 1) \qquad (3)$$

A_S^o is a measure of the adsorbed analyte present on the solid at the start of the contact time as measured in the leach analysis. This is not a measure of the total analyte concentration present in the solid, but a measure of the available adsorbed material that is able to participate in the exchange process for the K_d measurement. When no analyte is present on the solid, then $A_S^o = 0$; thus, the first term (A_S^o / A_L^f) becomes zero.

In principle, this relationship holds regardless of the initial concentrations of A in the solid and groundwater, so long as the amount of analyte in the groundwater phase does not exceed the available adsorption capacity of the solid. Addition of too much of the element may saturate the sites available for sorption of the analyte and give a false low value to the measured K_d. As is noted in the ASTM method introduction, the K_d measurement is sensitive to the pH and other properties of the groundwater. Care must be taken to minimize the change to the groundwater when isotopes of interest are added to allow the measurement of the distribution coefficient. Also, an unrealistically high K_d value can be generated if precipitation of the elements of interest or adsorption of those elements to the sample container occur during the time of the groundwater-soil interaction, lowering the measured A_L^f. Measurement of a 'Reference' sample with no soil contact is used to monitor for precipitation and adsorption to the container.

At the start of the K_d determination, either A_S^o and A_L^o need to be examined as A_S^o / A_L^f or $(V/M)*(A_L^o / A_L^f - 1)$ terms in Equation 3 need to be larger than the estimated K_d for the isotope. For most isotopes of interest, there is not a sufficient concentration of the element present in either the soil/rock or the groundwater at the start of the study and the isotope or a substitute (tracer) is added to the groundwater for the K_d measurement to adjust A_L^o. The use of tracers is allowed by the ASTM method. The tracer must have similar chemical properties. The K_d is not isotope dependent, and other isotopes of the same element or the natural element may be used as a tracer. The available concentration (parameter A_S^o) is measured by a room temperature 1 molar potassium nitrate overnight leach of a representative solid sample. This leach is designed to bring into solution all easily exchangeable ions in a reasonable time frame without dissolution of any soil or rock. When the analyte concentration in the final groundwater is not detected, A_L^f = ND, the term A_L^f defaults to the reporting limit "RL" for that analyte; thus, the K_d value gets reported using the ">" sign.

Moisture present in each soil or rock is measured as the loss in mass after heating a weighed portion at 110 degrees Celsius (°C) for several days. The moisture data are incorporated into the K_d calculations in several ways to conform to the standard definition of K_d on a dry-solid basis, to refine values for the volume of groundwater added, and to account for dilution of the spike that was added. To convert the soil mass to dry mass, the wet weight was multiplied by the factor (1- Moisture), where Moisture is the fractional weight loss observed on heating the soil. To account for dilution of the spiked groundwater by water in the soil, the concentration of each analyte in each test sample was multiplied by the factor $V_{sp}/(V_{sp}+\text{Moisture}*M)$, where Moisture is the mass fraction of water in the wet soil, M is the mass of soil added to the test, and V_{sp} is the volume of spiked groundwater added; this expression assumes a density of 1 for the water in the soil. To account for the groundwater volume added to the test with the rock, the volume used in calculating K_d was increased from V, the volume added as groundwater, to V + Moisture*M. This correction was also applied during the leach analysis.

Appendix C: ASTM Method Comparison

As mentioned above, our method is based on ASTM Method D 4319-93, "Standard Test Method for Distribution Ratios by the Short Term Batch Method." Over the years, the ACL has modified the procedure during research projects and has a modified method for determination of the K_d values.

ASTM D4646-03 (24-h Batch-type Measurement of Contaminant Sorption by Soils and Sediments) is the current ASTM standard for sorption affinity. However, Section 5.3 allows use of Test Method D 4319 as an alternate procedure of longer duration.
Primary deviations from ASTM D 4319-93 (Reapproved 2001):

1. Section 7.1 – Use of a riffle splitter. We do not use a riffle splitter; homogenized, crushed rock samples or a representative soil sample are provided.
2. Section 7.5 – We use a 1M potassium nitrate leach to remove the easily leachable constituents of the solid for the initial solid concentration value.
3. Section 7.8 – We do not run in triplicate every sample. Our experience has found all samples go to equilibrium by 20 days and we run everything that long. We also use a 1-to-1 ratio of soil to water as this gives the most consistent results for many soil sites and elements. In addition, we run replicates and QA checks with every batch.
4. Section 7.11 – We do not use a pre-treatment of the filters; we have disposable filters that work well with the elements of interest, and the blank and QA checks mentioned above have confirmed that there are no added interferences.

ASTM D 4319-93 is written to primarily utilize radionuclide analysis. Argonne's experience with K_d analysis has found that Inductively Coupled Plasma Mass Spectrometer (ICP-MS) analysis with elemental substitutes allows us to measure all of the elements of interest with the same method, precision, and accuracy and gives consistently acceptable results. Radiochemical analysis would usually entail chemical separations, and use of the mass spectrometer allows simultaneous analysis of most elements.

Appendix D: Chain-of-Custody Documents

Three pages are attached; one chain-of-custody (COC) form from Black and Veatch, one Sample Receipt log from Argonne and one COC form from GLEC.

Sample Custody Record

Client: Detroit Edison

Project: Fermi 3 COL Application

Sample Location See Field ID #

Page 1 **of** 1

Instructions:

1. After entry to the field temporary storage, all transfers shall be noted and signed for in the form below.
2. The original white copy shall remain at the FERMI site at all times.
3. When samples are initially transferred off the FERMI site, the yellow copy of this record shall accompany the samples. When received by the offsite location, the yellow copy shall be returned to the site with appropriate signatures and a copy shall be retained at offsite location where the samples are stored. Subsequent transfers to other locations shall be completed in a similar manner using the copy of the yellow copy.
4. Any unacceptable condition of sample shall be noted in the sample comments.

ACL CROSS Reference II
MJK 4-20-09

Field ID#	Sample Date	Sample Type	Date of Transfer				(optional) Lab ID	Sample Comments
			To Temp. Storage	To Lab Facility	To Final Storage	Other		
MW383D-KD	4/14/09	Grab-Rock		X			09-0104-02S	Depth 45'-45.5'
MW381D-KD	4/14/09	Grab-Rock		X			09-0104-01S	Depth 39.7'-40'
MW384D-KD	4/14/09	Grab-Rock		X			09-0104-03S	Depth 39.7-40.1
MW386D-KD	4/14/09	Grab-Rock		X			09-0104-04S	Depth 37'-38'
CBC1-KD	4/14/09	Grab-Rock		X			09-0104-06S	Depth 41.2'-41.5'
RWC3-KD	4/16/09	Grab-Rock		X			09-0104-05S	Depth 44.4-45'
CBC4-KD	4/16/09	Grab-Rock		X			09-0104-09S	Depth 39.8'-40.1'
RBC7-KD	4/16/09	Grab-Rock		X			09-0104-08S	Depth 39.5'-40'
EB/TSCC2-KD	4/16/09	Grab-Rock		X			09-0104-07S	Depth 39.6'-39.8'

- All samples shipped to Mike Kalensky at Argonne National Laboratory

Field Sampler(s) (signature) ______________________

Date of Transfer	Relinquished by: (signature)	Transferred by: (signature)	Date	Received by: (signature)	Date	Comments
4/16/09	Edwin W. Mayer, III	Edwin W. Mayer III	4/16/09	Michael J. Kalensky	4-20-09	

ARGONNE NATIONAL LABORATORY/ANALYTICAL CHEMISTRY LABORATORY
SAMPLE CHECK-IN LIST

Proposal - P-09073

1. Custody Seals present/[✓ absent]
   intact/not intact
2. Chain-of-Custody [✓ present]/absent
3. Sample Tags present/[✓ absent] Sample I.D only
4. Sample Tag Numbers listed/not listed on chain-of-custody

Case Number: Project - 163696
Air Bill Number: N/A
Date: 4-20-09
Document Control No.: N/A
Sample Custodian Signature: Michael J. Kalensky

Date Rec'd	Time Rec'd	COC Record Number	Sample Tag Number	Date of Collection	Client Sample Number	Assigned ACL Number	Does information on custody records, traffic reports, and sample tags agree?	Remarks about condition of sample shipment, etc.
4-20-09	11:00	N/A	N/A	4-14-09	MW-381D-KD	09-0104-01 S	yes	none
				4-14-09	MW-383D-KD	09-0104-02 S		
				4-14-09	MW-384D-KD	09-0104-03 S		
				4-14-09	MW-386D-KD	09-0104-04 S		
				4-16-09	RW-C3-KD	09-0104-05 S		
				4-14-09	CB-C1-KD	09-0104-06 S		
				4-16-09	EB/TSC-C2-KD	09-0104-07 S		
				4-16-09	RB-C7-KD	09-0104-08 S		
↓	↓			4-16-09	RB-C4-KD	09-0104-09 S		
4-20-09	11:00			4-15-09	MW-381D	09-0104-01 W		
				4-16-09	~~MW-389D~~ MK 4-20-09 MW-383D	09-0104-02 W		
				4-15-09	MW-384D	09-0104-03 W		
				4-15-09	MW-386D #1 of 3	09-0104-04 WA		
					MW-386D #2 of 3	09-0104-04 WB		
				↓	MW-386D #3 of 3	09-0104-04 WC		
				4-16-09	MW-387D #1 of 2	09 -X010405 WA		
↓	↓	↓	↓	↓	MW-387D #2 of 2	09-0104-05 WB	↓	↓
						MK 4-20-09		

NA - Not Applicable

ACL-92 (9/00)

CHAIN OF CUSTODY RECORD

(To be completed and submitted with samples)

Page 1 of 1

GLEC
Great Lakes Environmental Center
739 Hastings St.
Traverse City, MI 49686
Phone: 231-941-2230
Fax: 231-941-2240
www.glec.com

Facility Location: Mike Kalensky
Argonne National Laboratory
To: Building 205, 9700 S Cass Ave
Argonne IL 60439-4837
Sample Location: DTE ENSR; Monroe, MI

Date: 4/16/2009
Contact Person: Jamie Saxton
Email Address: jsaxton@glec.com
Phone Number: (231) 941-2230
Collector: Sara Reitz

Number & Bottle ~~ID~~	Date / Time of Sample	Volume Collected	Type of Sample Container	Sample Description (Site information / sample type)	Preservation	Alkalinity	BOD$_5$	Chloride	Chlorophyll a	Hardness	NH$_3$-N	NO$_3$/NO$_2$-N	TDS	TKN	TP	TSS				
1	4/5/09 1050	1L	HDPE Plastic Bottle	MW381D ✓	NONE															
1	4/15/09 1240	1L	HDPE Plastic Bottle	MW 384D ✓	↓															
3	4/15/09 1840	3L	HDPE Plastic Bottle	MW 386D ✓	↓															
1	4/16/09 930	1L	HDPE Plastic Bottle	MW 383D ✓	↓															
2	4/16/09 1106	2L	HDPE Plastic Bottle	MW 387D ✓	↓															

Check the requested analysis (see definitions below)

Shipper:	Date/Time:	Receiver:	Date/Time:	Temperature:
1. Sara Reitz	4/16/09	Michael J. Kalensky	4-20-09 11:00 AM	N/A
2.				

Definitions

BOD$_5$ = Biochemical Oxygen Demand-5 day
NH$_3$-N = Ammonia-Nitrogen
NO$_3$/NO$_2$-N = Nitrate/Nitrite-Nitrogen
TDS = Total Dissolve Solids
TKN = Total Kjeldahl Nitrogen
TP = Total Phosphorus
TSS = Total Suspended Solids

Abbreviations for other frequently requested analyses

NO$_2$-N = Nitrite Nitrogen
NO$_3$-N = Nitrate Nitrogen
Total N = Total Nitrogen
SRP = Soluble Reactive Phosphorus

Attachment 7
NRC3-10-0004

Supplemental Response to RAI letter related to Fermi 3 ER

RAI Question SE2.5.2-1
RAI Question SE2.5.2-2

NRC RAIs

A – RAI SE2.5.2-1

Provide information on the size and nature of the heavy construction industry, construction labor force within the region (size of the labor force, unemployment rates, wages) specific to the job categories that would be used to support Fermi 3 construction (i.e., boilermakers, pipefitters, electricians, iron workers, insulators, etc.)

More detailed information is needed to confirm assumptions on the availability of construction workers within the local area to further characterize impacts by jurisdiction on population, housing, public services, education, and public utilities.

B – RAI SE2.5.2-2

Provide information on the job categories that would be recruited for the operations workforce, and the size of the labor force, unemployment rates, and wages for these laborers within the region.

More detailed information is needed to confirm assumptions on the availability of operations workers within the local area to further characterize impacts by jurisdiction on population, housing, public services, education, and public utilities.

Supplemental Response

Based on discussions with the NRC on December 18, 2009, Detroit Edison was asked to provide a source reference for the information contained in Table 2 included in the original response to RAIs SE2.5.2-1 and SE2.5.2-2. The original response was submitted to the NRC in Detroit Edison letter NRC3-09-0016 (ML093380331), dated November 23, 2009.

Detroit Edison personnel collected this information from local union leaders in September, 2009. The unions that were contacted are in the region having primary and support coverage of the Monroe County area and include unions based in Monroe County, Detroit, Toledo, and southeast Michigan. Table 2 from the original response is being provided in the attached COLA markup as Table 2.5-28(A) with the reference included as an additional footnote.

Proposed COLA Revision

Table 2.5-28(A), attached, has been revised from the COLA markup previously provided with the response to RAIs SE2.5.2-1 and SE2.5.2-2. The additional footnote is colored blue.

Markup of Detroit Edison COLA
(following 1 page)

The following markup represents how Detroit Edison intends to reflect this RAI response in a future submittal of the Fermi 3 COLA. However, the same COLA content may be impacted by revisions to the ESBWR DCD, responses to other COLA RAIs, other COLA changes, plant design changes, editorial or typographical corrections, etc. As a result, the final COLA content that appears in a future submittal may be different than presented here.

Insert 2 Insert tables following Table 2.5-28 on page 2-524 of the COLA

Table 2.5-28(A) Regional Union Construction Labor Force and Wage by Major Craft Occupation

Primary Coverage Unions	Location	Area Total Journeymen	Area Total Apprentices	Base Journeyman Wages ($2008)
Iron Worker #55	Toledo	661	72	28.00
Boiler Makers #85	Toledo	256	144	33.43
Electrician #8	Toledo	1,520	194	34.00
Operating Eng. #324	Michigan (State wide)	4,500	77	32.75
Brick Layer-Allied	SEM*	1,550	138	29.00
Pipefitter/Plumber #671	Monroe	335	21	32.32
Cement Mason #886	SEM*	400	24	28.00
Sheet Metal Worker #33	SEM*	400	50	29.00
Carpenters	SEM*	4,391	338	30.16
Laborers #959	SEM*	1,091	63	26.28
Insulators #45	Toledo	110	57	29.37
Other Union Hall Locations				
Iron Workers #25	Detroit	2,500	200	29.00
Boiler Makers #169	Detroit	444	146	32.89
Electrician #58	Detroit	4,024	275	35.85
Pipefitter/Plumbers #636	Detroit	1,650	140	36.25
Insulators #25	Detroit	195	35	30.77

*SEM- Southeast Michigan

**Detroit Edison personnel collected this information from local union leaders in Sept. 2009

Attachment 8
NRC3-10-0004

Supplemental Response to RAI letter related to Fermi 3 ER

RAI Question SE4.4.2-7

NRC RAI SE4.4.2-7

Provide a list of job categories and wages/salaries of the construction and operations workforce.

Supplemental Information

The data are needed to confirm assumptions used to estimate local and non-local workforce; further characterize impacts on population, housing, public services, education, and public utilities based on demographic assumptions; and better characterize the economic impacts of the proposed project (ER Sections 4.4.2, 4.4.2.1, 4.4.2.4.6, 5.8.2.1, and 5.8.2.7).

Supplemental Response

Based on discussions with the NRC on December 18, 2009, Detroit Edison was asked to provide sources of information for Table 2 included in the response to RAI SE4.4.2-7, which was originally submitted to the NRC in Detroit Edison letter NRC3-09-0016 (ML093380331), dated November 23, 2009.

Detroit Edison used the information from Table 2 in the combined response to RAIs SE2.5.2-1 and SE2.5.2-2 from Detroit Edison letter NRC3-09-0016 (ML093380331), dated November 23, 2009, to generate an average wage for each key craft occupation. That reference has been added to Environmental Report (ER) Table 4.4-5, which is provided in the COLA markup included with this response.

Proposed COLA Revision

Refer to COLA markup. This markup represents a revised portion of the markup which has been previously provided in the response to RAI SE4.4.2-8 in Detroit Edison letter NRC3-09-0017, dated December 23, 2009. The track changes indicate the revisions made to the pages included, while the rest of the COLA markup pages which were not revised are not included with this markup.

Markup of Detroit Edison COLA
(following 4 pages)

The following markup represents how Detroit Edison intends to reflect this RAI response in a future submittal of the Fermi 3 COLA. However, the same COLA content may be impacted by revisions to the ESBWR DCD, responses to other COLA RAIs, other COLA changes, plant design changes, editorial or typographical corrections, etc. As a result, the final COLA content that appears in a future submittal may be different than presented here.

Insert on page 4-85 where marked "Insert 2":

Based on the "DOE NP2010 Nuclear Power Plant Construction Infrastructure Assessment" publication that lists craft requirements at peak, a weighted average direct wage (no fringes, overheads, or indirect are included) of the Fermi 3 construction workforce was then calculated to be $31.37 per hour (Table 4.4-5). Not including overtime, this hourly wage would result in an annual salary for craft workers of approximately $65,250 (2008 dollars). For the non-craft portion of the labor force, an average of $48.00 per hour was assumed; this equates to an annual salary of $99,840 (2008 dollars). Assuming craft labor comprises two-thirds of the total labor force and the non-craft comprises one-third of the labor force the weighted average annual direct wage during construction is $76,780 (2008 dollars). Taking $76,780 (2008 dollars) multiplied by 8,173 total man-years of employment equates to a revised estimate of wages paid during Fermi 3 construction of $627.5 million (2008 dollars).

From Subsection 4.4.2, the project is expected to create 8,173 man-years of employment and $627.5 million in direct wages, though not all man-years and wages are subject to the regional multiplier. Income and employment multipliers can be applied to income and employment for those workers moving into the primary impact area from outside the region, and to those workers living in the region, who will be hired from the ranks of the unemployed.

In terms of projecting the number of construction workers who will be hired from the ranks of the unemployed, current discussions with the craft trades in the Detroit and Toledo area indicated that current unemployment rates are 25 to 40 percent for most crafts. For purposes of this analysis, it is conservatively assumed that 25 percent of the Fermi 3 construction workforce hired from the region will be hired from the ranks of the unemployed and can be included in the multiplier impact analysis. The remaining 75 percent of the positions filled from the region are assumed to be filled by employed workers and are not subject to the multiplier impact analysis; hence, their multiplier is effectively one.

Table 4.4-~~5~~6 shows the calculation process that produces the total construction employment and earnings impact estimate for the region and for the primary impact area counties of Monroe, Wayne, and Lucas. The top portion of the table indicates that of the 15 percent of the construction workforce assumed to move to the region, 90 percent (392 workers) are assumed to relocate to the primary impact area counties. In addition, of the 85 percent of the workforce assumed to be located in the region, approximately 70 percent are assumed to be located in the primary impact area. These percentage assumptions were initially made with regard to the peak workforce, but are here also applied to the overall man-years and earnings distribution.

In terms of calculating an employment multiplier impact for the primary impact area counties, a multiplier is applied to the man-years associated with workers relocating to the primary impact area (90 percent of the 15 percent relocating to the region), and to the man-years associated with the 25 percent of the regional workforce living in the primary impact area that are assumed to be unemployed. Combining these group~~s~~ results is an estimate of 2,334 man-years of employment, as seen in row C in the middle section of Table 4.4-~~5~~6.

Applying the RIMS II direct effect employment multiplier for the primary impact area of 1.7113 times the 2,334 man-years of employment eligible for application of a multiplier yields a primary impact area employment impact of 3,994 man-years (row E). When combined with the 3,691 man-years of employment in the primary impact area not subject to the multiplier (these are those who are employed when hired for Fermi 3 construction, including the under employed), the total impact on the primary impact area is projected to be 7,685 man-years of employment (row G) in Table 1). For the Fermi 3 region as a whole (including those counties not in the primary impact area), the total man-years of employment including the multiplier impacts on the primary impact area will be 9,833 man-years as seen in row I of Table 4.4-~~5~~6.

Turning to earnings (all in 2008 dollars) and following a similar methodology, Table 4.4-~~5~~6 indicates that a multiplier is applied to the earnings of workers relocating to the primary impact area (90 percent of the 15 percent relocating to the region), and to the earnings of 25 percent of the regional workers living in the primary impact area assumed to be unemployed. Combining these groups in row L, it is seen that $179 million in primary impact area earnings is subject to the multiplier impact.

Applying the RIMS II direct effect earnings multiplier for the primary impact area of 1.5998 times the $179 million in earnings yields a primary impact area earnings impact of $287 million in row N of Table 4.4-~~5~~6. When combined with the earnings in the primary impact area not subject to the multiplier ($283 million associated with those employed when hired for the project, including the under employed), the total impact on the primary impact area will be $570 million in earnings as indicated in row P. For the Fermi 3 region as a whole (including those counties not in the primary impact area), the total earnings generated, including the multiplier impacts on the primary impact area, is estimated to be $735 million.

Insert on page 4-94 where marked "Insert 3":

Table 4.4-5 Average Wage Data for Key Craft Occupations in the Fermi Region[1]

Occupation	Weights	Average Wage (2008 dollars)
Iron Workers	19.7%	$28.50
Boiler Makers	4.1%	$33.16
Electricians	19.7%	$34.93
Operating Engineers	8.8%	$32.75
Pipefitters-Plumbers	18.4%	$34.29
Cement Mason	2.0%	$28.00
Sheet Metal Worker	3.4%	$29.00
Carpenters	10.9%	$30.16
Laborers	10.9%	$26.28
Insulators	2.0%	$30.07
Weighted Average		$31.37

[1] Information derived from ER Table 2.5-28(A)

Insert 3a after

Insert ~~on page 4-94 where marked "Insert 3":~~3a

Table 4.4-~~5~~6. Fermi 3 Construction Workforce Employment and Earnings Impacts

	15% Relocating		85% Locals	
Counties in Primary Impact Area	Relocating Distribution	Workers @ Peak	Fermi 3 Adjusted	Workers @ Peak
Monroe County (MI)	45.0%	196	11.0%	272
Wayne County (MI)	25.0%	109	38.5%	948
Lucas County (OH)	20.0%	87	21.4%	527
Primary Impact Area (PIA) Subtotal	*90.0%*	*392*	*70.9%*	*1,746*
Washtenaw County (MI)	3.0%	13	6.8%	168
Oakland County (MI)	3.0%	13	10.9%	267
Wood County (OH)	2.0%	9	3.9%	95
Lenawee County (MI)	1.0%	4	3.6%	89
Other County/Misc	1.0%	4	4.0%	99
Region Total	100.0%	435	100%	2,465

Estimated Employment Benefits with Multiplier Impacts

Total Man Years of Employment (based on 17 million hours)	8,173
A) In-migrant const. man-years (8173*0.15*.9)	1,103
B) Resident Unemployed Man-years (8173*0.85*0.709*0.25)	1,230
C) Man Years Multiplier Applicable (A+B)	2,334
D) RIMSII Employment Multiplier, Construction Sector	1.7113
E) PIA Man Years, Multiplier Applicable (C*D)	3,994
F) PIA Man-years not Multiplier Applicable (8173*0.85*0.709*0.75)	3,691
G) Total Man-years of Employment in PIA (E+F)	**7,685**
H) Regional Man-years not in PIA ((8173*0.15*0.1) + (8173*0.85*0.291))	2,148
I) Total Regional Impact, with PIA multiplier impact (H + G)	**9,833**

Estimated Earnings Benefits with Multiplier Impacts

Total Earnings Estimate	$627,526,667
J) In-migrant const. earnings ($627.5 M *0.15*0.9)	$84,716,100
K) Resident Unemployed Earnings ($627.5 M *0.85*0.709*0.25)	$94,478,062
L) Earnings Multiplier Applicable (J+K)	$179,194,162
M) RIMS II Earnings Multiplier, Construction Sector	1.5998
N) PIA Earnings, Multiplier Applicable (L*M)	$286,674,820
O) PIA Earnings Not Multiplier Applicable ($627.5 M *0.85*0.709*0.75)	$283,434,185
P) Total Earnings in PIA (N+O)	**$570,109,005**
Q) Regional Earnings not in PIA (($627.5 M *0.15*0.1) + ($627.5 M *0.85*0.291))	$164,898,320
R) Total Regional Impact, with PIA multiplier impact (P+Q)	**$735,007,325**

Note: The formulas shown in parentheses may differ to the corresponding result due to rounding.