BEFORE THE ILLINOIS POLLUTION CONTROL BOARD

P.C.# 46

IN THE MATTER OF:	)	
	)	
REVISIONS TO RADIUM WATER	)	**R04-21**
QUALITY STANDARDS: PROPOSED	)	**(Rulemaking – Water)**
NEW 35 ILL. ADM. CODE 302.307	)	
AND AMENDMENTS TO 35 ILL. ADM.	)	
CODE 302.207 AND 302.525	)	

NOTICE OF FILING

RECEIVED
CLERK'S OFFICE
AUG 15 2005
STATE OF ILLINOIS
Pollution Control Board

TO: See Attached Service List

PLEASE TAKE NOTICE that on August 15, 2005, we filed with the Office of the Clerk of the Pollution Control Board an original and ten copies of the attached ***COMMENTS SUBMITTED ON BEHALF OF THE CITY OF JOLIET***, a copy of which is served upon you.

Respectfully submitted,

THE CITY OF JOLIET

By: Roy M. Harsch
One of Its Attorneys

Roy M. Harsch
GARDNER CARTON & DOUGLAS LLP
191 Wacker Drive – Suite 3700
Chicago, Illinois 60606
(312) 569-1000

THIS FILING PRINTED ON RECYCLED PAPER

COMMENTS SUBMITTED ON BEHALF OF
<u>THE CITY OF JOLIET</u>

Introduction

The Illinois Environmental Protection Agency proposed a revised water quality standard for combined radium 226 and radium 228. Their proposal of no numeric standard except for a water quality standard of 5.0 pico-curies per liter combined radium 226 and radium 228 at water supply and food processing intakes provided the necessary protections for the public and was consistent with the standards adopted by other states.

The Illinois Environmental Protection Agency proposal had been the subject of two public hearings when Water Remediation Technologies, LLC decided to request an additional opportunity to participate in the proceedings. Water Remediation Technologies, LLC attempted to discredit the Illinois Environmental Protection Agency proposal using each and every method possible. Water Remediation Technologies, LLC would create additional opportunities for substantial profit if alternate radium water treatment methods cannot comply with a regulation resulting from their participation in the process.

The proposed rule subject to this first notice is apparently an attempt by the Board to propose a rule that addressed the concerns expressed by Water Remediation Technologies, LLC and yet at the same time provide relief to the publicly owned treatment works discharging wastewater containing combined radium 226 and 228. The proposed general limitation of 3.75 pico-curies per liter is consistent with the information presented by Water Remediation Technologies, LLC. and the 30 pico-curies per liter limitation for the first mile downstream from a wastewater treatment plant receiving influent including from a well system containing radium appears to provide relief to the discharger if adequate dilution of the wastewater occurs in the first mile.

The United States Environmental Protection Agency in their June 10, 2005 letter to the Hearing Officer makes it clear that the proposed rule will not be approved by the USEPA. No justification has been presented for adopting a general limitation of 3.75 pico-curies per liter and providing an alternate standard of 30 pico-curies per liter downstream from the wastewater treatment plants. The USEPA also points out that there is no national criteria recommendations for the development of a radium water quality standard to protect aquatic life or wildlife. By using USEPA methods, there is insufficient data to support the derivation of either the 3.75 pico-curies or 30 pico-curies per liter proposed in this rule.

As result of the USEPA letter, the Board will have to decide whether to adopt a standard that will insure Water Remediation Technologies, LLC an increased market for their services in Illinois or to adopt a standard consistent with the original IEPA proposal which was to provide relief from the current 1.0 pico-curie per liter requirement.

Wastewater Plant Data Collection and Analysis

The City of Joliet organized the efforts of water supplies and wastewater treatment agencies to respond to the first notice proposal. The intent of organizing the agencies was to obtain additional sampling results to present to the Board.

Joliet used the following procedure:

1. Listings of the water supplies that exceed the drinking water standard of 5.0 pico-curies per liter were obtained.
2. The water supplies were matched with wastewater treatment plants.
3. Listings of the discharge point and average flow from the treatment plants were obtained.
4. The seven day 10 year low flow from the receiving streams was obtained from maps prepared by the Illinois State Water Survey.
5. Wastewater Plants discharging to streams with a 0.0 c. f. s. seven day 10 year low flow more than 1.0 miles downstream of their discharge location were identified. This circumstance results in the wastewater plant being required to discharge effluent complying with the 3.75 pico-curies per liter standard proposed.
6. The water supply combined radium 226 and radium 228 concentrations were used as the influent value to the wastewater treatment plants.
7. The effluent concentrations were estimated based on 20%, 50% and 80% removal in the wastewater treatment plant.

Fourteen treatment plants were identified as having potential problems complying with the proposed standards. Most of the problems were identified in the condition of having low radium removal in the treatment plant (20%) and inadequate dilution downstream. Ten plants had potential problems based on 50% removal of radium in the wastewater treatment plant.

Joliet contacted these wastewater plants and encouraged them to collect samples and provide Joliet with the results. Joliet distributed the sampling results to the service list. One additional treatment works provided information to Joliet on August 4, 2005. Exhibit 1 includes the distributed results and the results received after distribution.

A review of the results for the five plants that provided influent and effluent data indicates that removals vary widely. Twenty-three reports were provided of influent and effluent samples collected at the same time. Fifteen of these reports were from the same community. The data is summarized as follows:

Average influent concentration all data	9.09 pico-curies per liter
Average effluent concentration all data	4.84 pico-curies per liter
Average removal %	45.6%

Since fifteen reports were from the same community, that community's samples influenced the average. A separate analysis using the average influent and average effluent for each of the five plants. The results are as follows:

Influent concentration	8.96 pico-curies per liter
Effluent concentration	4.69 pico-curies per liter
Removal %	47.6%

Other analysis also indicates that the anticipated removal of radium in a wastewater treatment plant is 45-50%. Based on an influent of 8.96 -9.09 , 50% removal results in effluent with a combined radium concentration of 4.44-4.54 pico-curies per liter. For plants discharging to a stream with a seven day 10 year low flow of 0.0 c.f.s., this exceeds the proposed 3.75 standard. Using this influent range, plants must remove approximately 57% of the radium to meet the proposed standard.

Anticipated Impact on Wastewater Treatment Plants

Using the 50% removal of radium in a wastewater treatment plant, nine wastewater treatment plants have been identified to have the potential to violate the proposed standard. The concentration of the radium in the water supply, the 50% removal and the discharge to a stream with inadequate dilution in the first mile downstream results in a concentration that exceeds 3.75 pico-curies per liter after one mile. Many of these plants represent the entire stream flow during dry conditions. Plants without significant dilution in the first mile must effectively meet the 3.75 pico-curies per liter at their discharge point.

Additional wastewater treatment plants would violate the 3.75 pico-curies per liter proposed standard if the Board does not proceed with the 30 pico-curies per liter alternate standard because the USEPA's objects. No specific estimate of the number of plants impacted has been developed.

The proposed standard is written requiring compliance with the water quality standard under all flow conditions. Joliet is aware that the use of annual average flow conditions may be proposed as an alternate. The use of the annual average would reduce the number of plants with potential violations from nine plants to a lesser number The number of plants is expected to range between two and six. This would result from the use of annual average flows, estimated at 43,560 cubic feet per acre with a background concentration of combined radium of 1.0 pico-curies per liter, to determine the average radium concentration in lieu of the seven day 10 year low flow. Some of the smaller plants may have adequate dilution to meet the 3.75 pico-curies at their discharge point under the annual average approach.

Anticipated Impact on Non-wastewater Treatment Plant Discharges

There is one other issue that was included in the record of the proceeding, but was not addressed in the proposed standard. There are other radium discharges in Illinois that do not originate from wastewater treatment plants. Deep wells are used for irrigation of golf courses and agriculture. Deep wells in communities using radium-bearing groundwater pump their wells to the storm sewers and other drainage ways during testing and at start-up. Communities using Lake Michigan as their water source have retained deep wells as an emergency supply. These wells are pumped to storm sewers and other drainage ways when the wells are exercised to verify operations. Fire hydrants are flushed on a regular basis and will discharge drinking water with a concentration less than 5.0 pico-curies per liter, but greater than 3.75 pico-curies per liter.

Since this water does not pass through a wastewater treatment plant, it is not eligible for the 30 pico-curies per liter standard, but must meet the 3.75 pico-curies per liter at the point of discharge. This water has not received any treatment and radium is discharged at the concentration that is pumped from the ground. Concentrations in wells in Joliet that discharge to locations with no dilution at the discharge point are included in Exhibit 1. Irrigation wells and standby wells in Lake Michigan communities have similar concentrations.

The use of an annual average stream flow does not provide any relief to the deep well situation. The Williamson Avenue Well in Joliet would require flow from other sources equivalent to the runoff of approximately 900 acres and having a radium concentration of 1.0 pico-curies per liter or less. The location of the storm sewer serving this location does not provide any opportunity for dilution of this magnitude. Other wells in Joliet require large volumes for dilution as well.

IEMA-IDNS Standards

The Illinois Emergency Management Agency, Division of Nuclear Safety provided comments in this proceeding stating their position that the protection of biota from radiation exposure was not the original intent of general use water quality standards. Biota has been protected from other constituents by water quality standards, but not from radiation. The Division of Nuclear Safety proposed a limit of 60 pico-curies per liter.

In spite of the comments from state agency with the most knowledge in this area, the Board gave great weight to the testimony provided by Water Remediation Technologies, LLC and ignored the Division of Nuclear Safety's recommendation.

Joliet provided support for the Illinois Emergency Management, Division of Nuclear Safety proposal in our post-hearing comments file in December 2004. Eli Port, Certified Heath Physicist calculated the limit that is protective of biota at 64 pico-curies per liter and recommended the 60 pico-curies per liter Illinois Environment Management Agency limit as being prudent.

Habitat for Sensitive Biota Not Present

Although no information has been presented to indicate that the discharge of water containing radium has harmed wildlife in Illinois, the proposed standard appears to be intended to protect wildlife. The discharges from identified wastewater plants with the potential to violate the proposed 3.75 pico-curies per liter standard are to streams with seven day ten year low flows ranging from 0.11 to 3.0 c. f. s. at the point that the 3.75 pico-curies per liter would apply.

When plants that could comply if an average flow was used to determine compliance, the seven day ten year low flows range from 0.11 to 0.24 c. f. s. The discharges from the wastewater treatment plants expected to violate the proposed standard range from 0.05 to 0.24 c. f. s. It is unlikely that sensitive species live in the receiving streams of these plants.

Joliet asked Don Blancher, PhD of Toxicological and Environmental Associates, Inc. to review the habitat for muskrats and the availability of habitat in Illinois. The review is attached to these comments as Exhibit 2. Dr. Blancher determined that low flow streams represent poor or unsuitable habitat for species like muskrat and the length of time for exposure in these areas would be minimal. This determination was based on the U.S. Fish and Wildlife Services Habitat Suitability Index Model for Muskrat which indicates that muskrat habitat is in streams with flow rates of 0.4 c. f. s. to 30 c. f. s. in waters with depth of greater than 18 inches. Dr. Blancher also reviewed the low flow stream maps provided by the Illinois State Water Survey and the National Wetlands Inventory for areas with radium discharges.

The Board has proposed a standard to protect species that do not live downstream of impacted treatment plants in Illinois. Without the sensitive species living downstream of wastewater treatment plants, there is no reason to establish such a restrictive standard. The Illinois Emergency Management Agency, Division of Nuclear Safety proposal of 60 pico-curies is appropriate.

As Joliet proposed in previous comments, if the Board is uncomfortable with the 60 pico-curies per liter proposal, a safety factor can be applied. If a safety factor of 2.0 was applied, the proposed water quality standard would be 30 pico-curies per liter. This standard would not impact wastewater plants, would allow irrigation and other direct discharges of well water to continue and provide the necessary protection of the streams.

COSTS OF COMPLIANCE

Throughout these proceedings, Water Remediation Technologies, LLC has indicated that their radium removal process is cost competitive with other water treatment processes. Joliet requested Strand Associates, Inc. to prepare a cost analysis comparing the technology used by Water Remediation Technologies, L.L.C. to the co-precipitation of radium with hydrous manganese oxide method. Exhibit 3 is the cost analysis.

The analysis reached many conclusions. Conclusions significant to these proceedings are as follows:

1. Co-precipitation of radium with hydrous manganese oxide has been demonstrated to be effective in several full-scale plants, while the WRT process just recently started full scale operations in one community in Illinois.
2. The costs of the WRT process are greater than the costs of hydrous manganese oxide (HMO). For the first year of a 20 year operating period, WRT is anticipated to cost 14.8% more than HMO. The last year of a 20 year operating period, WRT is anticipated to cost between 23.0% and 33.7% more. The first year cost difference for Joliet would be approximately $37,000 per year. The last year cost difference ranges between $645,000 and $1,045, 000. Although the first year cost differences do not appear significant, annual cost increases greater than 23% are significant when passed along to consumers.

Summary

A review of the available information in this proceeding can be summarized as follows:

1. The current standard of 1.0 pico-curies per liter Radium 226 is not being met in Illinois and must be revised.
2. The USEPA has not developed and is not developing water quality standard guidance based on a technical or scientific justification that will support either the 3.75 pico-curies per liter or the 30 pico-curies per liter standard. The USEPA will not approve the standard as currently proposed.
3. The original Illinois Environmental Protection Agency proposal of 5.0 pico-curies per liter at water supply and food processing intakes and no numeric standard as a general use water quality standard provides the necessary protections.
4. The Illinois Emergency Management Agency, Division of Nuclear Safety standard for discharge from facilities that they regulate is 60 pico-curies per liter.
5. The current proposal does not provide the intended relief to the current dischargers of radium.
6. No increased discharges of radium will occur as the result of establishing a standard in the range of 30-60 pico-curies per liter.
7. Wildlife in Illinois is at not risk due to radium discharges.
8. Communities that have complied with the 5.0 pico-curies per liter drinking water standard will face additional costs to supply with a standard that does not improve the environment if the proposed standard is approved. This would be a waste of public funds.
9. Communities in the process of complying with the drinking water standard should not face additional costs that other communities have not incurred without a commensurate improvement in the environment.

CH02/ 22403493.1

CERTIFICATE OF SERVICE

The undersigned certifies that he has served upon the individuals named on the attached Notice of Filing true and correct copies of ***COMMENTS SUBMITTED ON BEHALF OF THE CITY OF JOLIET*** by First Class Mail, postage prepaid, on August 15, 2005.

Roy M Harsch

R 04-21 SERVICE LIST

Deborah J. Williams Stephanie N. Diers Illinois Environmental Protection Agency 1021 N. Grand Avenue, East P.O. Box 19276 Springfield, IL 62794-9226	Dennis L. Duffield City of Joliet Department of Public Works & Utilities 921 E. Washington Street Joliet, Illinois 60431
Albert F. Ettinger Environmental Law & Policy Center 35 East Wacker Drive, Suite 1300 Chicago, Illinois 60601	Stanley Yonkauski Illinois Department of Natural Resources One Natural Resources Way Springfield, Illinois 62702-1271
Matthew J. Dunn Office of the Attorney General Environmental Bureau 188 West Randolph, 20th Floor Chicago, Illinois 60601	RoseMarie Cazeau Office of the Attorney General Environmental Bureau 188 West Randolph, 20th Floor Chicago, Illinois 60601
Dorothy M. Gunn Amy Antoniolli Illinois Pollution Control Board 100 West Randolph Street, Suite 11-500 Chicago, Illinois 60601	William Seith Total Environmental Solutions 631 E. Butterfield Road, Suite 315 Lombard, Illinois 60148
Claire A. Manning Brown, Hayes & Stephens LLP 700 First Mercantile Bank Building P.O. Box 2459 Springfield, Illinois 62705-2459	John McMahon Wilkie & McMahon 8 East Main Street Champaign, Illinois 61820
Richard Lanyon Metropolitan Water Reclamation District 100 East Erie Street Chicago, Illinois 60611	Lisa Frede CICI 2250 E. Devon Avenue, Suite 239 Des Plaines, Illinois 60018
Abdul Khalique Metropolitan Water Reclamation District Of Greater Chicago 6001 W. Pershing Road Cicero, Illinois 60804	Jeffrey C. Fort Letissa Carver Reid Sonnenschein Nath & Rosenthal 8000 Sears Tower 233 South Wacker Drive Chicago, Illinois 60606-6404

Exhibit 1

ROY M. HARSCH
(312) 569-1441
Fax: (312) 569-3441
rharsch@gcd.com

July 29, 2005

Deborah J. Williams
Stephanie N. Diers
Illinois Environmental Protection Agency
1021 North Grand Avenue East
P.O. Box 19276
Springfield, IL 62794-9276

Re: R 04-21 Radium Sampling Results

Dear Ms. Williams and Ms. Diers:

As set forth in Joliet's Motion for additional time, please find the enclosed Summary of Radium Samples for Various Communities in Northern Illinois.

Very truly yours,

Roy M. Harsch

Roy M. Harsch

RMH/dmc
Enclosure
cc: Service List

ROY M. HARSCH
(312) 569-1441
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rharsch@gcd.com

July 29, 2005

Mr. Albert F. Ettinger
Environmental Policy Center
35 E. Wacker Drive
Suite 1300
Chicago, IL 60601-2110

Re: R 04-21 Radium Sampling Results

Dear Mr. Ettinger:

As set forth in Joliet's Motion for additional time, please find the enclosed Summary of Radium Samples for Various Communities in Northern Illinois.

Very truly yours,

Roy M. Harsch

RMH/dmc
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ROY M. HARSCH
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rharsch@gcd.com

July 29, 2005

Mr. Matthew J. Dunn
Office of the Attorney General
environmental Bureau
188 West Randolph, 20th Floor
Chicago, IL 60601

Re: R 04-21 Radium Sampling Results

Dear Mr. Dunn:

As set forth in Joliet's Motion for additional time, please find the enclosed Summary of Radium Samples for Various Communities in Northern Illinois.

Very truly yours,

Roy M. Harsch

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ROY M. HARSCH
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July 29, 2005

Dorothy M. Gunn
Amy Antoniolli
Illinois Pollution Control Board
100 West Randolph St.
Suite 11-500
Chicago, IL 60601

Re: R 04-21 Radium Sampling Results

Dear Ms. Gunn and Ms. Antoniolli:

As set forth in Joliet's Motion for additional time, please find the enclosed Summary of Radium Samples for Various Communities in Northern Illinois.

Very truly yours,

Roy M. Harsch

RMH/dmc
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ROY M. HARSCH
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rharsch@gcd.com

July 29, 2005

Ms. Claire A. Manning
Brown, Hayes & Stephens LLP
700 Firs Mercantile Bank building
P.O. Box 2459
Springfield, IL 62705-2459

Re: R 04-21 Radium Sampling Results

Dear Ms. Manning:

As set forth in Joliet's Motion for additional time, please find the enclosed Summary of Radium Samples for Various Communities in Northern Illinois.

Very truly yours,

Roy M. Harsch

RMH/dmc
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ROY M. HARSCH
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Fax: (312) 569-3441
rharsch@gcd.com

July 29, 2005

Richard Lanyon
Metropolitan Water Reclamation District of Greater Chicago
100 East Erie St.
Chicago, IL 60611-2803

Re: R 04-21 Radium Sampling Results

Dear Mr. Lanyon:

As set forth in Joliet's Motion for additional time, please find the enclosed Summary of Radium Samples for Various Communities in Northern Illinois.

Very truly yours,

Roy M. Harsch

RMH/dmc
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ROY M. HARSCH
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rharsch@gcd.com

July 29, 2005

Abdul Khalique
Metropolitan Water Reclamation District
Of Greater Chicago
6001 W. Pershing Road
Cicero, Illinois 60804

Re: R 04-21 Radium Sampling Results

Dear Mr. Khalique:

As set forth in Joliet's Motion for additional time, please find the enclosed Summary of Radium Samples for Various Communities in Northern Illinois.

Very truly yours,

Roy M. Harsch

RMH/dmc
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ROY M. HARSCH
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rharsch@gcd.com

July 29, 2005

Mr. Dennis L. Duffield
Dir. of Public Works & Utilities
City of Joliet
921 East Washington St.
Joliet, IL 60433

Re: R 04-21 Radium Sampling Results

Dear Mr. Duffield

As set forth in Joliet's Motion for additional time, please find the enclosed Summary of Radium Samples for Various Communities in Northern Illinois.

Very truly yours,

Roy M. Harsch

Roy M. Harsch

RMH/dmc
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ROY M. HARSCH
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July 29, 2005

Mr. Stanley Yonkauski
Illinois Department of Natural Resources
One Natural Resources Way
Springfield, IL 62702-1271

Re: R 04-21 Radium Sampling Results

Dear Mr. Yonkauski:

As set forth in Joliet's Motion for additional time, please find the enclosed Summary of Radium Samples for Various Communities in Northern Illinois.

Very truly yours,

Roy M. Harsch

Roy M. Harsch

RMH/dmc
Enclosure
cc: Service List

ROY M. HARSCH
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rharsch@gcd.com

July 29, 2005

Rosemarie E. Cazeau
Illinois Attorney General's Office
Environmental Bureau
188 W. Randolph Street
Chicago, IL 60601

Re: R 04-21 Radium Sampling Results

Dear Ms. Cazeau:

As set forth in Joliet's Motion for additional time, please find the enclosed Summary of Radium Samples for Various Communities in Northern Illinois.

Very truly yours,

Roy M. Harsch

RMH/dmc
Enclosure
cc: Service List

ROY M. HARSCH
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rharsch@gcd.com

July 29, 2005

William Seith
Total Environmental Solutions
631 E. Butterfield Road, Suite 315
Lombard, Illinois 60148

Re: R 04-21 Radium Sampling Results

Dear Mr. Seith:

As set forth in Joliet's Motion for additional time, please find the enclosed Summary of Radium Samples for Various Communities in Northern Illinois.

Very truly yours,

Roy M. Harsch

RMH/dmc
Enclosure
cc: Service List

CH02/ 22399673.1

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July 29, 2005

John McMahon
Wilkie & McMahon
8 East Main Street
Champaign, Illinois 61820

Re: R 04-21 Radium Sampling Results

Dear Mr. McMahon:

As set forth in Joliet's Motion for additional time, please find the enclosed Summary of Radium Samples for Various Communities in Northern Illinois.

Very truly yours,

Roy M. Harsch

Roy M. Harsch

RMH/dmc
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ROY M. HARSCH
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July 29, 2005

Ms. Lisa Frede
Director of Regulatory Affairs
Chemical Industry Council of Illinois
2250 E. Devon Avenue
Suite 239
Des Plaines, IL 60018

Re: R 04-21 Radium Sampling Results

Dear Ms. Frede:

As set forth in Joliet's Motion for additional time, please find the enclosed Summary of Radium Samples for Various Communities in Northern Illinois.

Very truly yours,

Roy M. Harsch

RMH/dmc
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July 29, 2005

Jeffrey C. Fort
Letissa Carver Reid
Sonnenschein Nath & Rosenthal
8000 Sears Tower
233 South Wacker Drive
Chicago, Illinois 60606-6404

Re: R 04-21 Radium Sampling Results

Dear Mr. Fort and Ms. Reid:

As set forth in Joliet's Motion for additional time, please find the enclosed Summary of Radium Samples for Various Communities in Northern Illinois.

Very truly yours,

Roy M. Harsch

RMH/dmc
Enclosure
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	Date	Radium 226	Radium 228	Combined Radium	
Influent Samples					
Joliet Eastside Wastewater Treatment Plant					
	Feb-04	3	5.3	8.3	
	8-Mar-04	1.9	4.3	6.2	
	12-May-05	1.1 +/- 0.6	2.2 +/-0.7	3.3 +/-1.3	
Joliet Westside Wastewater Treatment Plant					
	Feb-04	2.9	5.1	8	
	8-Mar-04	3.9	6.1	10	
	12-May-05	1.8 +/- 0.6	2.7 +/-0.9	4.5	
Community A					
	Jul-00	4.3 +/- 0.8	1.4 +/-1.0	5.7 +/-1.0	
	8-Feb-01	2.7 +/- 0.1	3.9 +/- 0.1	6.6 +/- 0.1	
	22-Feb-01	2.6 +/- 0.1	3.6 +/- 0.1	6.2 +/- 0.2	
	Dec-02	5.2-8.8	NA	3.7-6.9	Note 1
	Jan-03	0.2-2.2	NA	2.6-4.2	Note 1
	Feb-03	5.6 +/- 1.9	<6.0	11.6 +/6.0	
	Mar-03	3.1 +/- 1.2	5.6 +/- 1.2	8.7 +/- 2.4	
	Apr-03	5.7 +/- 1.9	8.5 +/- 3.0	14.2 +/- 4.9	
	May-03	3.24 +/- 1.48	8.22 +/- 4.23	11.46 +/- 5.71	
	Jun-03	7.38 +/- 2.03	8.82 +/- 2.54	16.2 +/- 4.57	
	Jul-03	6.85 +/- 1.9	1.76 +/- 1.6	8.61 +/- 3.5	
	Aug-03	2.9 +/- 0.9	6.1 +/- 1.7	9 +/- 1.6	
	Sep-03	7.47 +/- 1.7	6.19 +/- 1.6	13.66 +/- 3.3	
	Jan-04	5.75 +/- 1.6	8.12 +/- 2.1	13.87 +/- 3.8	
	Feb-04	5.25 +/- 1.4	3.13 +/-0.96	8.38 +/- 2.36	
	Apr-04	3.87 +/- 1.1	1.86 +/- 0.71	5.73 +/- 1.81	
	Jun-04	3.12 +/- 0.9	3.55 +/- 0.88	6.67 +/- 1.78	
Community B	28-Apr-05	3 +/- 0.2	2.9 +/- 0.6	5.9 +/- 0.8	
DeKalb Sanitary District	11-May-05	0.8 +/- 0.5	4.5 +/- 1.3	5.3 +/- 1.8	

Prepared by City of Joliet
Department of Public Works and Utilities

	Date	Radium 226	Radium 228	Combined Radium	
Effluent Samples					
Joliet Eastside Wastewater Treatment Plant					
	Feb-04	1.2	3.9	5.1	
	8-Mar-04	2.6	3.5	6.1	
	12-May-05	<0.7	1.5 +/-0.7	1.5 +/-1.4	
Joliet Westside Wastewater Treatment Plant					
	Feb-04	2	2.9	4.9	
	8-Mar-04	0.9	1	1.9	
	12-May-05	0.6 +/- 0.6	1.6 +/-0.7	1.5 +/-1.3	
Community A					
	Jul-00	2.2 +/- 0.8	1.5 +/-0.9	3.7 +/-1.0	
	8-Feb-01	2.1 +/- 0.1	<1.0	3.1 +/- 0.2	
	22-Feb-01	<0.9	<1.0	<1.9	
	Dec-02	3.0-5.2	NA	3.3-4.9	Note 1
	Jan-03	2.7-5.1	NA	2.7-4.3	Note 1
	Feb-03	3.6 +/- 1.9	<3.8	7.4 +/1.4	
	Mar-03	2.8 +/- 1.2	2.9 +/- 1.2	5.7 +/- 2.4	
	Apr-03	2.8 +/- 1.9	4.2 +/- 1.8	7.0 +/- 3.0	
	May-03	2.26 +/- 1.48	3.97 +/- 1.66	6.23 +/- 2.63	
	Jun-03	2.33 +/- 0.84	3.72 +/- 1.76	6.05 +/- .6	
	Jul-03	1.96 +/- 0.7	3.12 +/- 1.4	5.08 +/- 2.1	
	Aug-03	3.4 +/- 1.0	3.4 +/- 1.2	6.8 +/- 2.2	
	Sep-03	2.88 +/- 0.75	2.47 +/- 1.1	5.35 +/- 1.85	
	Jan-04	3.01 +/- 1.1	3.22 +/- 1.2	6.23 +/- 2.3	
	Feb-04	2.74 +/- 1.0	1.94 +/- 0.75	4.68 +/- 1.75	
	Apr-04	3.43 +/- 1.1	0.54 +/- 0.53	3.97 +/- 1.63	
	Jun-04	3.21 +/- 0.96	2.69 +/- 0.69	5.9 +/- 1.65	

	Date	Radium 226	Radium 228	Combined Radium
Community B	28-Apr-05	3	2.9	5.9
Romeoville	15-Apr-05	0.7 +/- 0.1	0.5 +/- 0.5	1.2 +/- 0.6
Monmouth North	11-May-05	<0.6	<6.6	<7.2
Monmouth Main	11-May-05	1.0 +/- 0.5	<6.0	<7.0
DeKalb Sanitary District	10-May-05	<0.3	1.4 +/- 0.5	1.7 +/- 0.8
Channahon	15-Apr-05	1.1 +/- 0.9	0.79 +/- 0.83	1.9 +/- 0.9
Upstream Samples				
DesPlaines River at Jefferson Street	12-May-05	1.1 +/-0.1	<0.7	1.1
Hickory Creek Upstream Joliet ESWW1	12-May-05	<0.1	<0.7	<0.8
Downstream Samples				
DesPlaines River at Brandon Road	12-May-05	<0.7	<0.7	<1.4
DesPlaines River at I-55	12-May-05	<0.1	<0.7	<0.8
Romeoville, 1 mile downstream	15-Apr-05	0.1 +/- 0.1	0.5 +/- 0.4	0.6 +/- 0.5

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	Date	Radium 226	Radium 228	Combined Radium
Other sites				
DuPage River at Caton Farm Road	12-May-05	<0.1	<0.6	<0.7
Well Sample Results for Wells pumped to storm sewers with no dilution in the first mile downstream				
Williamson Ave	18-May-05	9.9 +/- 0.3	10.8 +/- 1.1	20.7 +/- 1.4
9-D	18-May-05	5.5 +/- 0.2	7.7 +/- 1.0	13.2 +/- 1.2
10-D	18-May-05	6.4 +/- 0.3	7.7 +/- 1.1	14.1 +/- 1.4
11-D	18-May-05	5.6 +/- 0.3	5.4 +/- 0.9	11.0 +/- 1.2
12-D	18-May-05	7.7 +/- 0.3	9.2 +/- 1.2	16.9 +/- 1.5
15-D	18-May-05	2.9 +/- 0.2	4 +/- 8	6.9 +/- 1.4
17-D	18-May-05	2.9 +/- 0.1	5.1 +/- 0.6	8.0 +/- 0.7
18-D	18-May-05	5.8 +/- 0.3	4.5 +/- 0.7	10.3 +/- 1.4
21	18-May-05	3.2 +/- 0.2	2.9 +/- 0.5	6.1 +/- 0.7

Note 1 Due to insufficient sample volume, results are reported as a range. Results are based on statistical average results for multiple analysis

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Department of Public Works and Utilities

R 04-21 SERVICE LIST

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EXHIBIT 1
SUPPLEMENT

Protecting Our Water Environment

Metropolitan Water Reclamation District of Greater Chicago

100 EAST ERIE STREET CHICAGO, ILLINOIS 60611-3154 312·751·5600

Richard Lanyon
Director of Research & Development

312·751·5190

August 3, 2005

Mr. Dennis L. Duffield
Director of Public Works and Utilities
921 E. Washington Street
Joliet, IL 60431

Dear Mr. Duffield:

SUBJECT: Radium Level at the Lemont Water Reclamation Plant (WRP) Influent and Effluent, and in the Chicago Sanitary and Ship Canal (CSSC) at the Upstream of Lockport Powerhouse.

The Village of Lemont uses groundwater, containing naturally occurring radium, for its community water supply. The water treatment process backwash is discharged to the Lemont Water Reclamation Plant (WRP), which is owned and operated by the Metropolitan Water Reclamation District of Greater Chicago (District). At your request, the District sampled the influent and effluent of the Lemont WRP and a location downstream of the plant in the Chicago Sanitary and Ship Canal for radium-226 and radium-228. The results are presented below.

Sample Location	Radium-226 (pCi/L)	Radium-228 (pCi/L)
Lemont WRP Influent	8.0 ± 0.4	8.9 ± 1.6
Lemont WRP Effluent	4.8 ± 0.4	4.7 ± 1.3
CSSC - upstream of Lockport Powerhouse	<0.1	<1.2

Please feel free to call Dr. Abdul Khalique at 708-588-4071 if any further information is required.

Sincerely,

R Lanyon

Richard Lanyon
Director of Research and Development

RL:AK:nu
cc: Granato/O'Connor/Khalique

Exhibit 2

Toxicological & Environmental Associates, Inc.

MEMORANDUM

To: Dennis Duffield

From: Don Blancher, Ph.D.

CC: Chris Ulm, Jane Carlson

Date: May 16, 2005

Re: Joliet – Radium Issues

Work on Radium Impact Review

Impact of Radium is focused on the impact to various riparian species, especially mammals, and especially the muskrat. We have reviewed a variety of information including:

- Habitat Requirements of Muskrats
- Low Flow Illinois Streams
- National Wetlands Inventory of the study area
- Riparian Species of Interest

One must keep in mind that risk from exposure to any toxicant, including radiological compounds, is dependent on dose and exposure. Based on our review of the information available, the risk from exposure to radium isotopes discharged from wastewater plants to low-flow surface waters in northern Illinois is extremely low for aquatic mammals. This is based on the fact that these low-flow streams represent poor to unsuitable habitat for species like muskrat, and the length of time for exposure in these areas would be minimal. The only time these organisms may occasion these areas is during high flow situations, when dilution would further minimize the exposure associated risks. The risk for aquatic mammalian species like beaver and otter is even less likely due to their life history and behavior.

Habitat Requirements of Muskrat

Review of the US Fish and Wildlife services Habitat Suitability Index Model (HSI) for Muskrat, indicate that this riparian mammal does not typically inhabit streams with either a very high flow rate (greater than 30 cu ft/sec) or streams with low flow rates less than 0.4 cu ft/sec (Allen and Hoffman, 1984). Of particular interest is the fact that the muskrat does not inhabit waters with a depth of less than 18 inches. This restricts the mammal to a certain stream size with enough flow to maintain suitable depth for the animal. Additionally, the organisms require sufficient aquatic vegetation for forage, and according to the HSI model the organisms would typically avoid areas lacking suitable aquatic species. It has been noted that cattail (*Typha spp.*) are the preferred diet, and this vegetation is typically found in abundance around ponds, wetlands, and larger streams, with perennial (in)flow. More definitive delineation of specific habitats could be reasonably predicted using the HSI model. However, it is highly likely that intermittent streams and small streams do not provide suitable habitat because of lack of water depth and flow, and lack of adequate forage and cover.

Similar habitat restrictions would be applicable to other aquatic mammalian species, such as otter. All these organisms are dependent on sufficient aquatic resources. Habitat Suitability models for many of these species are also available.

Low-Flow Illinois Streams

Maps of the Illinois low-flow (7Q10) streams were reviewed to provide information relative to areas of concern. The maps of interest are presented in a power point presentation associated with this memo. These data represent a starting point for comparison with various wetlands maps to define habitats of interest to the radium – discharge – exposure question.

National Wetlands Inventory of Study Area

National Wetlands Inventory maps of the study area are available online (http://wetlandsfws.er.usgs.gov/) and have been captured and presented in a series of power point slides for this review (see associated PPT files). These data are also available online as ESRI Shape files (http://wetlands.fws.gov/wetlands/shapedata_nad83/). Alternate sources of data which describe wetlands areas in Illinois include the analyses performed by the GAP program to identify habitat areas of concern and associated models of vertebrates inhabiting such habitats. (http://www.inhs.uiuc.edu/cwe/gap/vertmodeling.htm). Unfortunately, GAP analyses are unavailable for Illinois.

Riparian Species of Interest

Endangered Species (mammals) for the area includes several species of bats and a couple of field mice species but not riparian. See http://dnr.state.il.us/espb/datelist.htm. There are some mussels and crayfish potentially of interest, but these species are relatively unaffected by the levels of radiation in the range discussed and/or have a rapid turnover (crayfish, insects). Also, in the low flow areas of interest, we do not have good information on whether the mussels even utilize that small stream habitat.

Amphibians such as the bullfrog and the red-spotted newt will be found within these areas as well and have HSI models available. Since these are mostly insectivorous, it is not clear if they would be affected and perhaps this warrants further investigation.

A review of Illinois riparian mammals resulted in the following riparian species of interest:

Muskrat (*Ondatra zibethicus*)

Beaver (*Castor Canadensis*)

Mink (*Mustella vison*)

River Otter (*Lutra Canadensis*)

There are some voles, lemmings and shrews in other states that get listed as riparian, but it is not clear that they spend significant time in the riparian area. Raccoon and opossum are wide ranging, as are weasels, but they are not strictly riparian or aquatic. Hence, you would have to factor in to any risk assessment the time of exposure in the riparian zone. Thus, Muskrat are the primary animals who spend all their time in the water or riparian zone and have a small range (except during one season). They eat only aquatic vegetation and are considered a good bioindicator of what happens in the riparian zone. Weasels may also occasion the riparian zone but are still considered woodland and field species. Mink have muskrat in their diet, and would be the next logical species to carefully look at, and are always close to water.

The otter and beaver are even less likely to be encountered in the low-flow streams under consideration. And it has been shown studying bioaccumulation of radium in riparian organisms, that animals like the beaver accumulate less radium than do muskrat, presumably because of feeding habits and food source (Murka, et al. 1996).

Other species considered were the Marten, (*Martes americana*) and the Fisher, (*Martes pennanti*) but these two species are presumed extirpated from Illinois according to the NatureServe Explorer website (http://www.natureserve.org/explorer/).

References Cited:

Allen, A.W. and R. D. Hoffman. 1984. Habitat Suitability Index Models: Muskrat. FWS/OBS-82/10.46

FWS/OBS-82/10.46
JUNE 1984

HABITAT SUITABILITY INDEX MODELS: MUSKRAT

Fish and Wildlife Service

S. Department of the Interior

MODEL EVALUATION FORM

Habitat models are designed for a wide variety of planning applications where habitat information is an important consideration in the decision process. However, it is impossible to develop a model that performs equally well in all situations. Assistance from users and researchers is an important part of the model improvement process. Each model is published individually to facilitate updating and reprinting as new information becomes available. User feedback on model performance will assist in improving habitat models for future applications. Please complete this form following application or review of the model. Feel free to include additional information that may be of use to either a model developer or model user. We also would appreciate information on model testing, modification, and application, as well as copies of modified models or test results. Please return this form to:

Habitat Evaluation Procedures Group
U.S. Fish and Wildlife Service
2627 Redwing Road, Creekside One
Fort Collins, CO 80526-2899

Thank you for your assistance.

Species ____________ Geographic Location ______________________________

Habitat or Cover Type(s) ____

Type of Application: Impact Analysis ____ Management Action Analysis _____
Baseline _____ Other ____

Variables Measured or Evaluated _______________________________________

____

____

____

Was the species information useful and accurate? Yes ____ No ____

If not, what corrections or improvements are needed?___________________

____

____

____

Were the variables and curves clearly defined and useful? Yes ____ No ____

If not, how were or could they be improved? ______________________________
____
____
____

Were the techniques suggested for collection of field data:
Appropriate? Yes ____ No ____
Clearly defined? Yes ____ No ____
Easily applied? Yes ____ No ____

If not, what other data collection techniques are needed? ______________
____
____
____

Were the model equations logical? Yes ____ No ____
Appropriate? Yes ____ No ____

How were or could they be improved? ______________________________________
____
____
____

Other suggestions for modification or improvement (attach curves, equations, graphs, or other appropriate information) ____________________
____
____
____

Additional references or information that should be included in the model:
____
____
____
____
____

Model Evaluater or Reviewer __________________________ Date ______________

Agency ____

Address ____
____
____

Telephone Number Comm: ________________________ FTS ____________________

FWS/OBS-82/10.46
June 1984

HABITAT SUITABILITY INDEX MODELS: MUSKRAT

by

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2627 Redwing Road
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This report should be cited as:

Allen, A. W., and R. D. Hoffman. 1984. Habitat suitability index models: Muskrat. U.S. Fish Wildl. Serv. FWS/OBS-82/10.46. 27 pp.

PREFACE

This document is part of the Habitat Suitability Index (HSI) Model Series (FWS/OBS-82/10), which provides habitat information useful for impact assessment and habitat management studies. Several types of habitat information are provided. The Habitat Use Information Section is largely constrained to those data that can be used to derive quantitative relationships between key environmental variables and habitat suitability. The habitat use information provides the foundation for HSI models that follow. In addition, this same information may be useful in the development of other models more appropriate to specific assessment or evaluation needs.

The HSI Model Section documents each habitat model and the information pertinent to its application. Each model synthesizes the habitat use information into a framework appropriate for field application and is scaled to produce an index value between 0.0 (unsuitable habitat) and 1.0 (optimum habitat). The application information includes descriptions of the geographic ranges and seasonal application for each model, its current verification status, and a listing of model variables with recommended measurement techniques for each variable.

In essence, the models presented herein are hypotheses of species-habitat relationships and not statements of proven cause and effect relationships. Results of model performance tests, when available, are referenced. However, models that have demonstrated reliability in specific situations may prove unreliable in others. For this reason, feedback is encouraged from users of these models concerning improvements and other suggestions that may increase the utility and effectiveness of this habitat-based approach to fish and wildlife planning. Please send suggestions concerning the freshwater muskrat model to:

Habitat Evaluation Procedures Group
Western Energy and Land Use Team
U.S. Fish and Wildlife Service
2627 Redwing Road
Ft. Collins, CO 80526-2899

Suggestions or questions concerning the application of the estuarine muskrat model should be forwarded to:

Coastal Habitat Evaluation Procedures Project
National Coastal Ecosystems Team
U.S. Fish and Wildlife Service
1010 Gause Boulevard
Slidell, LA 70458

CONTENTS

ACKNOWLEDGMENTS

We gratefully acknowledge Dr. Robert Brooks, Dr. R. Chabreck, Mr. Alfred Gardner, Mr. Greg Linscombe, Dr. Thomas Michot, Mr. John Organ, Ms. Cathy Rewcastle, Mr. R. R. P. Stardom, and Mr. Thomas Thornhill for their reviews of earlier drafts of the HSI models for the muskrat. The comments and suggestions of these persons have added significantly to the quality of these HSI models. Appreciation is also extended to Dr. Jon Bart for the work he conducted in evaluating earlier drafts of the inland and estuarine muskrat HSI models. The cover of this document was illustrated by Jennifer Shoemaker. Word processing was provided by Carolyn Gulzow and Dora Ibarra.

The estuarine HSI model was developed for the National Coastal Ecosystems Team. Appreciation is extended to Rebecca Howard who served as Project Officer for the development and evaluation of the estuarine portion of this document.

Partial funding for the development of this model was provided by the Engineering and Research Center, U.S. Bureau of Reclamation, Denver, CO.

MUSKRAT (*Ondatra zibethicus*)

HABITAT USE INFORMATION

General

The muskrat (*Ondatra zibethicus*) is the most valuable semi-aquatic furbearer in North America, with a total fur trade income in the millions of dollars (Willner et al. 1980). With the exception of Florida, and coastal Georgia and South Carolina, native and introduced populations of muskrats occur throughout most of North America. Muskrats are an important component of the marsh ecosystem, serving as a food source for many predators (Wilson 1968), and can have a major impact on wetland vegetation (O'Neil 1949; Errington 1961, 1963; Weller and Spatcher 1965).

Food

Muskrats are primarily herbivorous although animal matter also is consumed (Errington 1963). Muskrats utilize the most available plant species, therefore commonly consumed foods will vary with the type of habitat (Takos 1947; Errington 1963; Neal 1968; Willner et al. 1980). Perry (1982) presented a regionalized listing of food plants used by muskrats throughout North America. The basal portions of aquatic vegetation are eaten most often followed by rhizomes and leaves (Neal 1968). Cattail (*Typha* spp.) has frequently been identified as a highly preferred food of the species (Hamerstrom and Blake 1939; Takos 1947; Bellrose 1950; Sather 1958; Errington 1963). Errington (1948) concluded that broad-leaved cattail (*T. latifolia*) was a highly preferred muskrat food and that marshes comprised of this species could support twice the density of muskrats as marshes dominated by other types of emergent vegetation. Feeding studies conducted in Manitoba have indicated that cattail can support approximately seven times as many muskrats as an equivalent amount of bulrush (*Scirpus* spp.) (Stardom pers. comm.). Other important food plants include sweetflag (*Acorus calamus*), waterlily (*Nymphaea* spp.), arrowhead (*Sagittaria* spp.), sedge (*Carex* spp.), and wild rice (*Zizania aquatica*) (Takos 1947). A wide variety of vegetation, including agricultural crops, will meet the dietary needs of stream-dwelling muskrats (Errington 1961). The foods consumed by stream and canal-dwelling muskrats tend to be more diverse than those used by muskrats inhabiting marshes (Perry 1982). Muskrats inhabiting lakes and reservoirs tend to be opportunistic feeders and may feed upon animal matter to a greater degree than do muskrats that inhabit marshes (O'Neil 1949).

In coastal marsh habitats muskrats are heavily dependent on bulrush and cattail (Willner et al. 1975). Olney bulrush (S. olneyi) made up 80% of the muskrat's diet in brackish Louisiana marshes (O'Neil 1949). Olney bulrush, common three-square bulrush (S. americanus), and cattail (T. latifolia, T. angustifolia) accounted for 80% of the muskrat's diet in coastal Maryland marshes (Smith 1938). Olney bulrush has the highest weight per square meter of any common marsh plant and grows year-round in Louisiana (O'Neil 1949). The salinity tolerance of Olney bulrush has been investigated in several studies (O'Neil 1949; Harris 1952; Schmidt 1958; Palmisano 1970; Rose and Chabreck 1972). Results of these studies indicate that the salinity most suitable for the growth of Olney bulrush ranges from 5 to 20 parts per thousand. Food is limited in winter, and appreciable quantities are not stored by muskrats (Smith 1938; Errington 1941; Schwartz and Schwartz 1959). The main advantage of cattail is that its rhizomes are of high nutritive quality and are available as a winter food source (Cook 1952).

Muskrats typically reach their greatest densities in aquatic habitats that provide dense emergent vegetation and are bordered by terrestrial herbaceous vegetation (Errington 1963). Brooks and Dodge (1981) recorded more muskrat burrows and signs of activity in riverine habitats bordered by open and agricultural land, whereas forested river banks had a significant negative effect on muskrat burrow abundance. Increasing muskrat density in Iowa was associated with the presence of dense emergent vegetation (Neal 1968). Declining population levels were associated with less densely vegetated habitat. "Food-poor" open water lakes, ponds, or dry lowlands choked with vegetation are not conducive to high muskrat densities in northern regions (Errington 1963). In addition to the amount of emergent vegetation, the amount of additional food plants and materials available for lodge construction also may regulate muskrat populations (Bishop et al. 1979). Ponds in Ohio with "good" vegetative cover produced an average of 9.6 muskrats/0.4 ha (9.6/acre) (Gilfillan 1947). Ponds with "fair" vegetative cover yielded an average of 8.7 muskrats/0.4 ha (8.7/acre), whereas ponds with no vegetative cover produced no muskrats.

The importance of vegetation in providing cover is difficult to separate from its role as a food source. In high quality habitat, 50% or more of the area is covered with dense, emergent vegetation. Dozier (1953) believed that an 80:20 ratio of emergent vegetation to water would provide ideal muskrat habitat. Errington (1963) rated marsh conditions as excellent when two-thirds of the marsh was covered, but gave a poor rating to a marsh with only 17% coverage. Bishop et al. (1979) recorded an 18-fold increase in muskrats after a lake in Iowa revegetated to a 75:25 ratio of vegetation to open water.

Muskrat feeding and house construction activities may have detrimental effects upon aquatic vegetation (Willner et al. 1980). Danell (1978) reported that stands of horsetail (Equisetum fluviatile) decreased as muskrat population density increased. High muskrat population density may result in the elimination of preferred food plants in an area and an eventual decline in the muskrat population (Errington 1963). "Eat-outs" by muskrats, discussed in detail by Errington (1951), Harris (1952), Sipple (1979), and Willner et al. (1980), may severely affect the humus layer and thus retard vegetative regeneration for several years.

Water

Suitable muskrat habitat requires a permanent supply of still or low velocity water (Errington 1963). Stream gradient and discharge were believed to be key factors in determining the potential quality of streams as muskrat habitat in a Massachusetts study (Brooks and Dodge 1981). Muskrats were present where the stream gradient was low [< 6.1 m/km (32.2 ft/mi)] and discharge exceeded 0.1 m^3/s (4 ft^3/s) but were absent on streams with a gradient in excess of 9.0 m/km (47.5 ft/mi) and discharge flows of less than 0.1 m^3/s. Riverine habitats with mean annual discharge in excess of 30 m^3/sec (approximately 1,000 ft^3/s) are probably poor muskrat habitat because of water level fluctuation, scouring, and erosion of the banks. Water stability has a more direct effect on habitat quality than does water depth (Hamerstrom and Blake 1939). Bellrose and Brown (1941) reported that muskrats were more abundant in lakes having stable water levels than in lakes with fluctuating water levels. Muskrat population density was more affected by changes in water level than by the types of emergent vegetation present. Low water levels result in reduced food and cover availability (Errington 1939). Low water level during winter has a greater affect on muskrats than low water conditions during summer (Perry 1982). Low water during winter may permit the entire water column to freeze resulting in reduced availability of food resources in the normally unfrozen water and substrate. Seabloom and Beer (1964) associated the absence of snow cover in North Dakota to heavy ice formation resulting in freezeout and subsequent high muskrat mortality.

High water also results in habitat deprivation by altering vegetative composition and forcing muskrats out of refuge (lodge and burrow) sites (Sather 1958; Olsen 1959). Lakes in Ohio that were subjected to severe flooding [> 0.6 m (2 ft) rise in water level], produced 0.17 muskrats/0.4 ha (0.17/acre) (Gilfillan 1947). Lakes that did not experience such severe flooding produced 1.45 muskrats/0.4 ha (1.45/acre). Muskrat production in severely flooded marshes was 4.24 animals/0.4 ha (4.24/acre) as compared to 8.59 animals/0.4 ha (8.59/acre) in marshes with stable water levels. The best muskrat marshes in Manitoba experience cyclic water level fluctuations of approximately 0.6 m (2 ft) (Rewcastle pers. comm.). It is believed that water fluctuation is required with some regularity (approximately every 5 years) to provide a suitable seedbed for vegetative regeneration.

Water depth between 0.46 m (18 inches) and 1.2 m (4 ft) is most suitable for muskrats (Errington 1963). Danell (1978) reported that 96% of all muskrat lodges located in his study area were constructed in water or within 1 m (3.3 ft) of water. The average water depth at lodge sites was 0.2 m (0.6 ft), whereas the average water depth within 2 m (6.6 ft) of the lodge was 0.33 m (1.0 ft). All lodges located during a California study were in water 0.3 m (1.0 ft) deep or less (Earhart 1969). Optimum water depth for lodge construction in Illinois was 0.3 to 0.40 m (1 to 1.5 ft) (Bellrose and Brown 1941). Muskrats inhabiting streams prefer deep holes and backwater areas; however, a lack of such conditions is not critical if adequate food is present (Errington 1937). Brooks and Dodge (1981) found that the number of coves and islands was strongly associated with muskrat abundance in an evaluation of riverine habitats in Massachusetts. Coves, islands, and other deviations in the main channel provided increased shoreline length, areas of lower water velocity, and often provided a source of emergent vegetation.

Lay and O'Neil (1942) and Lay (1945) believed that water depth in Gulf of Mexico coastal marshes should be maintained at depths of 2.0 to 30.0 cm (0.8 to 11.8 inches) year-round to provide the best muskrat habitat. Palmisano (1967) recommended that the water level should be maintained near the marsh surface and should not fall more than 8.0 cm (3.1 inches) below the substrate surface for optimum propagation of Olney bulrush. Bellrose (1950) reported that muskrats frequently moved to marginal vegetation when water depth dropped to unfavorable levels. Fluctuating water depths were found to be the critical factor limiting muskrat populations in North Carolina coastal marshes (Wilson 1949). Water level fluctuations also prevented establishment of desirable muskrat food plants in Louisiana (Moody 1950). Perry (1982), citing a study by Wilson (1968), concluded that in general, Atlantic coastal marshes managed with control structures can yield 3 to 5 times as many muskrats as undiked marshes.

Cover

Muskrats may construct conical lodges or dig burrows in the banks adjacent to aquatic habitats (Willner et al. 1980). The ability to build either type of shelter enables the species to inhabit most types of wetland habitats. Water depth, soil texture, and the amount of vegetation all influence site selection for lodge construction (Danell 1978). Muskrats often build two types of lodges, a main dwelling lodge and smaller feeding lodges or platforms (Dozier 1947; Sather 1958). Lodge construction typically begins on a firm substrate and is made up of the dominant emergent plants available in the immediate vicinity of the lodge site (Willner et al. 1980). Submergent vegetation seldom provides suitable material for lodge construction (Errington 1963).

MacArthur and Aleksiuk (1979) distinguished between dwelling and feeding lodges primarily on the basis of external size. Feeding lodges are smaller than dwelling lodges and vary considerably in construction. In summer, and throughout the year in the South, feeding lodges are usually thin-walled and may be simple platforms. They are thick-walled in winter to provide insulation in the northern region of the muskrat's range. Structures called push-ups are made when muskrats chew through ice or snow and push a 30.0 to 45.0 cm (11.8 to 17.7 inches) pile of vegetation onto the surface. Push-ups are typically used as temporary feeding sites (Perry 1982). Other temporary shelters include hollow logs, the dens of other animals, and overhanging banks (MacArthur and Aleksiuk 1979).

In the absence of sufficient emergent vegetation muskrats may establish shelter in bank burrows (Dozier 1953). Three types of burrows were identified in a California study: (1) breeding burrows composed of numerous entrance tunnels and chambers; (2) winter burrows composed of one tunnel and chamber; and (3) shallow, simple feeding burrows (Earhart 1969). Clay soils provide the most suitable substrate for burrow construction (Errington 1937, 1963; Beshears and Haugen 1953; Earhart 1969). Beshears and Haugen (1953) reported that the amount of sand in the soil was inversely related to burrow longevity. Embankments with soils containing more than 70% sand supported only temporary burrows in California (Earhart 1969). Soils with a high sand content may provide suitable burrowing sites if dense vegetation is present (Errington

1937). Earhart (1969) believed that burrow construction required a bank slope of 10° or more regardless of soil sand content. Gilfillan (1947) reported that optimum conditions for bank burrows exist when the slope of the bank is 30° or more and a minimum height of 0.5 m (1.6 ft). Muskrat burrows were absent in riverine habitats in a Massachusetts and Pennsylvania study where the bank height was less than 0.2 m (0.6 ft), bank slopes were less than 10%, or the bank composition was in excess of 90% sand and gravel (Brooks 1982).

High quality muskrat habitat along streams generally has an abundance of retreats (e.g., downfall, lodged debris, deep pools, backwaters, undercut banks) and is bordered by dense herbaceous vegetation (Errington 1937). Muskrat burrows in Massachusetts and Pennsylvania riverine habitats were established where dense herbaceous vegetation or littoral zone emergent vegetation was present (Brooks 1982). Ohio muskrat harvest data indicated that streams bordered by agricultural crops produced an average of 89 muskrats/1.6 km (89/mi), whereas, those bordered by dense and sparse native vegetation produced 45 muskrats/1.6 km (45/mi) and 22 muskrats/1.6 km (22/mi), respectively (Gilfillan 1947). Although the main channel may serve as a travel avenue, large streams and rivers are generally unsuitable habitat if they are subject to fluctuating water levels, or are highly turbid (Errington 1963). In such conditions, muskrats may be common in oxbows, tributary streams or wetlands adjacent to the main channel. The availability of cover and backwater areas is strongly correlated with muskrat abundance in riverine habitats (Brooks 1980). Evaluation of riverine muskrat habitat in Massachusetts and Pennsylvania indicated that pools and backwater coves were inhabited by muskrats 35% more often than their relative availability (Brooks 1982). Shallow, steep gradient streams with high water velocity and rocky substrate are poor muskrat habitat (Errington 1937). Stream gradient and discharge were believed to be the most influential characteristics in determination of muskrat habitat quality in small streams in Massachusetts and Pennsylvania (Brooks and Dodge in prep.). High gradient streams were characterized as having rocky, coarse to fine substrates as compared to low gradient streams that had substrates comprised of fine to organic materials.

Intensive grazing of livestock has detrimental effects on muskrat density due to decreased vegetative cover, increased bank erosion, and trampling of burrow systems (Errington 1937). Muskrat harvest data from Iowa indicated that more than twice as many animals were captured along streams with ungrazed banks than were along streams with grazed banks (Gilfillan 1947).

Brackish marshes in coastal habitats appear to have the greatest potential as muskrat habitat. Aerial surveys of Louisiana coastal marshes indicated that approximately 72% of the muskrat lodges counted were in brackish waters although this habitat type occupied only 37% of the area surveyed (Palmisano 1972). Brackish marshes characterized as being comprised of cordgrass (Spartina spp.), saltgrass (Distichlis spicata), needle rush (Juncus roemerianus) and Olney bulrush were attributed to be the most productive muskrat habitat in coastal Texas (Lay and O'Neil 1942). Slightly brackish marshes, dominated by Olney bulrush and cattail, adjacent to wooded areas supported the greatest muskrat production in Maryland coastal habitats (Dozier et al. 1948).

Reproduction

The reproductive habitat requirements of the muskrat are assumed to be identical with its water, food, and cover requirements as described above.

Interspersion

The area occupied by muskrats may be influenced by a variety of factors that include environmental conditions, the size, configuration and diversity of the aquatic habitat, social pressures, and season (Perry 1982). Neal (1968) believed that habitat quality was more important in determining muskrat density than were intraspecific interactions. Muskrat home ranges in Iowa were consistently larger in aquatic habitats with less dense vegetation than they were in habitats with dense emergent vegetation. Danell (1978) reported that the mean distance between muskrat lodges was 110 m (360.8 ft) and no houses were closer together than approximately 40 m (131.2 ft). Most summer and fall home ranges of muskrats in Iowa were 45.7 to 60.9 m (150 to 200 ft) in diameter (Neal 1968). More than 50% of muskrat observations in Manitoba were recorded within 15 m (49.2 ft) of the primary dwelling lodge (MacArthur 1978). Few movements of muskrats exceeded 150 m (492 ft) whereas almost all foraging took place within 5 to 10 m (16.4 to 32.8 ft) of the lodge. Most muskrats recorded in a New Brunswick study remained in the same habitat type, within a relatively confined area, throughout the summer and fall seasons (Parker and Maxwell 1980). Movement between habitat types occurred most frequently between the fall and spring seasons probably due to muskrats being forced from winter lodges and burrows because of early spring increases in the water level. Several authors have reported that the home range size for bank-dwelling muskrats in riverine habitats ranges from 200 to 300 m (656 to 984 ft) along the stream or river channel (Errington 1963; Stewart and Bider 1974). Brooks (1982) estimated the home range for muskrats inhabiting riverine habitats to range between 250 to 400 m (273 to 437 yds) in length. Muskrats inhabiting edge or linear habitats may have oblong home ranges, whereas inhabitants of interior portions of marshes may have home ranges that are more circular in shape (Perry 1982).

O'Neil (1949) reported that high-quality coastal Olney bulrush marshes in Louisiana could support about 13 muskrats/0.4 ha (13/acre), although densities were occasionally much higher for short periods of time because of immigration. Marshes managed for muskrat production also may have much higher densities (Perry 1982). Considerable variation occurs, however, in muskrat density between years. These "cycles" in northern inland marshes have been extensively discussed by Errington (1951, 1954, 1963); however, their causes are not well understood. Lowery (1974) summarized the stages in a cycle as low muskrat numbers, development of an abundant food supply, followed by a rapid build-up of muskrat density with eventual severe overpopulation, habitat destruction, and, finally, starvation. The length of the cycle varies geographically, and cycles may be out of phase within a region.

HABITAT SUITABILITY INDEX (HSI) MODELS

Model Applicability

Geographic area. The inland muskrat model has been developed for application in freshwater habitats throughout the range of the species.

The estuarine model is applicable to Atlantic and Gulf of Mexico coastal marshes (Fig. 1).

Figure 1. Geographic applicability of the estuarine muskrat HSI model. The freshwater muskrat model is applicable to wetland and riverine cover types throughout the range of the species.

Season. These models have been developed to evaluate the potential quality of year-round habitat in both freshwater and estuarine habitats. Since vegetation type and density must be determined, application of the models may be most effective during the growing season.

Cover types. The freshwater muskrat model was developed to evaluate habitat quality in the following cover types (terminology follows that of U.S. Fish and Wildlife Service 1981): Herbaceous Wetland (HW); and Riverine (R).

The estuarine model is applicable in the following classes of the estuarine intertidal (EI) habitats as described by Cowardin et al. (1979): Emergent (EM); Aquatic Bed (AB); and Unconsolidated Shore (US).

Minimum habitat area. Minimum habitat area is the minimum area of contiguous habitat necessary before an area will be occupied by a species. Information on the minimum habitat area for the muskrat was not found in the literature. It is assumed that potential muskrat habitat will exist in any freshwater or estuarine cover type large enough to be classified as such, if adequate food, water stability, and cover are provided.

Verification level. The freshwater and estuarine muskrat HSI models provide habitat information useful for impact assessment and habitat management. The models are hypotheses of species-habitat relationships and do not reflect proven cause and effect relationships.

The freshwater muskrat models were reviewed by: Dr. Robert Brooks, Pennsylvania State Univeristy, University Park; Mr. Alfred Gardner, U.S. Fish and Wildlife Service, National Museum of Natural History, Washington, DC; Mr. John Organ, U.S. Fish and Wildlife Service, Newton Corner, Massachusetts; Mr. Richard Stardom, Manitoba Department of Natural Resources, Winnipeg; and Ms. Cathy Rewcastle, Manitoba Department of Natural Resources, Winnipeg. Suggestions and comments for improvement were incorporated into the model.

An earlier version of the herbaceous wetlands muskrat model was evaluated by Dr. Jonathan Bart, Ohio Cooperative Wildlife Research Unit, Ohio State University (Bart et al. 1984). HSI values were compared to 1 year's estimates of muskrat house density on 25 sites in northwest Ohio. The minimum amount of persistent emergent vegetation present on any site was 30.6% and all but three sites had greater than 40% emergent vegetation canopy cover. Measuring the degree of linear relationship between muskrat lodge density and HSI's yielded a correlation coefficient of 0.441.

The estuarine model has been reviewed by: Mr. Greg Linscombe, Louisiana Department of Wildlife and Fisheries, New Iberia, LA; Dr. R. Chabreck, Louisiana State University, School of Forestry and Wildlife, Baton Rouge; Mr. Thomas Thornhill, U.S. Fish and Wildlife Service, Daphne, AL; and Dr. Thomas Michot, U.S. Fish and Wildlife Service, Lafayette, LA. The comments and suggestions of these individuals have been incorporated into this model.

An earlier version of the model was evaluated in coastal Louisiana marshes using the 3-year average pelt take as an indication of habitat suitability. Subsequent revisions in the model were based on the results of this field evaluation.

Model Description

Freshwater. Year-round habitat requirements of the muskrat can be fulfilled within wetland habitats that provide herbaceous vegetation and permanent surface water with minor fluctuations in water levels. Wetlands characterized by seasonal drying, an absence of emergent vegetation, or both, have less potential as year-round muskrat habitat than wetlands with permanent water and an abundance of emergent vegetation. It is assumed that food and cover are interdependent characteristics of the muskrat's habitat and that measures of vegetative abundance and water permanence within a wetland can be aggregated to reflect habitat conditions favoring maintenance of the muskrat's food and cover requirements. The reproductive habitat requirements of the species are assumed to be met when adequate water, food, and cover conditions are present.

Estuarine. The estuarine muskrat model describes and defines the variables affecting habitat suitability in coastal (brackish and salt water) wetlands. The model consists of a single component that reflects the potential quality of food and cover. In order to provide potentially suitable year-round habitat for muskrats, coastal marshes must support relatively stable water levels and the water must be of sufficient chemical composition to support an adequate food source. Prior to applying the following estuarine muskrat model, the following factors must be considered to determine if the model is applicable to the habitat being evaluated.

If marsh water level fluctuates more than 90.0 cm (35.4 inches) per year or below the marsh substrate during summer or winter, or water salinity exceeds 30 ppt for more than one week - - - - - - - - - - - - Do not continue with model; HSI for muskrats is assumed to be 0.0.

If marsh water level is relatively stable, does not fluctuate > 90.0 cm (35.4 inches) per year or below marsh surface in summer or winter, and water salinity does not exceed 30 ppt for more than one week - Continue with model application to determine a HSI value.

The following sections provide documentation of the logic and assumptions used to translate habitat information for the muskrat into the variables and equations used in the HSI models. Specifically, these sections cover: (1) identification of variables; (2) definition and justification of the suitability levels of each variable; and (3) description of the assumed relationships between variables. Figure 2 is an illustration of the relationships of habitat variables, life requisites, and cover types to a habitat suitability value for the muskrat in freshwater habitats. Figure 3 is an illustration of the relationships of habitat variables, life requisites, and cover types to a habitat value for the muskrat in estuarine habitats.

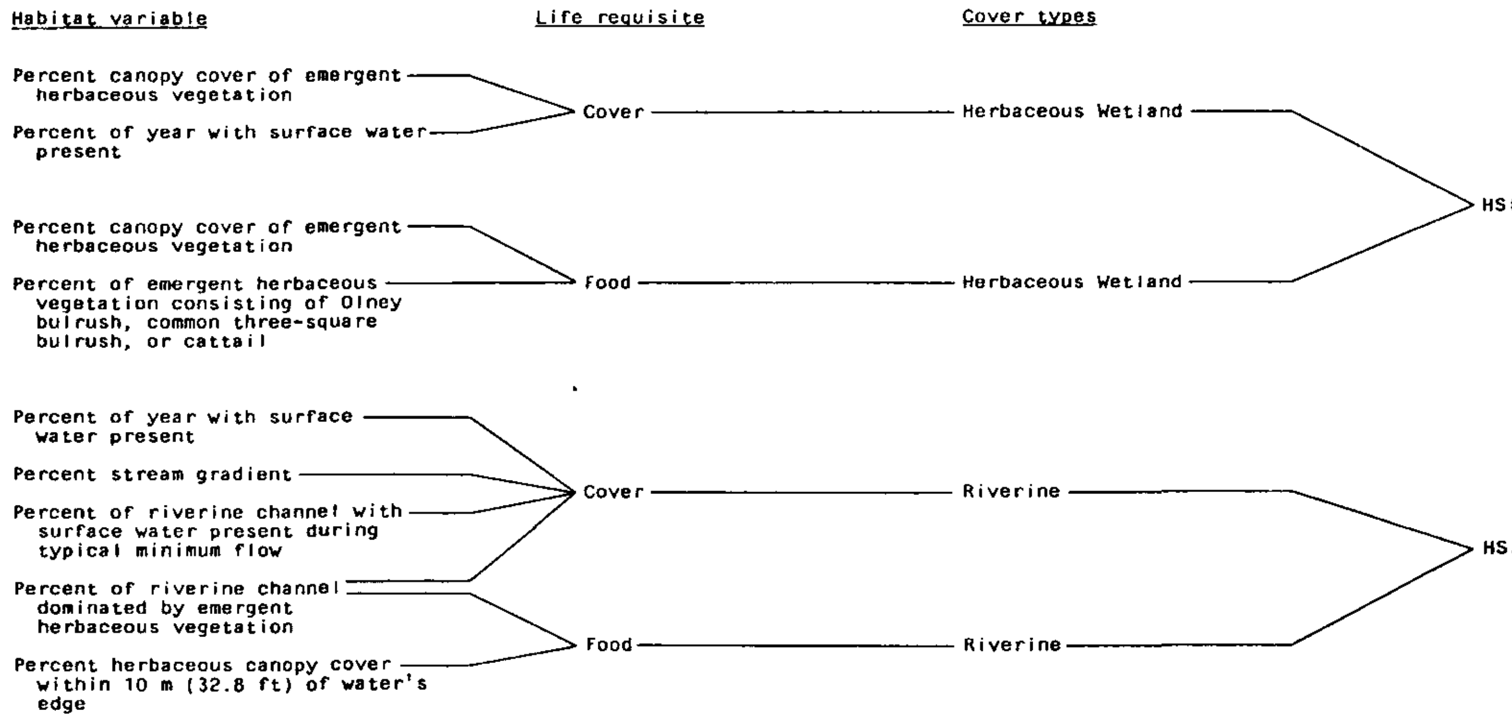


Figure 2. Relationships of habitat variables, cover types, and life requisites in the freshwater muskrat model.

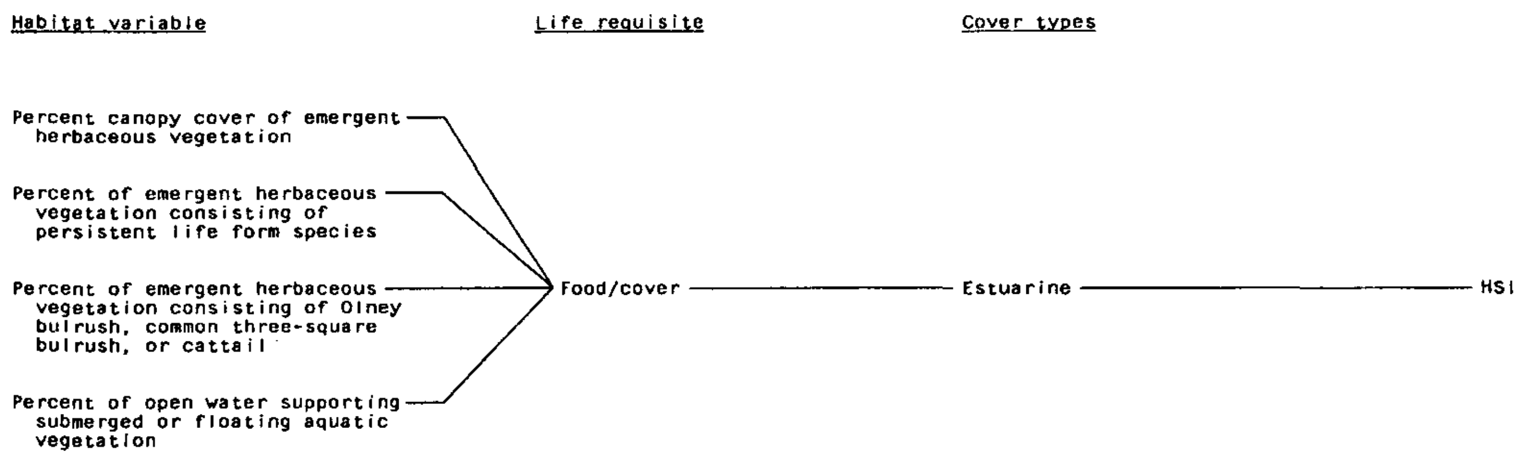


Figure 3. Relationships of habitat variables, cover types, and life requisites in the estuarine muskrat model.

Cover component: freshwater. Suitable cover for muskrats in wetland cover types is a function of the presence and abundance of emergent vegetation suitable for lodge construction and the permanence of water within the wetland basin. Persistent emergent vegetation, such as cattail, normally remains standing throughout the winter months as compared to nonpersistent emergent vegetation whose leaves and stems break down at the end of the growing season (Cowardin et al. 1979). Although both types of emergent vegetation may provide food and cover for muskrats during the growing season, nonpersistent vegetation will not provide optimum lodge construction materials. Woody vegetation in shrub or forested wetlands may provide some cover and physical support for lodge construction. However, it is assumed that emergent vegetation also must be present in these cover types to provide suitable cover and material for lodge construction. If emergent vegetation is absent in these cover types, the cover is assumed to be minimal regardless of the amount of woody vegetation present. It is assumed that optimum cover conditions are present when 50 to 80% of a wetland basin is dominated by emergent vegetation. Canopy cover of emergent vegetation below 50% is assumed to reflect less suitable cover for muskrats. Muskrats may establish bank burrows and are not totally dependent upon the availability of vegetation for lodge construction, therefore, wetlands devoid of emergent vegetation are assumed to have minimal value as muskrat habitat. As the density of emergent vegetation increases above 80%, it is assumed that habitat quality will decrease slightly due to a reduction in escape cover that is provided by open water. Muskrats inhabiting riverine areas establish burrows within river and stream banks and are less dependent upon emergent vegetation for providing adequate cover.

Water permanence is an important characteristic that defines muskrat habitat potential and is assumed to be equally as important as the presence and abundance of emergent vegetation in defining the quality of muskrat habitat. Wetlands that provide permanent year-round surface water are assumed to provide potentially optimum habitat conditions for muskrats. Conversely, wetlands that contain water on a seasonal basis are assumed to have little, if any, potential for meeting the year-round cover requirements of the species. Major changes in water level, either drawdown or flooding, will result in habitat deprivation for the species. Wetlands with water present for 75% of the year (9 months) or less are assumed to be less suitable muskrat habitat, regardless of the amount of persistent emergent vegetation present. Wetlands with water present for 50% of the year (6 months) or less are assumed to be unsuitable year-round muskrat habitat.

Within riverine cover types muskrats require permanent water of low velocity for optimum cover conditions. The cover potential of muskrat habitat in riverine cover types is assumed to be a function of the permanence of surface water and stream gradient. A measure of actual water velocity may yield a more precise indication of riverine habitat quality. However, due to the potential variability in water velocity a measure of velocity at one point in time may yield a relatively inaccurate estimate of habitat conditions when considered on an annual basis. For the purposes of this model, water velocity is assumed to be a function of stream gradient. Low gradient streams are assumed to have greater potential as muskrat habitat than high gradient streams. High water velocity, rocky substrate, low pool/riffle ratio, and less cover immediately adjacent to the water's edge are typically associated with high gradient streams (Reid 1961). In contrast, low gradient streams are characterized as having low water velocity, substrates consisting of finer sediments, high pool/riffle ratio, and more cover in the form of undercut banks, debris and vegetation in and immediately adjacent to the water's edge. It is assumed in this model that riverine reaches with a gradient of 1% [10 m/km (53 ft/mi)] or less will be indicative of potentially optimum cover conditions for the muskrat by providing water of low velocity and banks suitable for the establishment of burrow systems. A gradient of 4% [40 m/km (211 ft/mi)] or greater is assumed to be indicative of marginal muskrat habitat. Brooks (pers. comm.) cautioned that stream gradient may give an inaccurate indication of muskrat habitat quality when applied over long distances [> 1.0 km (0.6 mi)]. The presence of a dam or rapids may yield an incorrect estimate of habitat quality when long stream reaches are evaluated. For example, evaluation of a stream reach containing a large rapid may result in a relatively high gradient value, indicating low muskrat habitat potential, even though the stream channel both above and below the rapid may be of low gradient and represent potentially high quality muskrat habitat. Brooks (pers. comm.) suggested that the evaluation of riverine habitat conditions by Stream Order (Horton 1945) may be a more accurate method when used on an individual watershed.

Riverine cover types must provide permanent surface water for ideal muskrat habitat. However, the amount of surface water present also has an influence on habitat potential for the species. The amount of suitable muskrat habitat in riverine cover types is probably no greater than the amount of surface water present during minimum flow periods. Riverine cover types with relatively stable discharge have greater habitat potential than do those that have widely fluctuating flows. Intermittent streams probably have little, if any, year-round habitat potential for muskrats due to a seasonal absence of water in the channel. Riverine habitats that maintain minimum flows and/or isolated pools during low flow periods are of minimum value as muskrat habitat. Depending upon their size and depth, isolated pools may provide adequate habitat during low flow periods from which muskrats may disperse during higher flow periods. Therefore, in riverine habitats, the cover potential for muskrats is assumed to be a function of the percent of the riverine channel with surface water during minimum discharge periods.

Food component: freshwater. The major component of the muskrat's diet is herbaceous vegetation. High-density muskrat populations are typically associated with wetland habitats that support dense stands of emergent vegetation. Cattail has often been identified as a preferred food in fresh water wetlands, and is believed to be capable of supporting higher numbers of muskrats than other types of emergent vegetation. Nonpersistent vegetation, submerged aquatic vegetation, and terrestrial herbaceous vegetation also are consumed by muskrats. However, it is assumed that the stems, leaves, and rhizomes of emergent vegetation are the primary components of the muskrat's annual diet. Within wetland cover types food quality is assumed to be related to the total amount of emergent vegetation present and the proportion of that vegetation that consists of cattail.

Emergent vegetation, persistent or nonpersistent, is assumed to be most suitable as a potential food source when present at a density of 50 to 80% canopy closure. Canopy coverage less than 50% or greater than 80% is assumed to be indicative of less suitable food quality. Food quality is assumed to be positively correlated to the amount of cattail making up the total amount of emergent vegetation present. Stands of emergent vegetation consisting wholly of cattail will be of maximum value as a muskrat food source. Stands of emergent vegetation other than cattail are assumed to be of lower value as a potential food source even though total density may be within the optimum range. Wetlands with a density of emergent vegetation in excess of 80% are assumed to have a lower potential as a diverse year-round food source for muskrats due to a decreased availability of submergent vegetation resulting from a reduction in open water. Inasmuch as muskrats will forage on submerged aquatic and terrestrial herbaceous vegetation, wetlands devoid of emergent herbaceous vegetation are assumed to have minimum potential for providing muskrat food. However, not all wetlands are suitable muskrat habitat. For example, alkaline wetlands (pH ≥ 7.4) probably have no potential as muskrat habitat.

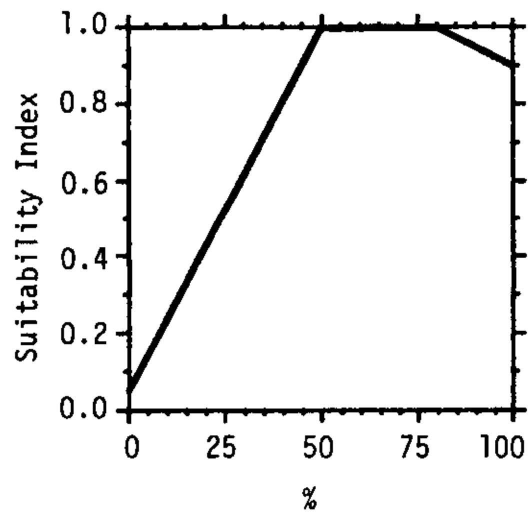
Muskrats inhabiting riverine habitats obtain most of their food from terrestrial vegetation adjacent to the stream channel. Emergent vegetation may be an adequate food source if present; however, the absence of such vegetation will not limit the potential food value if terrestrial herbaceous vegetation is present in an adequate amount. Due to the muskrat's relatively small home range size, it is assumed that density of herbaceous vegetation within 10 m (32.8 ft) of the water's edge will indicate potential food availability. The value of terrestrial herbaceous vegetation as a potential muskrat food source is assumed to be positively related to density. Stream channels bordered by trees and/or shrubs will probably have less dense herbaceous ground cover than would channels bordered by open ground or cropland. Emergent vegetation is an additional food source in riverine habitats that probably contributes to a more stable food supply when considered on an annual basis. The abundance of emergent vegetation is assumed to be twice as important as the presence and abundance of terrestrial herbaceous vegetation in determining potential year-round values of food resources for muskrats in riverine habitats.

Food/cover component: estuarine. Emergent vegetation provides food and cover for muskrats. The estuarine model does not attempt to separate these functions. Fifty to 80% canopy coverage of emergent herbaceous vegetation is assumed to be characteristic of optimum muskrat habitat in estuarine habitats. Although muskrats will create small amounts of open water in dense stands of emergent vegetation as a result of their feeding and lodge construction activities, estuarine habitats with a density of emergent vegetation in excess of 80% are assumed to be of slightly lower habitat potential due to a decreased availability of escape cover provided by open water. Estuarine habitats with no emergent vegetation are assumed to have almost no potential as muskrat habitat. However, because dikes or shoreline habitats may provide sites for bank burrows and submerged and floating aquatic vegetation may provide a limited food source, the complete absence of emergent herbaceous vegetation is assumed to represent estuarine habitats with minimum muskrat habitat potential.

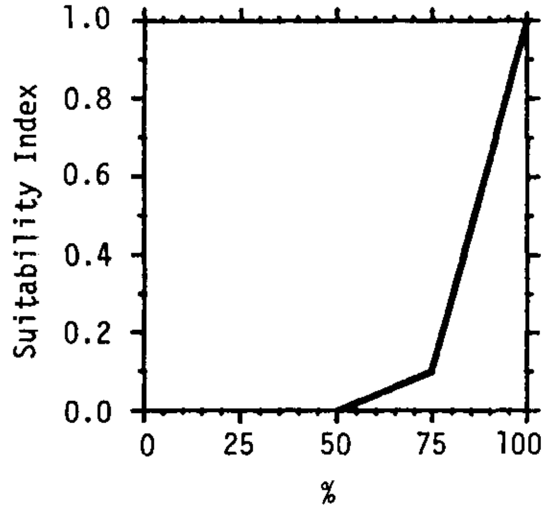
Persistent emergent herbaceous vegetation is believed to be of greater value for providing food and cover for the muskrat than is nonpersistent emergent vegetation. Therefore, the suitability of muskrat habitat is assumed to increase as the proportion of emergent vegetation consisting of persistent life form species increases. However, the estuarine muskrat model is based on the assumption that a marsh with no persistent emergent vegetation does have a low value as muskrat habitat. Although there is no evidence that muskrats exhibit a preference among emergent vegetation used as lodge construction materials, coastal muskrats do prefer bulrush (Olney and common three-square) and cattails as food items. It is assumed that an 80 to 100% occurrence of these preferred species represents optimum food and cover conditions in estuarine wetlands. However, these species are not required by muskrats and wetlands with a 0 to 10% occurrence of bulrush and cattails are assumed to retain a low value as muskrat habitat. Muskrats also feed on submerged and floating-leafed aquatic vegetation and use these forms of vegetation in lodge construction to a limited degree. It is assumed that the value of open water habitat increases as the percentage of the habitat that supports submerged and floating vegetation increases. The absence of submerged or floating aquatic vegetation in a mixed open water/emergent marsh is assumed not to preclude muskrat use of the area.

Model Relationships

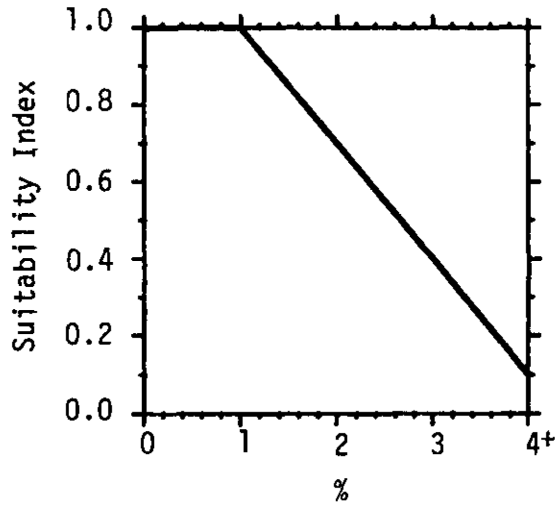
Suitability Index (SI) graphs for habitat variables. The relationships between various values of habitat variables and habitat suitability for the muskrat are graphically presented in this section.

Cover type	Variable		
HW, EI	V_1	Percent canopy cover of emergent herbaceous vegetation.	

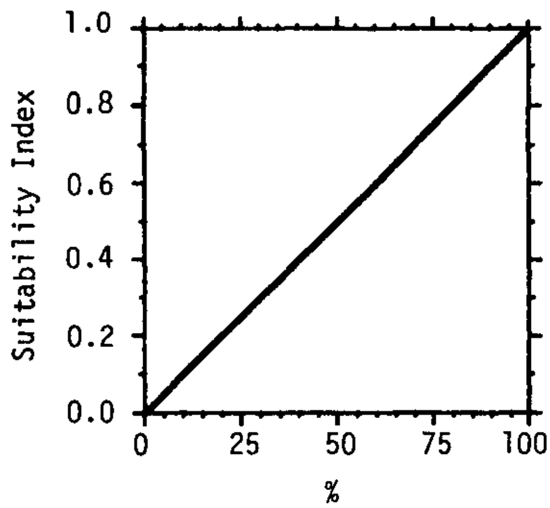
HW V_2 Percent of year with surface water present.



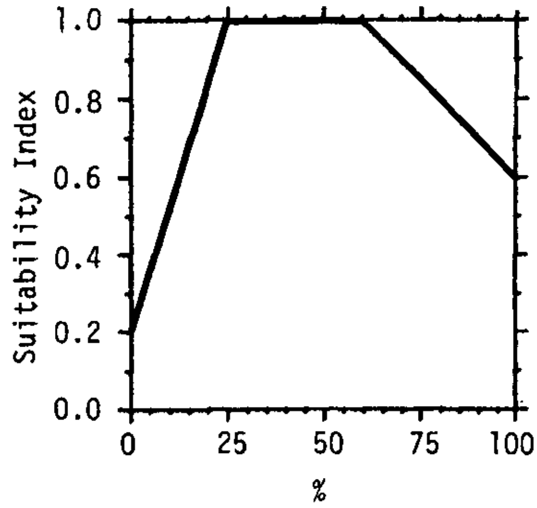
R V_3 Percent stream gradient.



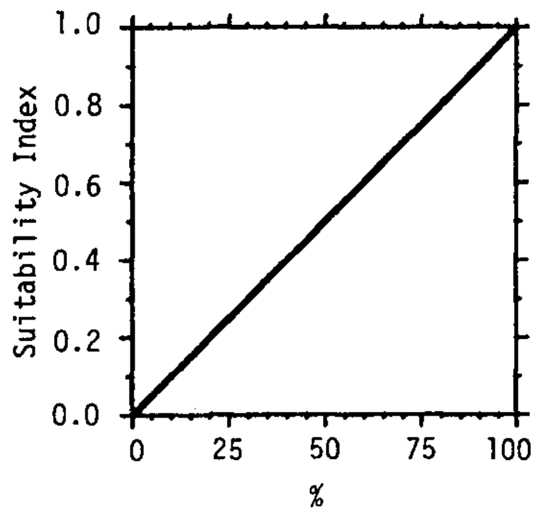
R V_4 Percent of riverine channel with surface water present during typical minimum flow.



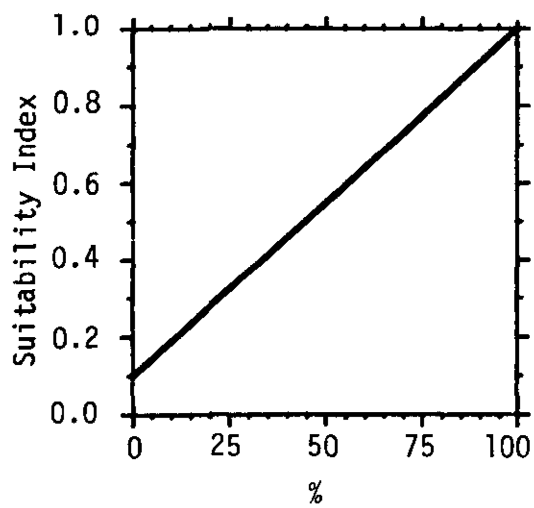
R V_5 Percent riverine channel dominated by emergent herbaceous vegetation.



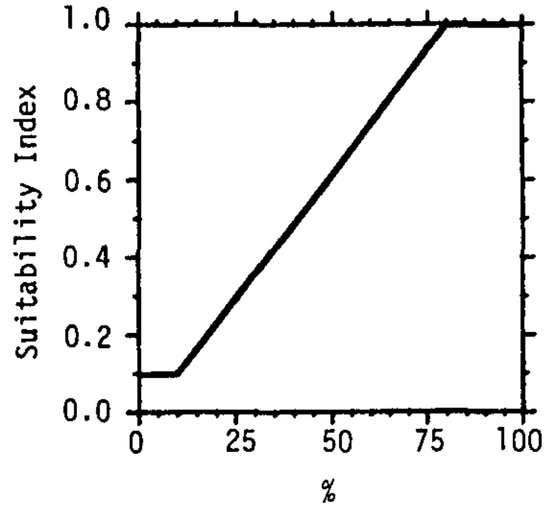
R V_6 Percent herbaceous canopy cover within 10 m (32.8 ft) of water's edge.



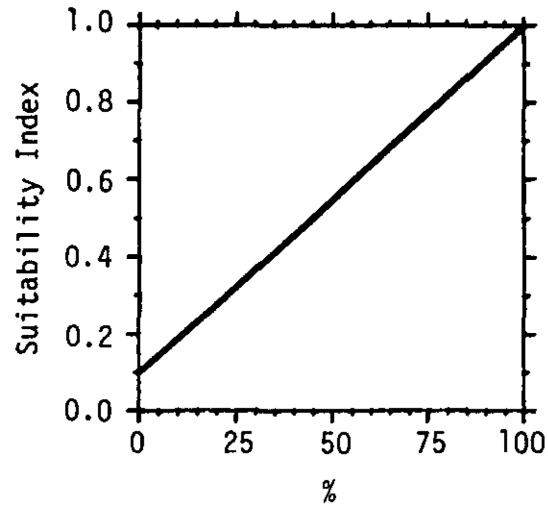
EI V_7 Percent of emergent herbaceous vegetation consisting of persistent life form species.



HW,EI V_8 Percent of emergent herbaceous vegetation consisting of Olney bulrush, common three-square bulrush, or cattail.



EI V_9 Percent of open water supporting submerged or floating aquatic vegetation.



Equations. In order to obtain life requisite values for the muskrat, the SI values for appropriate variables must be combined through the use of equations. A discussion and explanation of the assumed relationships between variables for freshwater and estuarine habitats was included under Model Description. The suggested equations for obtaining life requisite and HSI values are presented in Figure 4.

Life requisite	Cover type	Equation
Cover	HW	$(V_1 \times V_2)^{1/2}$
Food	HW	$(V_1 \times V_8)^{1/2}$
Cover	R	$\dfrac{(V_2 \times V_3 \times V_4)^{1/3} + V_5}{2}$
Food	R	$\dfrac{V_6 + 2(V_5)^*}{2}$ *In instances where a value greater than 1.0 is obtained, the value should be considered to equal 1.0.
Cover/Food	EI	$[(V_1 \times V_7 \times V_8^2)^{1/4} \times (a)] + [V_9 \times (b)]^{**}$ where: a = the percent of the total estuarine habitat being evaluated that supports > 10% emergent vegetation canopy cover b = the percent of the total estuarine habitat being evaluated that supports ≤ 10% emergent vegetation canopy cover **See Application of the Model section for specific instructions for the calculation of this value.

Figure 4. Equations for determining life requisite values by cover type for the muskrat.

HSI determination. The HSI value in freshwater herbaceous wetlands and riverine cover types is computed by assuming a limiting factor mechanism. The HSI will equal the lowest life requisite value received for either cover or food in either cover type. The HSI value in estuarine cover types is equal to the cover/food life requisite value.

Application of the Model

Calculation of the food/cover life requisite for estuarine muskrat habitat is a function of: (1) the quality of emergent vegetation (V_1, V_7, V_8); (2) the area dominated by emergent vegetation (> 10% canopy closure); (3) the percentage of the evaluation area in open water (≤ 10% canopy closure of emergent vegetation); and (4) the amount of floating or submerged aquatic vegetation in open water areas (V_9). A weighted (weighted by area) food/cover value is calculated by performing the following steps:

1. Stratify the estuarine habitat into areas dominated by emergent vegetation and open water.

2. Determine the area dominated by emergent vegetation, area dominated by open water, and total estuarine area.

3. Determine an SI value for the area dominated by emergent vegetation $[(V_1 \times V_7 \times V_8^2)^{1/4}]$ and an SI value for the area dominated by open water (V_9).

4. Multiply the area dominated by emergent vegetation and the area dominated by open water by their respective SI values (Step 3).

5. Add the products calculated in step 4 and divide the sum by the total area of the estuarine habitat to obtain the weighted food/cover life requisite value.

Definitions of variables and suggested field measurement techniques (Hays et al. 1981) are provided in Figure 5.

Variable (definition)		Cover types	Suggested technique
V_1	Percent canopy cover of emergent herbaceous vegetation (the percent of the water surface shaded by a vertical projection of the canopies of all emergent herbaceous vegetation, both persistent and non-persistent).	HW,EI	Remote sensing, line intercept
V_2	Percent of year with surface water present (the proportion of the year in which the cover type has surface water present).	HW	Remote sensing, local data
V_3	Percent stream gradient (specific expression of decrease in elevation of a stream or river bed; determined by dividing the change in elevation between two points of the riverine reach by the horizontal distance between those two points, then multiplying the product by 100).	R	Topographic map
V_4	Percent of riverine channel with surface water present during typical minimum flow (the proportion of the riverine channel covered by surface water during the lowest discharge in the driest period of the year).	R	Remote sensing, line intercept

Figure 5. Definitions of variables and suggested measurement techniques for the freshwater and estuarine muskrat model.

Variable (definition)		Cover types	Suggested technique
V_5	Percent of riverine channel dominated by persistent emergent vegetation [the percent of the stream or river channel's bed that supports emergent vegetation that normally remains standing after the growing season e.g., cattail (*Typha* spp.) or bulrush (*Scirpus* spp.)].	R	Remote sensing, line intercept
V_6	Percent herbaceous canopy cover within 10 m (32.8 ft) of water's edge (the percent of the ground surface within 10 m of the edge of the riverine cover type which is shaded by a vertical projection of all nonwoody vegetation).	R	Line intercept, quadrat
V_7	Percent of emergent herbaceous vegetation consisting of persistent life form species [the proportion of the emergent herbaceous vegetation that normally remains standing after the growing season (e.g., cattail or bulrush)].	EI	Remote sensing, line intercept
V_8	Percent of emergent herbaceous vegetation (both persistent and nonpersistent) consisting of Olney bulrush, common three-square bulrush, or cattail.	HW,EI	Remote sensing, line intercept, quadrat
V_9	Percent of open water supporting submerged or floating aquatic vegetation.	EI	Remote sensing, line intercept, quadrat

Figure 5. (concluded).

SOURCES OF OTHER MODELS

Brooks (1980) and Brooks and Dodge (in prep.) have developed a model using principle component regression for estimating muskrat density in riverine habitats. The model can be used to identify favorable riverine muskrat habitat and rank watersheds with respect to potential muskrat abundance. Habitat information gathered from remote sensing data are used to identify gross physiognomic features of potential muskrat habitat. Microhabitat characteristics and local population attributes are investigated by on-site reconnaissance. The model is not recommended for application in northern coniferous forests, riparian habitats in arid regions, or tropical climates.

No other habitat model designed for the evaluation of coastal muskrat habitat was located in the literature.

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			14.
15. Supplementary Notes			

16. Abstract (Limit: 200 words)

Habitat preferences of the muskrat (*Ondatra zibethicus*) are described in this report, which is one of a series of Habitat Suitability Index (HSI) models. A review and synthesis of the literature is followed by development of estuarine and freshwater habitat models incorporating life requisites of the muskrat. HSI models are designed for use with Habitat Evaluation Procedures previously developed by the U.S. Fish and Wildlife Service.

17. Document Analysis a. Descriptors

Mathematical models
Wildlife
Habitability

b. Identifiers/Open-Ended Terms

Habitat Suitability
Muskrat
Ondatra zibethicus

c. COSATI Field/Group

18. Availability Statement	19. Security Class (This Report)	21. No. of Pages
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Illinois Low-Flow Maps

Radium Issue

Joliet, Ill.

MAP1 ROCK RIVER REGION

ROCK RIVER AND MISSISSIPPI RIVER DRAINAGE UPSTREAM OF ROCK ISLAND

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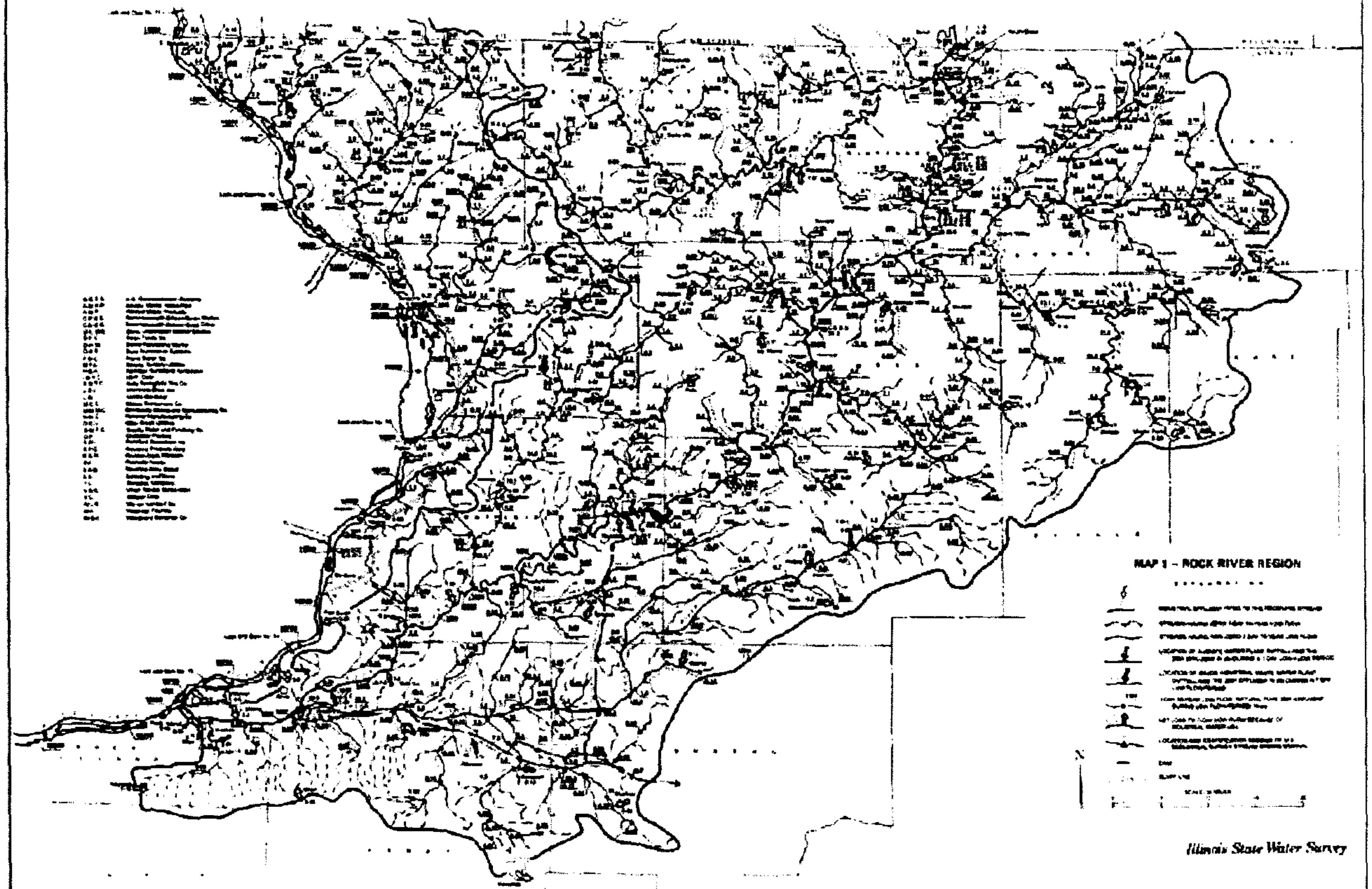
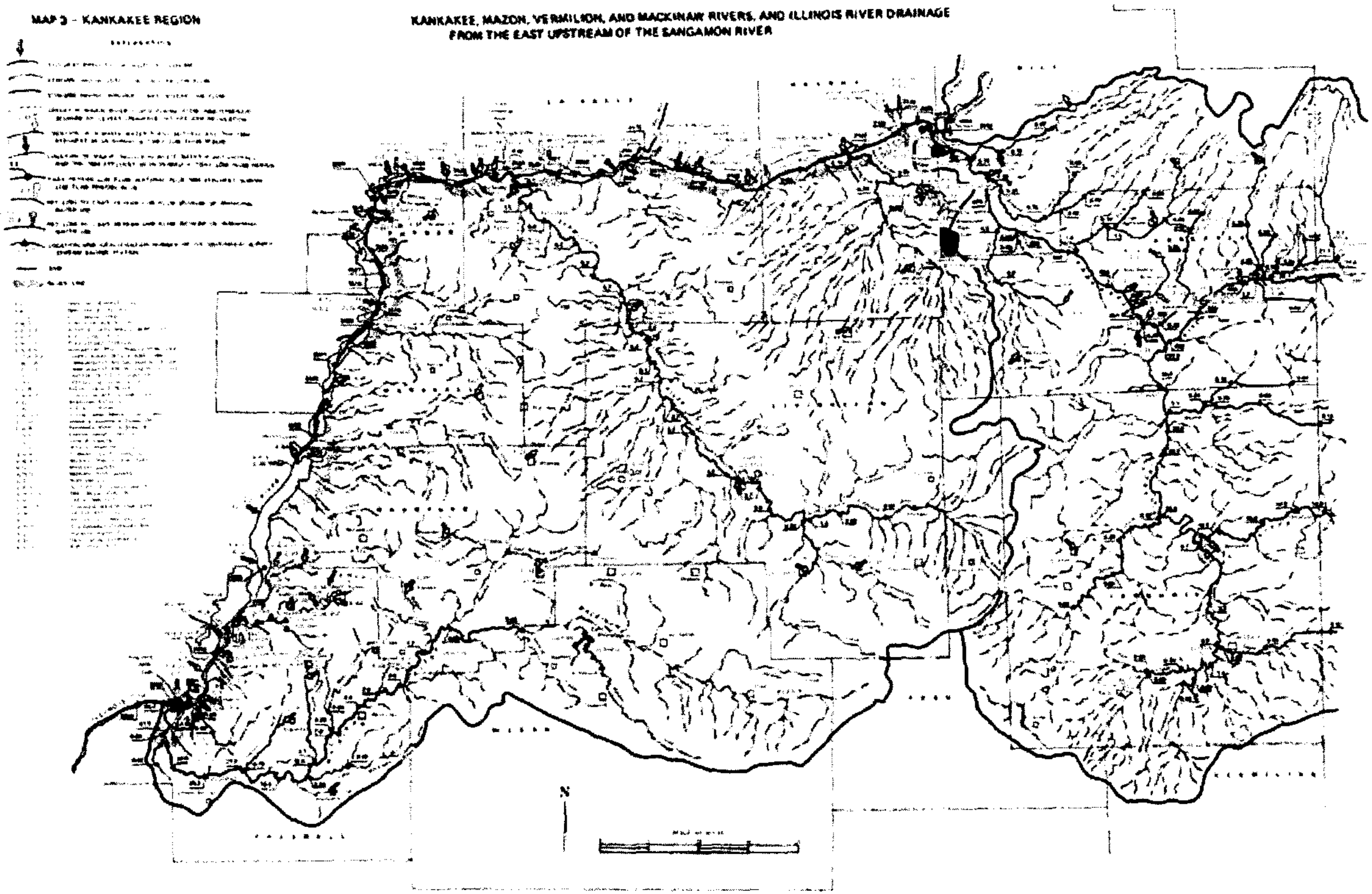


MAP 3 KANKAKEE REGION

KANKAKEE, MAZON, VERMILION, AND MACKINAW RIVERS, AND ILLINOIS RIVER DRAINAGE FROM THE EAST UPSTREAM OF THE SANGAMON RIVER



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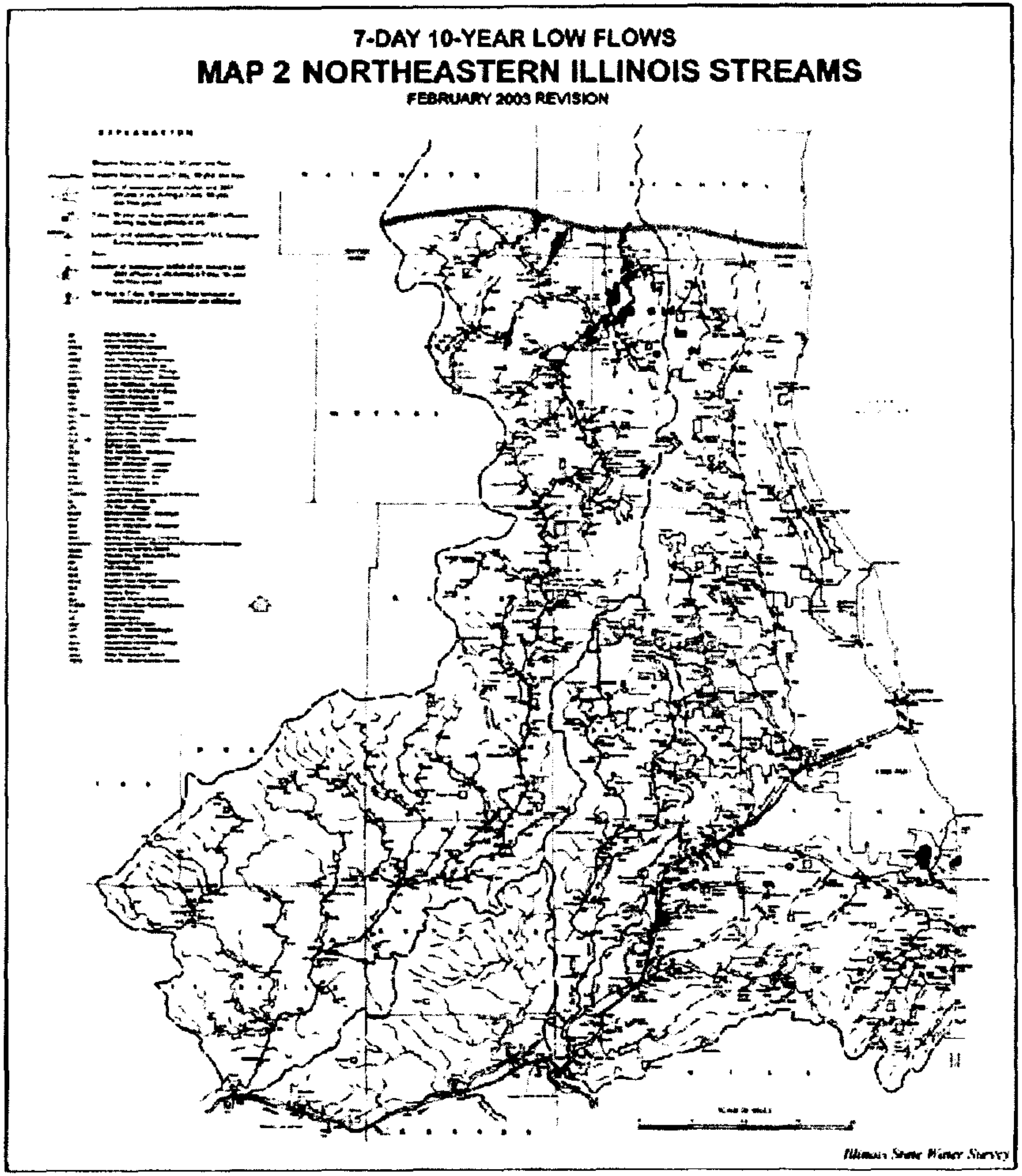
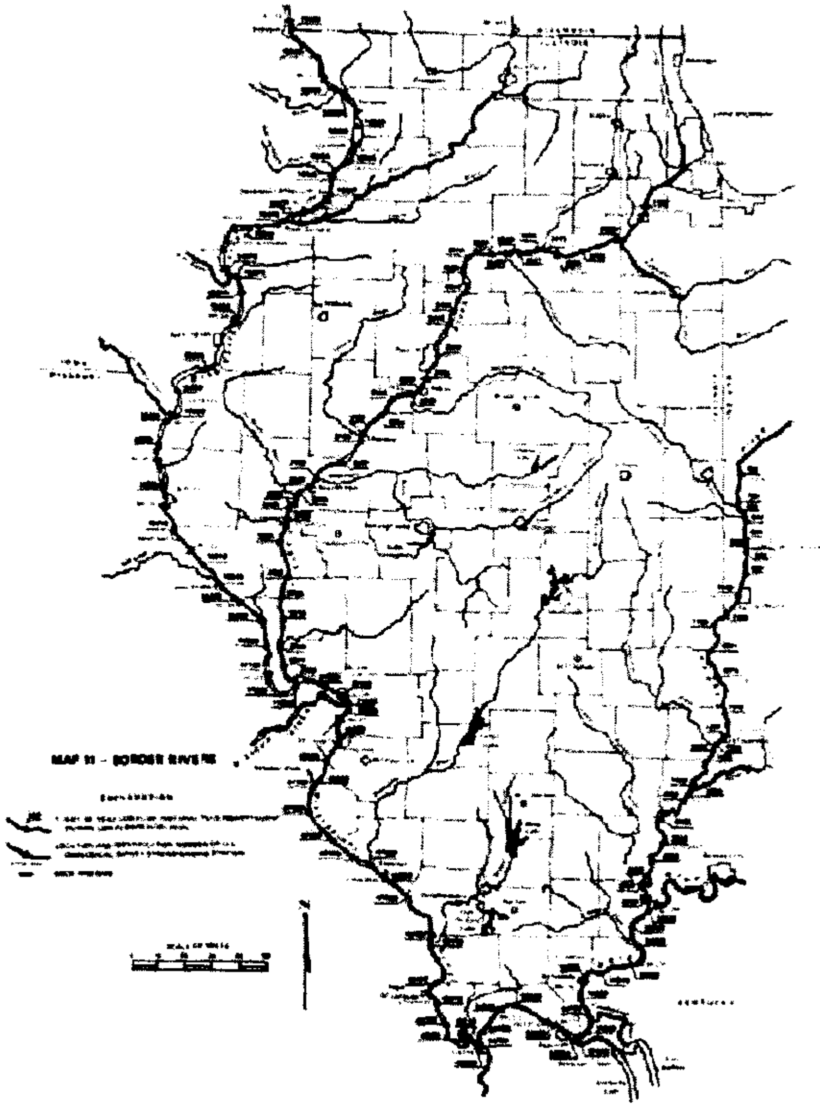

7-DAY 10-YEAR LOW FLOWS
MAP 2 NORTHEASTERN ILLINOIS STREAMS
FEBRUARY 2003 REVISION
Illinois State Water Survey

MAP 11 BORDER RIVERS

MAIN STEM ONLY OF MISSISSIPPI, WABASH, AND OHIO RIVERS ALONG ILLINOIS BOUNDARY AND THE ILLINOIS RIVER



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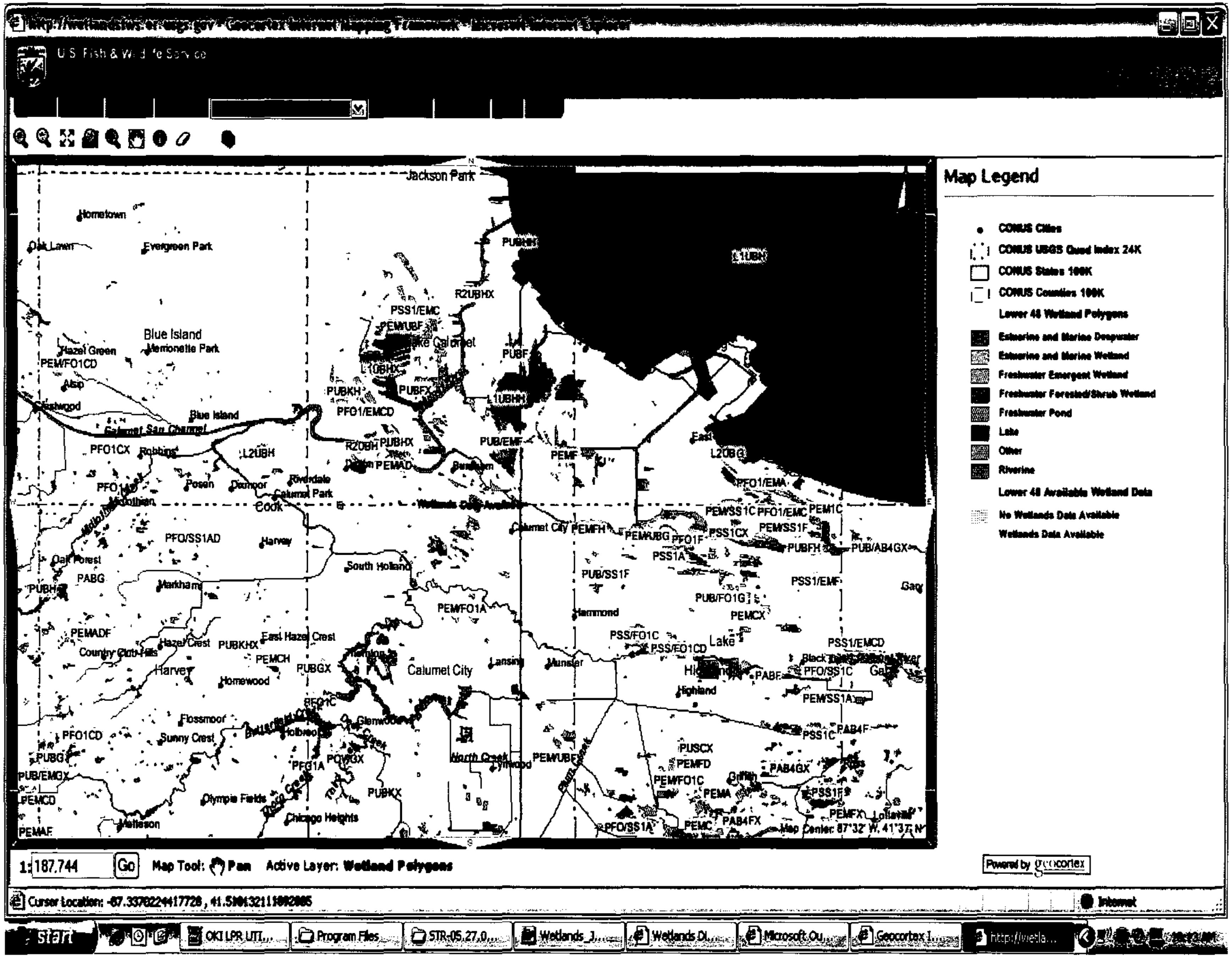

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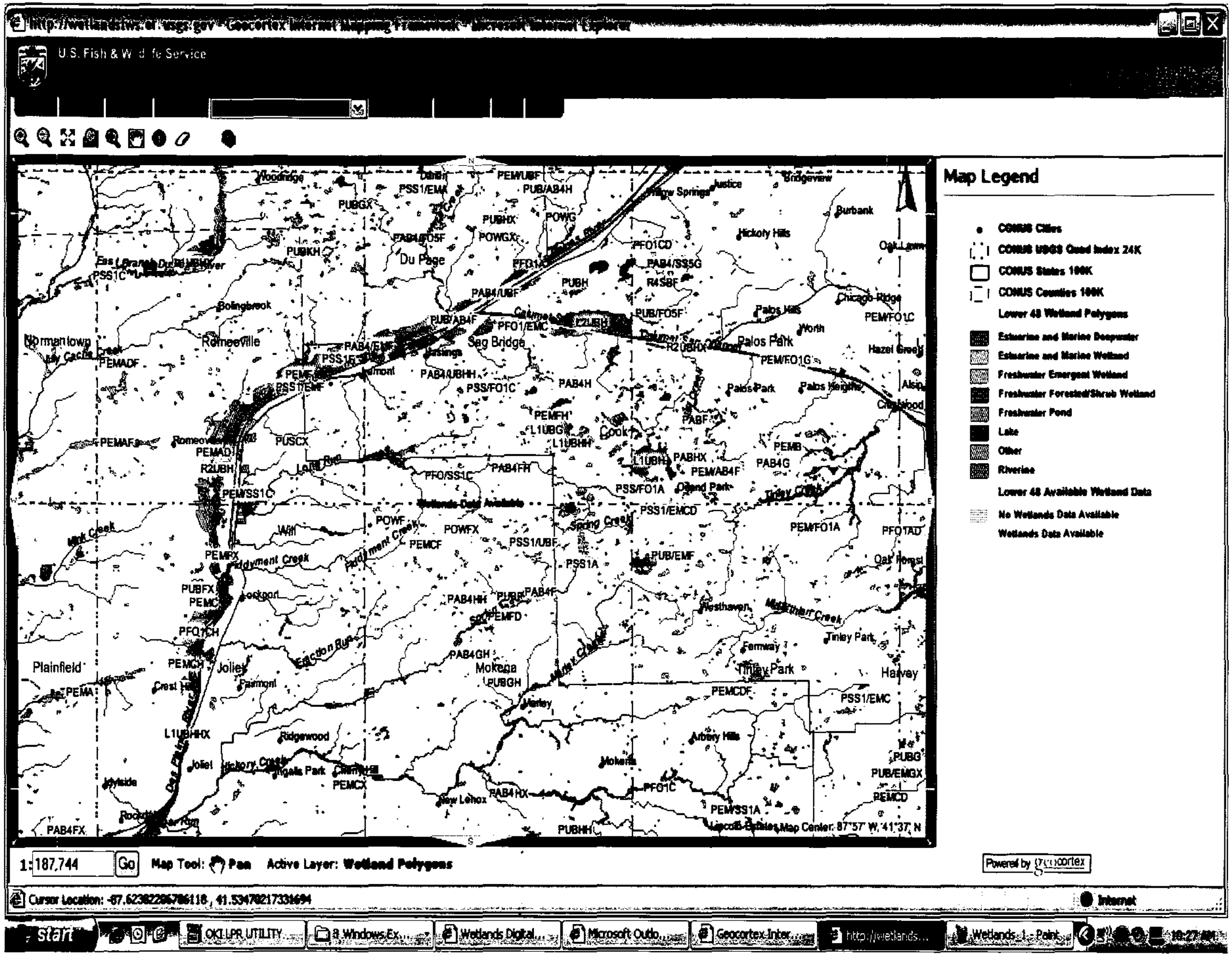
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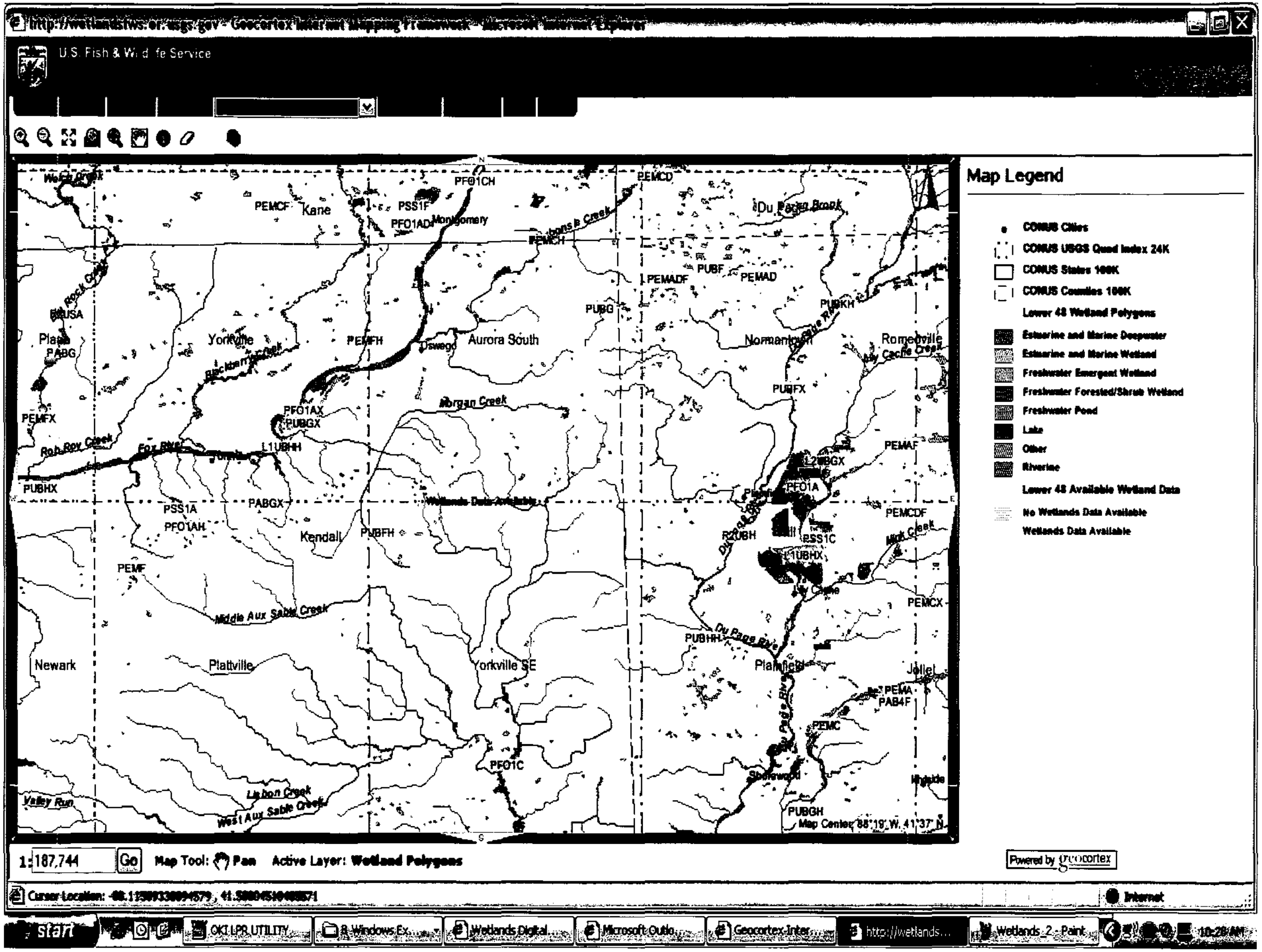
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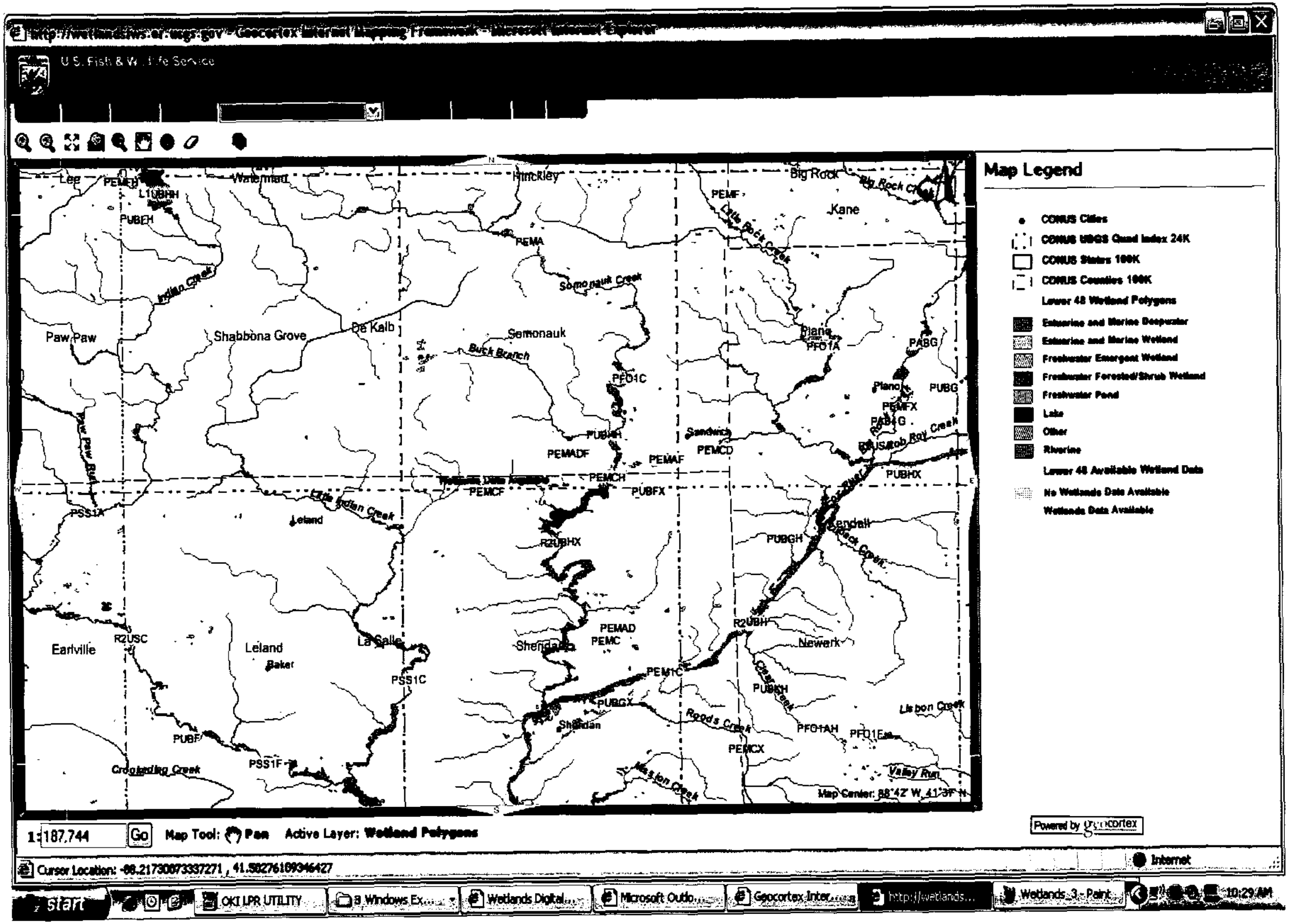

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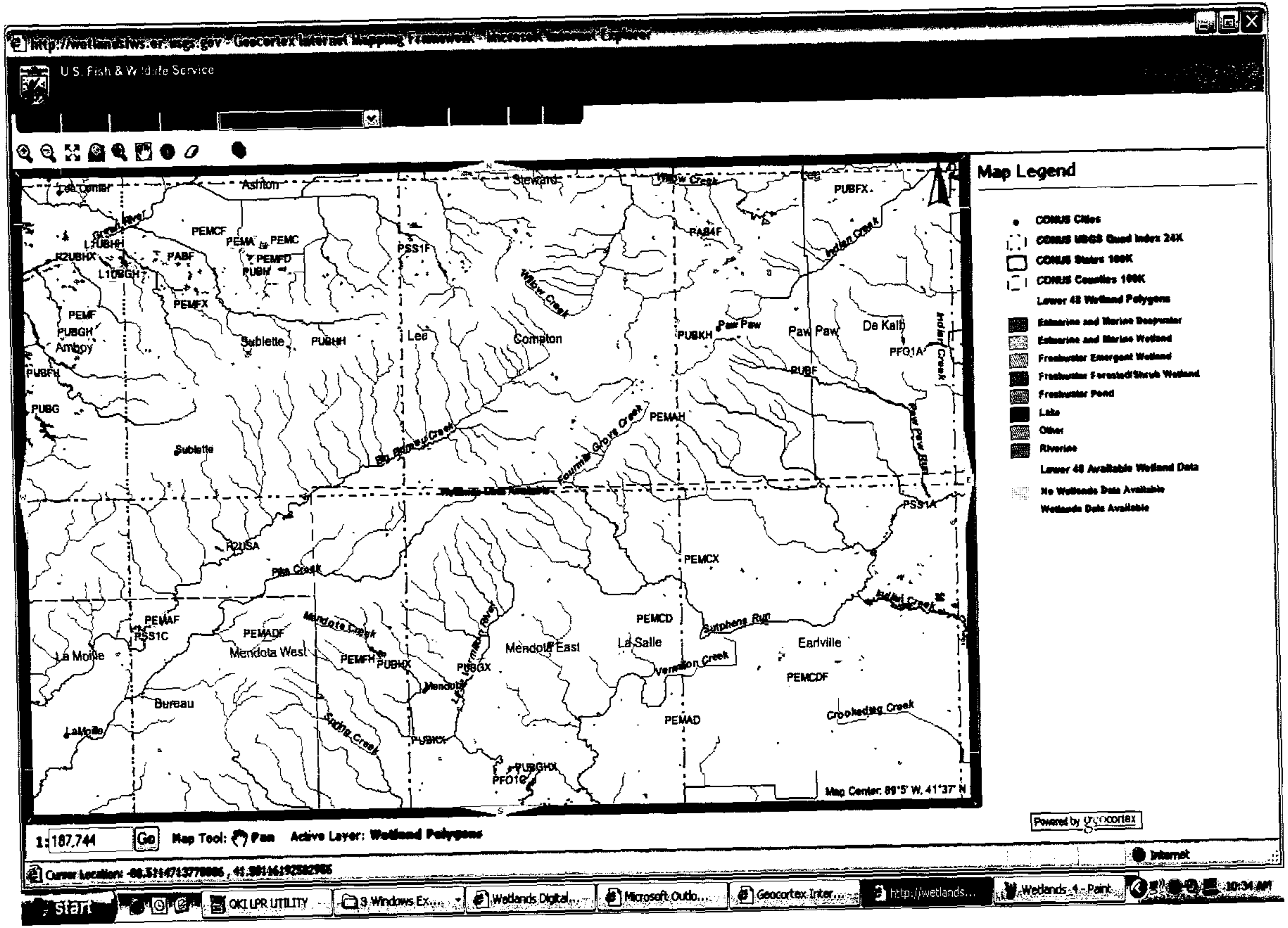
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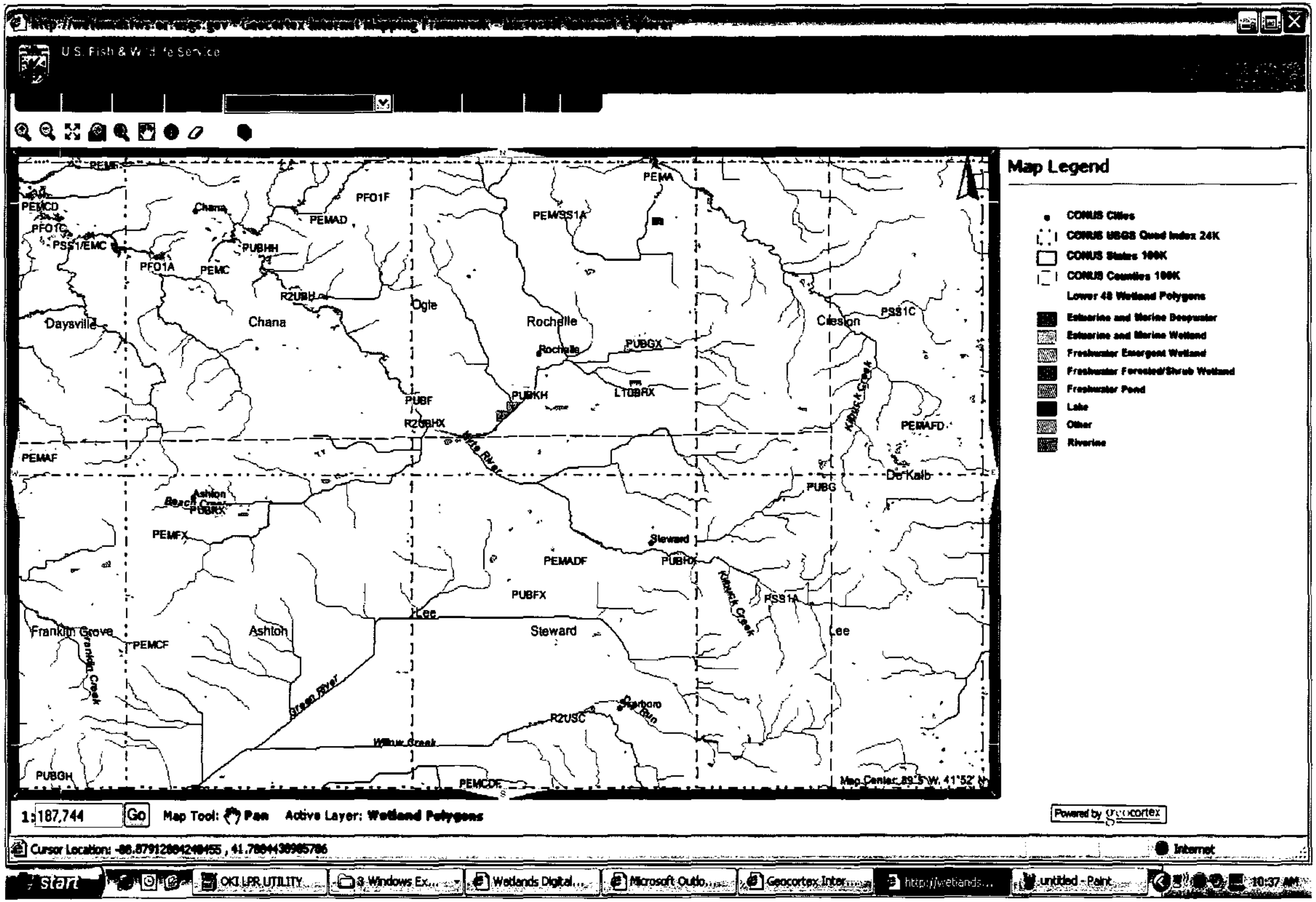

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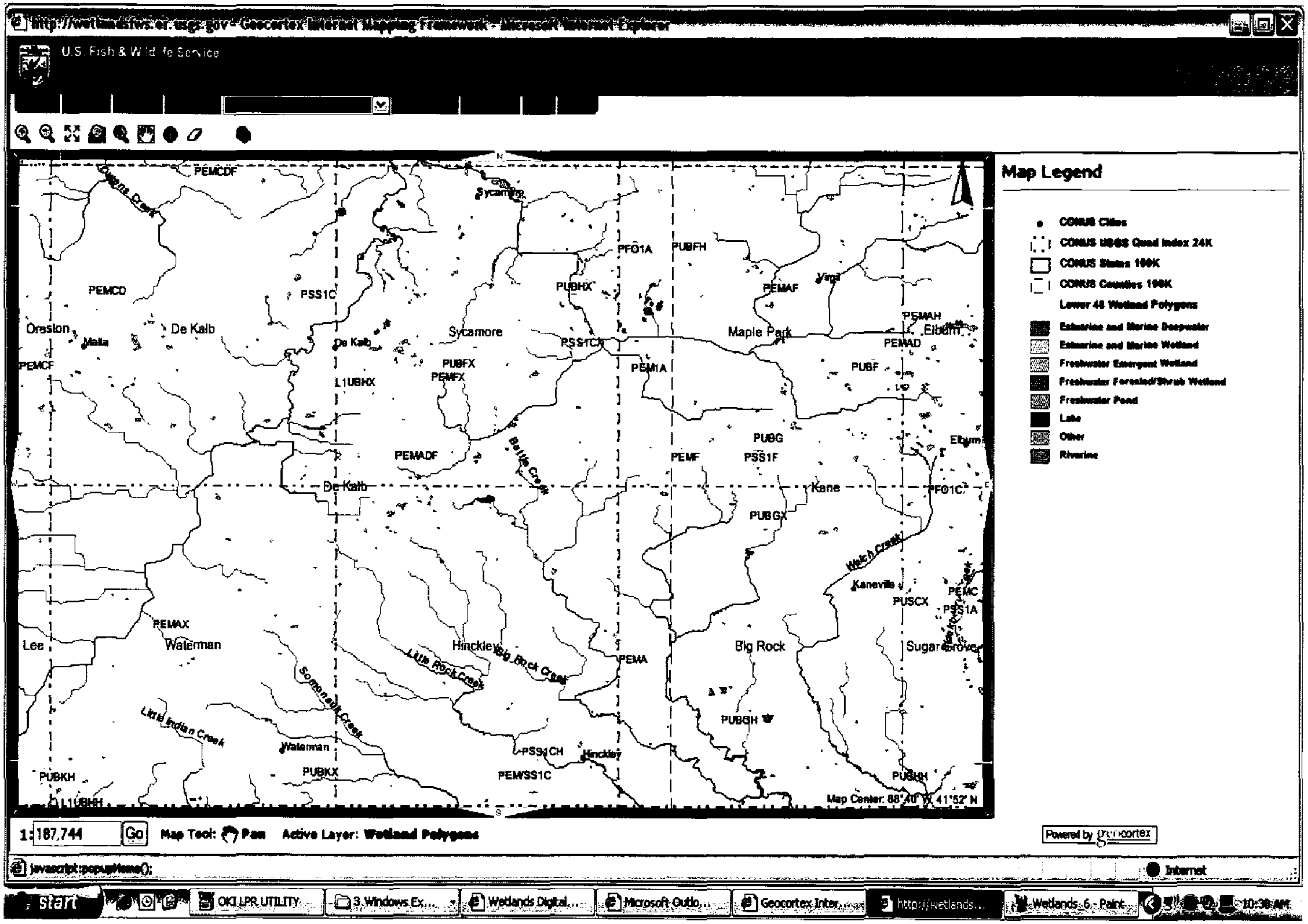
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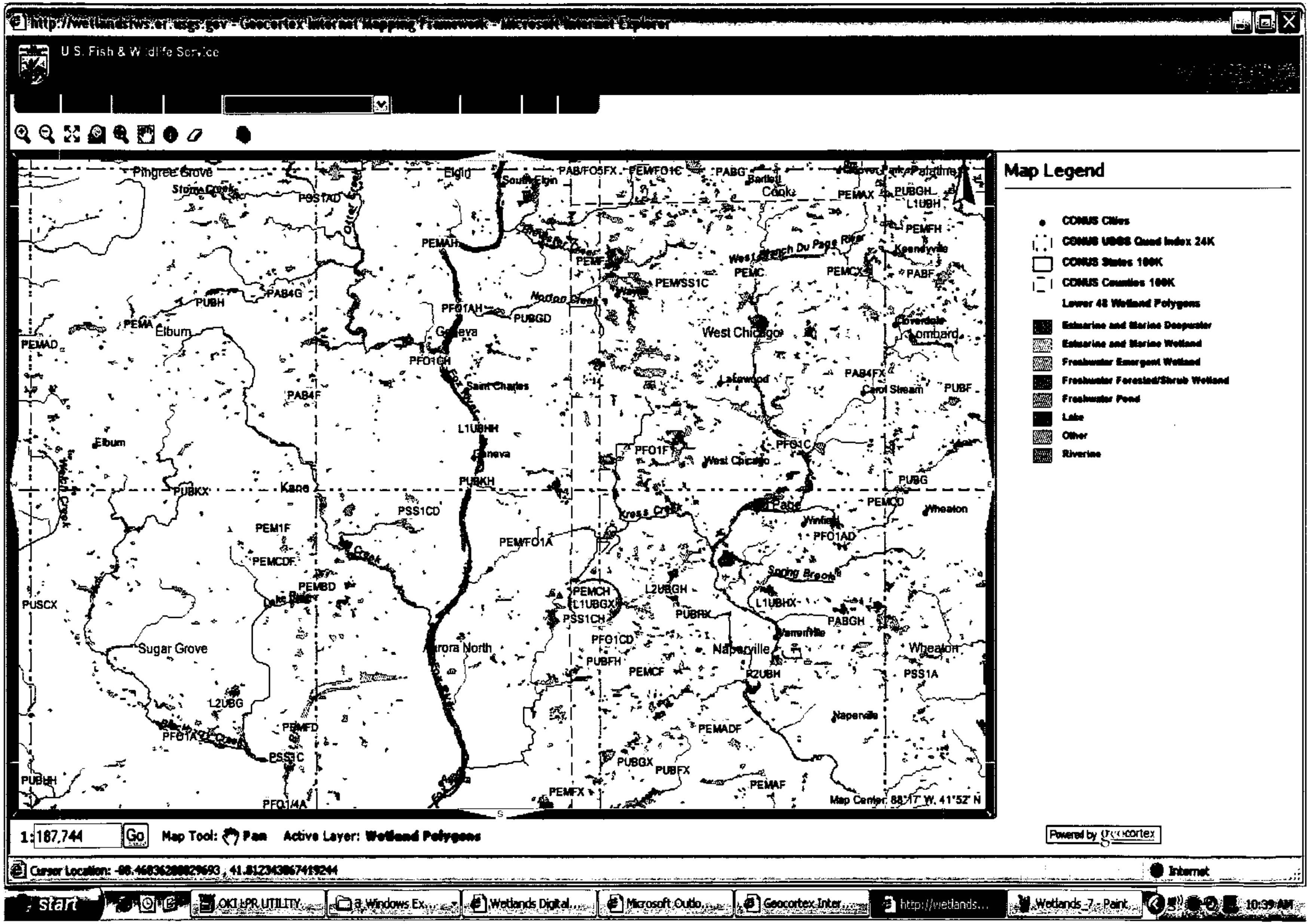
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Freshwater Emergent Wetland
Freshwater Forested/Shrub Wetland
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Lake
Other
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Pingree Grove
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Cook
West Chicago
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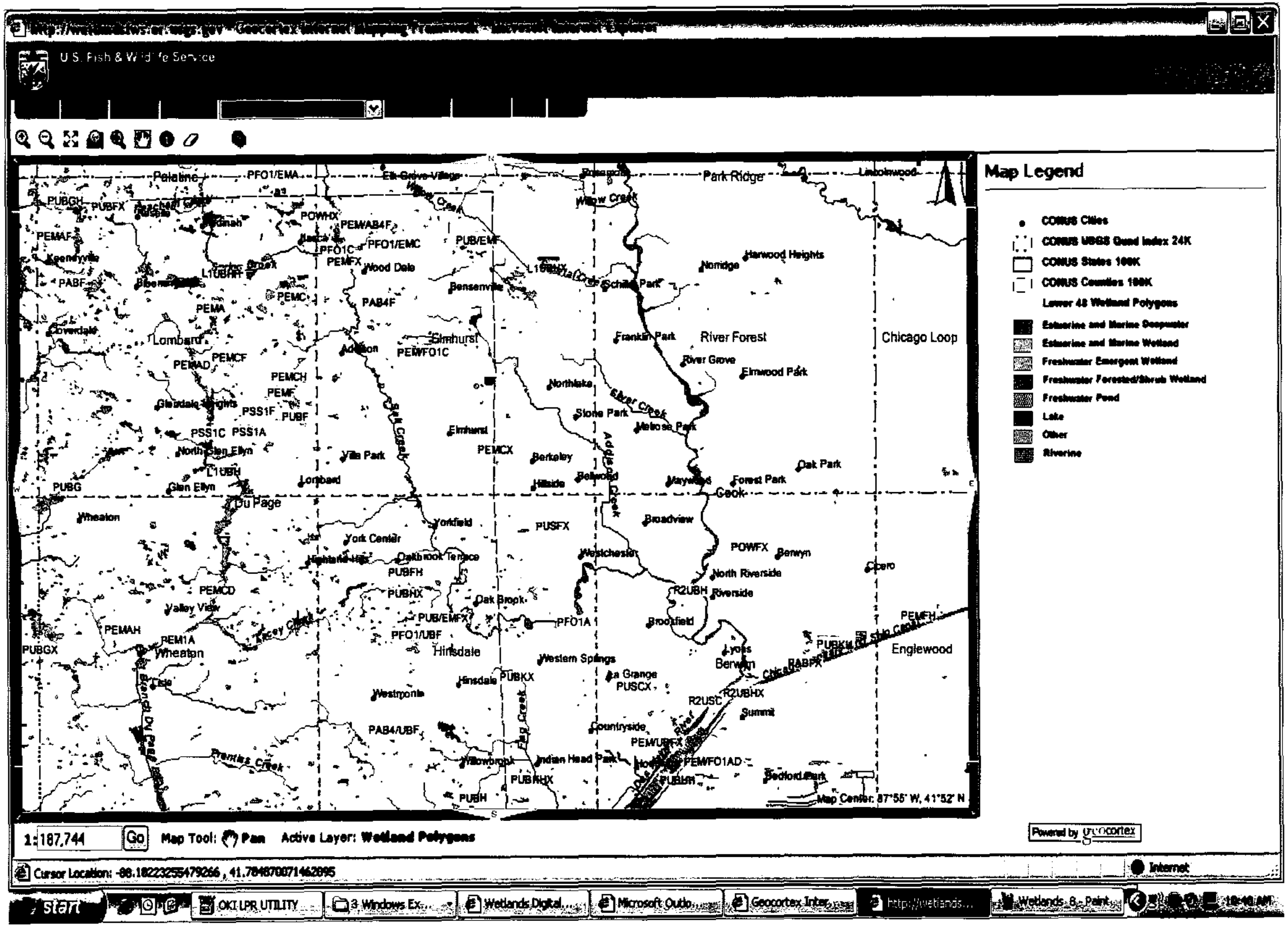
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La Grange
Western Springs
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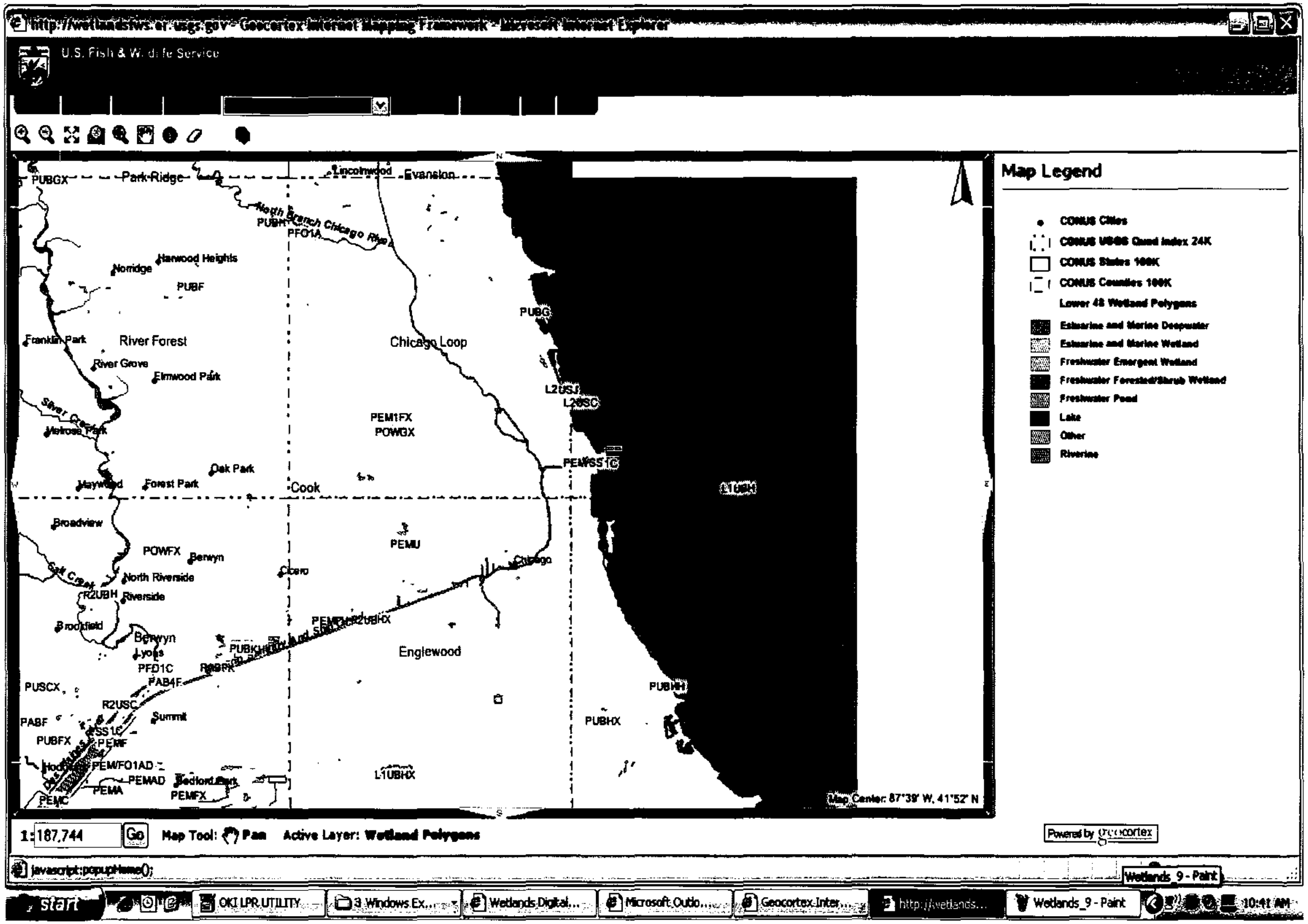
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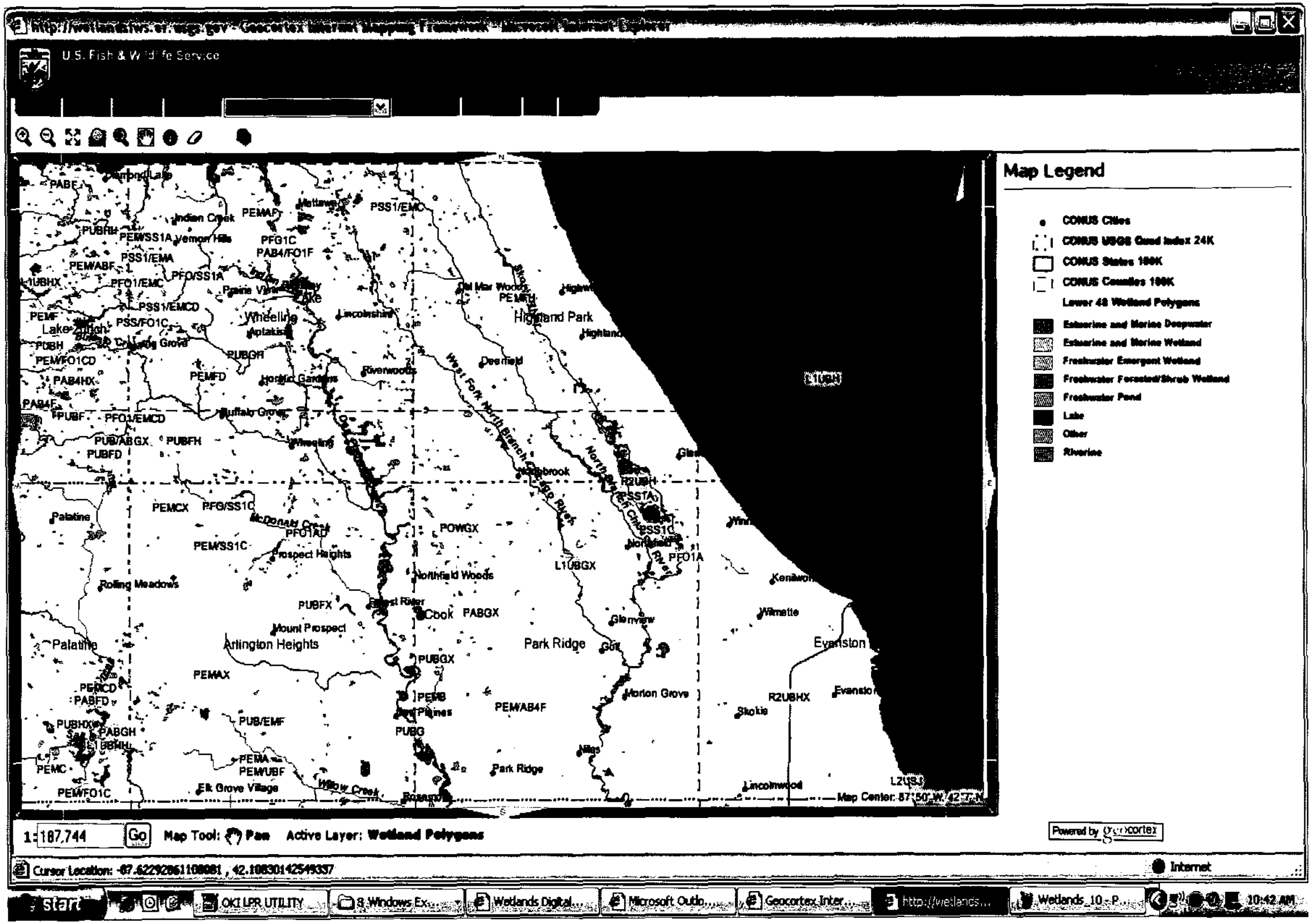

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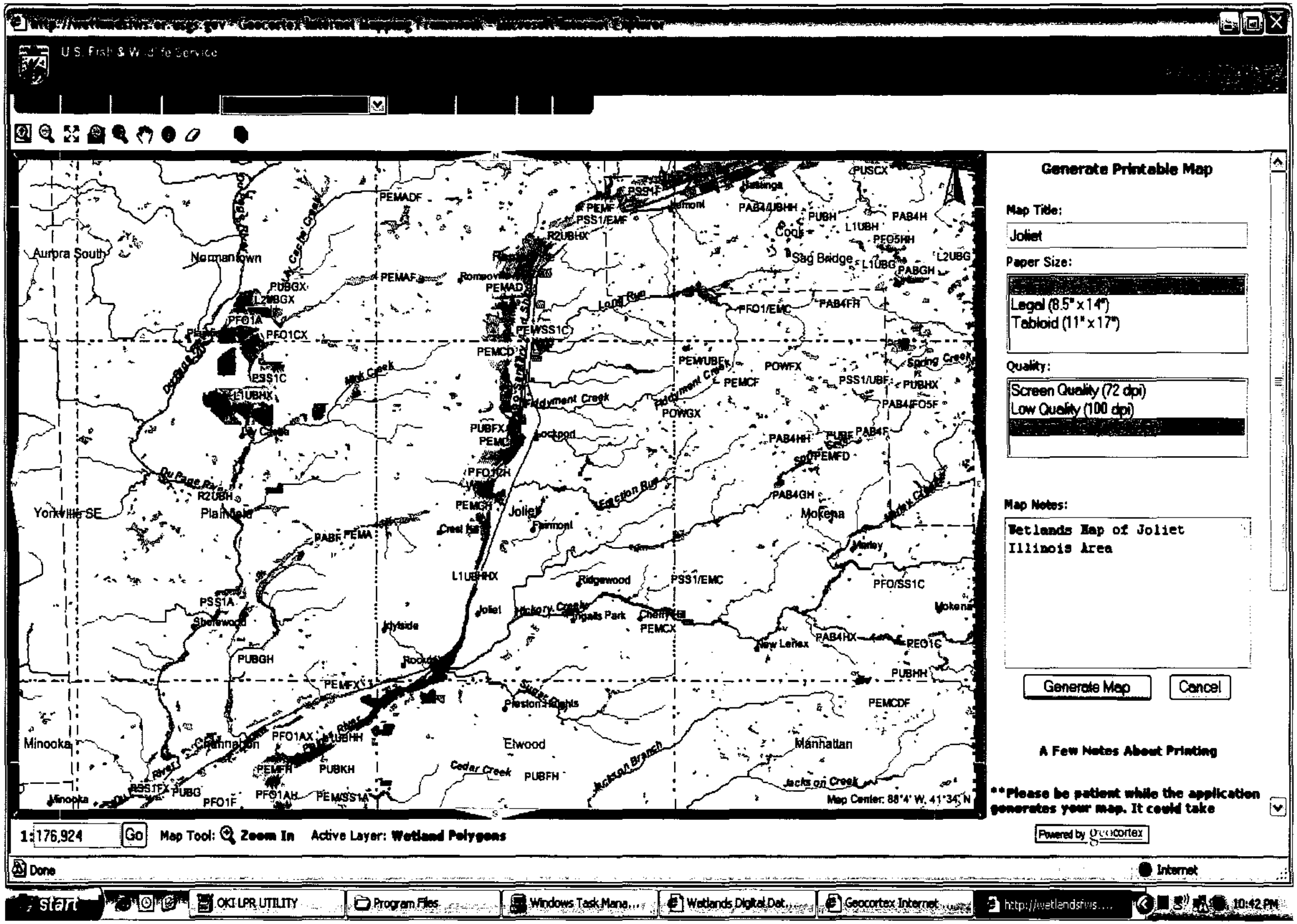
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Exhibit 3

STRAND ASSOCIATES, INC.®
ENGINEERS

1170 South Houbolt Road
Joliet, IL 60431
Phone: 815-744-4200
Fax: 815-744-4215

Strand Associates, Inc.
Madison, WI
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Louisville, KY
Lexington, KY
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Division Offices
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Columbus, IN
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TAI
Mobile, AL

www.strand.com

August 1, 2005

Mr. Dennis Duffield, P.E., Director of Public Works and Utilities
City of Joliet
921 East Washington Street
Joliet, IL 60433

Re: Cost Analysis: WRT vs. HMO

Dear Dennis,

At your request, we have performed a preliminary cost analysis comparing construction and operating costs over time for two radium-removal technology approaches. Results of the analysis are summarized below. Spreadsheets and graphs demonstrating analysis results are attached to this letter report.

Conclusion

Removing radium via the Water Remediation Technology LLC (WRT) process is estimated to cost up to $33 million more than the hydrous manganese oxide (HMO) process over a 20-year period, under the various conditions analyzed. That cost differential rises to as great as $45 million using an extended, 30-year period of evaluation.

Should regulatory restrictions on radium-containing treatment wastes be enforced, the City may wish to convert from an HMO treatment process to an alternative treatment. Analysis of conversion from HMO to a radium-selective media (RSM) treatment indicates that installation and operation of a convertible HMO/RSM process would be more costly than use of the WRT process if conversion occurs within the first five years of operation and no additional WRT fees are imposed. WRT is likely to be more costly than the HMO/RSM option when conversion occurs after the sixth year, under the most likely sets of conditions.

Background

The three technologies considered for use in Joliet that are examined in this cost analysis are radium-selective media provided by WRT, coprecipitation of radium with manganese removal using HMOs, and radium removal using a Dowex RSM system. All three technologies were demonstrated to be effective in removing radium from Joliet's wells during a pilot test performed between June 3, 2004, and July 15, 2004. The HMO system and Dowex media generally removed greater than 90 percent of radium from treated water, while the WRT system removed nearly 98 percent of combined Radium-226 and Radium-228. All three technologies removed radium to levels significantly better than the minimum level desired for effective treatment of Joliet water.

In analyzing the overall cost of each technology, consideration was given to the following factors:

1. HMO filtration also will remove the iron produced by the City's shallow wells. WRT and RSM treatment will not. Thus, an iron removal facility will be required if an East Side WRT radium removal facility is constructed to treat the combined shallow wells. Likewise, if HMO filtration is converted to RSM, an upstream iron removal facility would be necessary to treat the combined shallow wells.

2. Radon regulations have not been finalized. Currently, it appears that the minimum contaminant level (MCL) standard for radon in Illinois will be 300 pCi/L. Naturally occurring radon levels in untreated Joliet water have been measured between 110 pCi/L and 180 pCi/L. WRT media captures and holds radium, which naturally decays to radon. Radon emissions would be expected to increase as the WRT media ages, unless WRT also holds radon. If radon emissions from radium-laden WRT media are found to be a problem for treated water, intermediate aeration, storage, and booster pumping will be necessary. This same condition may occur if RSM technology is used.

   Preliminary investigation into the likelihood of radon accumulation from WRT treatment is under way. Figure 1 shows the results of radon testing on samples taken during an extended pilot study of WRT technology downstream of the WRT system at Joliet Well 9-D, as well as on raw-water samples drawn from Well 9-D during the same time period. Also shown in the figure are linear-fit trendlines for the sample data from each source. The trendlines indicate that radon concentrations would be expected to increase with time for both WRT and raw water supplies, while experience indicates that radon concentrations should remain relatively level with time for the raw water.

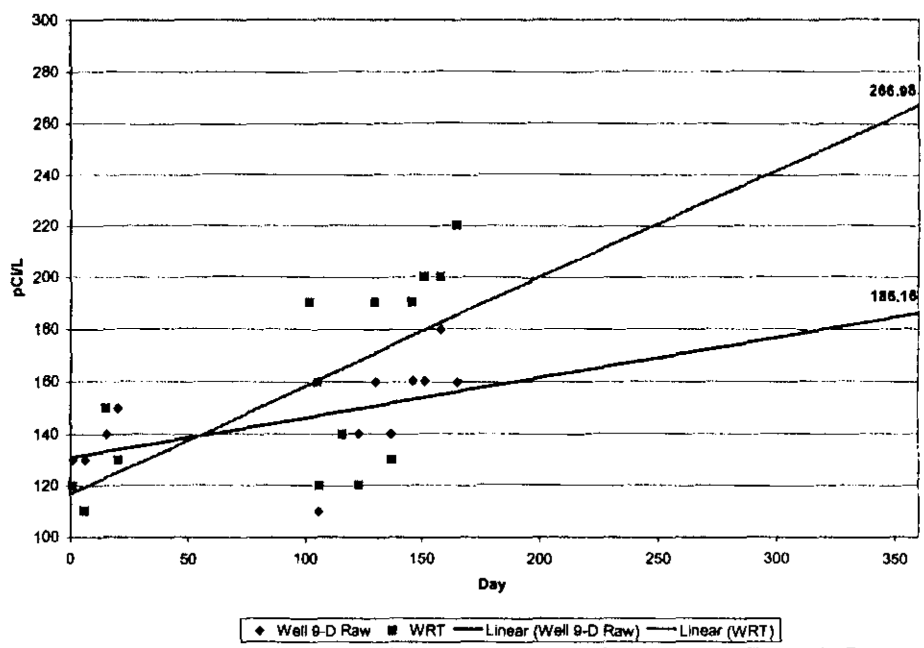

Figure 1 Radon Concentrations Derived from Extended Pilot Study of WRT

A linear projection of the data for both sample streams places radon levels at approximately 265 pCi/L for WRT and 185 pCi/L for raw water after 365 days of operation. Statistical analysis of the data suggests that a linear correlation between radon concentration and time is somewhat likely for the WRT data but less likely for the raw water data. This would indicate that there is limited confidence in projections using raw water data to a 1-year timeframe, and slightly more confidence in projections using WRT-treated water data. Should the linear projections be accurate, the statistical analysis indicates that WRT-treated water would not contain radon concentrations in excess of the anticipated standard for Illinois if the WRT media is replaced annually. It should be noted, however, that it is possible radon concentrations would increase nonlinearly with time. We therefore present a cost-analysis scenario that incorporates radon-removal treatment, with the understanding that such measures may or may not become necessary when using WRT and RSM technologies.

3. HMO filtration has been demonstrated to be effective in several full-scale operating plants, while the WRT process has just recently started full-scale operation in one Illinois community. As a result, information on operating issues and costs associated with the HMO process is available from field operations, but such information is not available for the WRT process. All costs and potential operating issues associated with WRT can be derived only from observations of pilot operation and from WRT representatives.

4. The draft WRT agreement is nearly 70 pages long and includes numerous clauses for increasing payment for WRT treatment. The cost impact of several of these clauses is impossible to evaluate since we cannot predict potential future regulatory or physical-change impacts on such fees. Future media-disposal charges or changes in water quality conditions, for example, cannot be anticipated. For the purpose of this analysis, it is assumed that all base conditions remain constant for the duration of the period under consideration. Actual annual charges required by WRT under its agreement could be significantly greater than reported here, should these conditions change with time. Additionally, the Illinois Department of Nuclear Safety reportedly has indicated to communities with WRT facilities under construction that a reserve fund will be required in case WRT is unable to maintain facility operations over time. The magnitude of the reserve fund cannot be determined at present, and is not accounted for in this analysis.

5. WRT has not yet provided information as to how construction of additional wells would be incorporated into the radium-removal agreement. It is assumed for the purposes of this analysis that no new wells are added during the 20-year period under consideration.

6. Potential changes in regulation of radium in the waste stream could force the City of Joliet to seek an alternative technology to HMO in the near future. Consideration is given in this analysis to the possibility that an HMO facility may require conversion to a radium-selective system that would not release significant radium into the waste stream during backwashing. For the purposes of this analysis, HMO facilities are designed for conversion to RSM. Additional modifications, including an East Side iron filtration plant and, potentially, radon-removal equipment, would be constructed upon conversion from HMO to RSM.

Analysis Conditions

Three likely demand scenarios were developed to evaluate costs using the WRT and HMO systems.

1. Scenario A used a flat, average day water demand of 14.9 mgd, as determined in the November 2003 Joliet *Radium Compliance and Water Supply Improvements* report. Figure 2 shows the Scenario A demand projection through 2024.

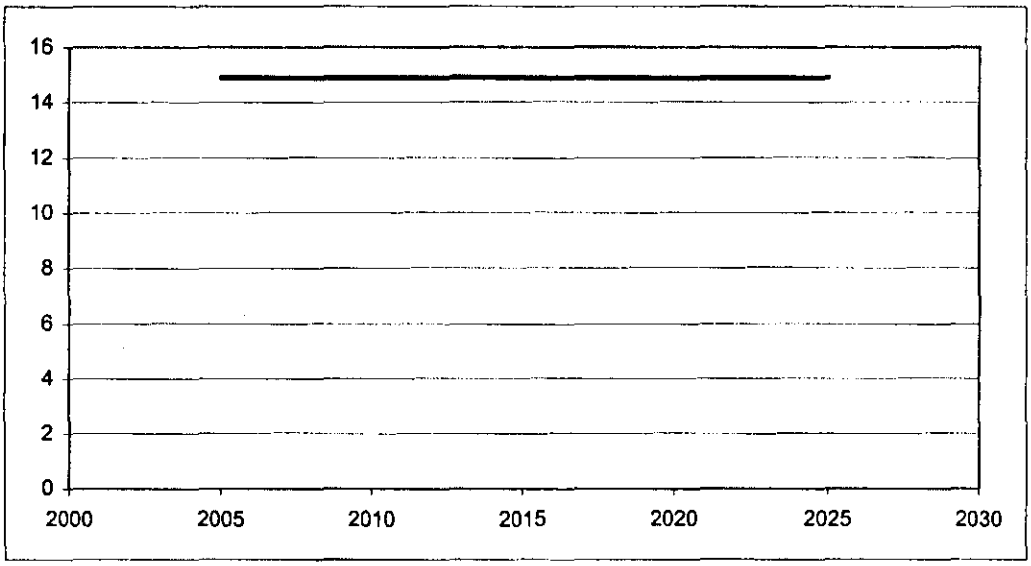

Figure 2 Projected Average-Day Water Demand Scenario A

2. Scenario B used a linearly increasing water demand based upon a 2006 average day estimate of 14.9 mgd and a 2023 average day demand estimate of 20.1 mgd, as generated by the November 2003 report. Figure 3 shows the Scenario B demand projection.

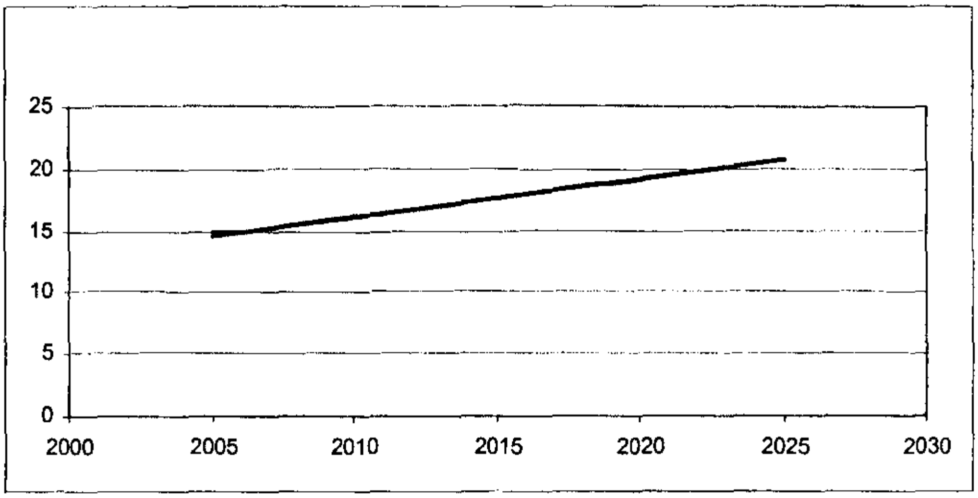

Figure 3 Projected Average-Day Water Demand Scenario B

3. Scenario C used a randomly varying annual average day water demand, using water system fluctuations of typical magnitude as determined by a review of water-use data for similarly sized communities. The overall increase in water demand between 2005 and 2025 statistically mirrors the linearly increasing demand of Scenario B with time. Figure 4 shows the Scenario C demand projection.

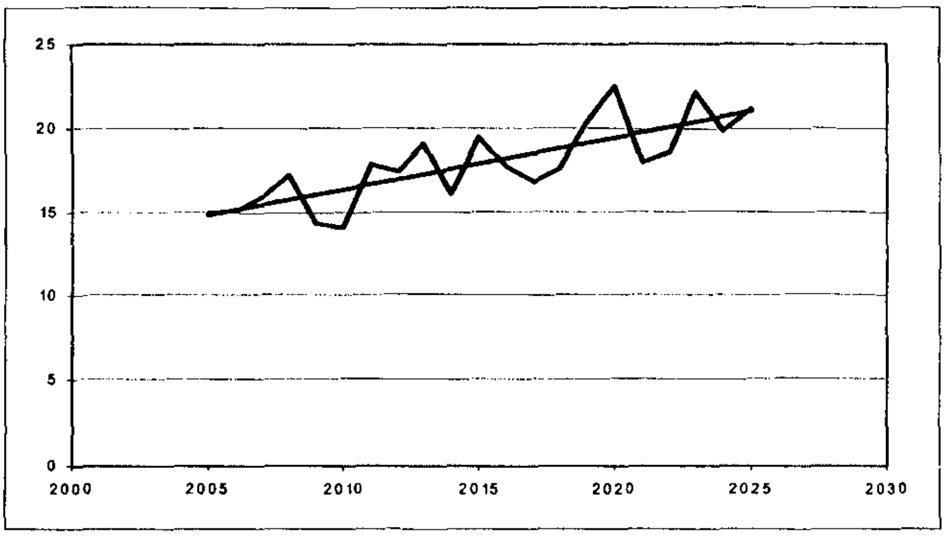

Figure 4 Projected Average-Day Water Demand Scenario C

Inflation projections were generated using Consumer Price Indices between 1980 and 2004. Future CPI values were generated by projecting increase trends linearly to the year 2025. Figure 5 depicts the actual CPI values, as well as the linear trend line projecting future CPI values.

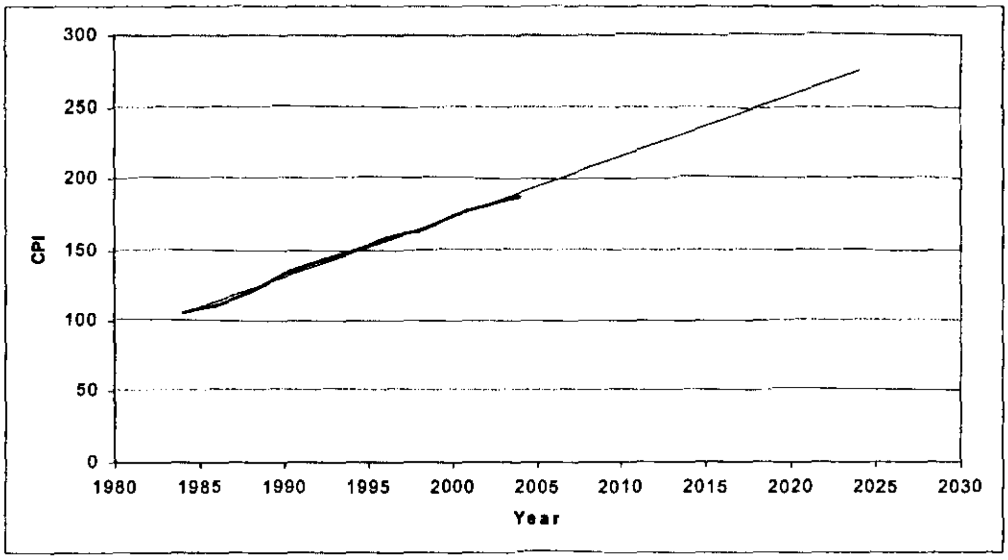

Figure 5 Projection of Consumer Price Index Through the Year 2025

Capital costs were determined using previously generated opinions of probable cost for construction of six 1,000 gpm facilities, two 2,000 gpm facilities, one 4,000 gpm facility and one 6,000 gpm facility. Construction costs for the WRT option included only the buildings that would house WRT equipment. Construction costs for the HMO option included both the building and HMO/filtration equipment (an alternative evaluation incorporating conversion to RSM treatment is provided below and is not included here). Because of the need for iron filtration at the Fairmont/Garvin facility, an additional capital expenditure for construction of a filter facility was included in the WRT construction costs. Total construction costs for each option were amortized over a period of 20 years at 4 percent interest to determine annual expenditure. Table 1 shows the calculation of construction costs for both WRT and HMO processes.

Operating cost components for each option differ significantly. Primary components of the WRT operating costs, as incorporated into Condition Set No. 1, include annual contractual treatment charges, additional volume charges, and costs associated with backwashing the iron removal filters at Fairmont/Garvin. An additional expense is included in Condition Set No. 2 for removal of excessive radon in the treated water, as discussed above. Condition Set No. 3 provides an alternative scenario in which it is assumed spent media must be disposed of in an alternate site at a higher cost that equals the value proposed in current WRT agreements with other Illinois communities. The alternate site and cost, based on information provided by WRT, is more than double the cost of media disposal incorporated into the proposed Joliet agreement. This third condition set also includes costs for removal of excessive radon and, with the other two scenarios, generates a likely range of annual costs resulting from WRT treatment.

Potential charges and fees not included in any of the scenarios include new taxes or government fees for disposal, fees resulting from water quality change other than radium that affects media life, potential state-required reserve funds to support removal technology, and additional fees resulting from an increase in source-water radium content. For the purposes of this analysis, it is assumed that disposal charges, regulatory fees, and taxes do not increase beyond the rate of inflation and that water quality (both radium and nonradium) remains constant throughout the life of the term.

Components of the HMO operating charges consist of chemical costs, costs associated with backwashing the co-filtration vessels, and excess labor costs to maintain HMO operations. Chemical costs were determined based upon chemical use at facilities where full-scale HMO treatment is operational. No economy of chemical costs because of bulk volume is assumed for the purpose of this analysis.

Table 2 shows a list of calculation values used to determine operating expenses for HMO and WRT treatment processes. The same values were used for both processes when comparable operating costs were generated (for example, backwash water costs for the Fairmont/Garvin iron filtration plant using WRT and for all pressures filters using HMO).

Process	Unit	Value
Iron Filter Backwash Costs	Dollars/1000 gallons	$0.50
Labor	Hours/mgd/year	312
Average wage - 2005	Dollars/hour	$15
Base WRT volume	Million gallons/yr	5,438.5
Base inflation index	n/a	194.74
Base WRT treatment charge	Dollars/yr	$1,124,200
Base WRT volume charge	Dollars/1000 gallons	$0.22
Base WRT disposal charge	Dollars/cubic foot	$35
Agreed WRT radium concentration	pCi/L	13.84

Table 2 Calculation Values Used in WRT/HMO Cost Analysis

Results

Evaluation of operating and construction costs for the two processes using each of the three scenarios described above and no requirement for radon removal yielded the results shown in Figure 6. The broken lines represent Scenario A, in which demand remains constant throughout the study period; the dashed lines represent Scenario B, in which demand increases linearly with time; and the jagged lines represent Scenario C, in which demand changes irregularly with time

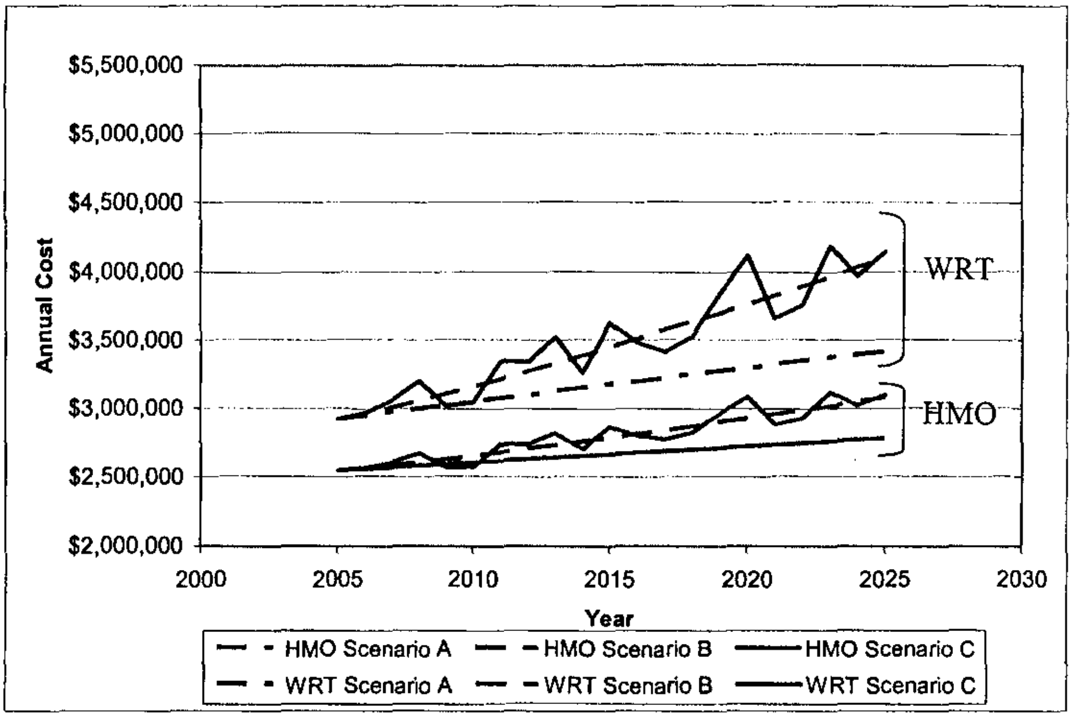

Figure 6 Cost Analysis of WRT vs. HMO With No Radon Removal

The actual dollar difference between the two technologies ranges from $376,000 for all three scenarios in the first year to between $640,000 and $1.05 million in the final year of the 20-year study period, depending upon scenario.

Table 3 shows the percent difference between WRT and HMO annual costs with no radon removal. For all three demand scenarios, WRT is nearly 15 percent costlier than HMO in the first year. That difference increases to between 23 and 34 percent by the final year of the study period, depending upon selection of scenario.

Year	Percent Diff In Cost (WRT higher than HMO) Demand Profile		
	Scenario A	Scenario B	Scenario C
2005	**14.8%**	**14.8%**	**14.8%**
2006	**15.2%**	**15.2%**	**15.5%**
2007	**15.6%**	**16.2%**	**17.2%**
2008	**16.1%**	**17.1%**	**19.7%**
2009	**16.5%**	**18.1%**	**17.6%**
2010	**17.0%**	**19.0%**	**18.4%**
2011	**17.4%**	**20.0%**	**22.2%**
2012	**17.8%**	**20.9%**	**22.1%**
2013	**18.2%**	**21.9%**	**25.0%**
2014	**18.6%**	**22.8%**	**20.7%**
2015	**19.1%**	**23.8%**	**26.6%**
2016	**19.5%**	**24.7%**	**24.2%**
2017	**19.9%**	**25.6%**	**23.2%**
2018	**20.3%**	**26.6%**	**24.9%**
2019	**20.7%**	**27.5%**	**29.7%**
2020	**21.1%**	**28.5%**	**33.4%**
2021	**21.5%**	**29.4%**	**26.9%**
2022	**21.9%**	**30.3%**	**28.3%**
2023	**22.2%**	**31.2%**	**34.3%**
2024	**22.6%**	**32.2%**	**31.3%**
2025	**23.0%**	**33.1%**	**33.7%**

Table 3 Percent Difference in Cost for WRT Treatment, Compared with HMO, With No Radon Removal

Radon removal significantly increases WRT costs. Figure 7 shows annual costs for WRT and HMO treatment options when radon removal is required.

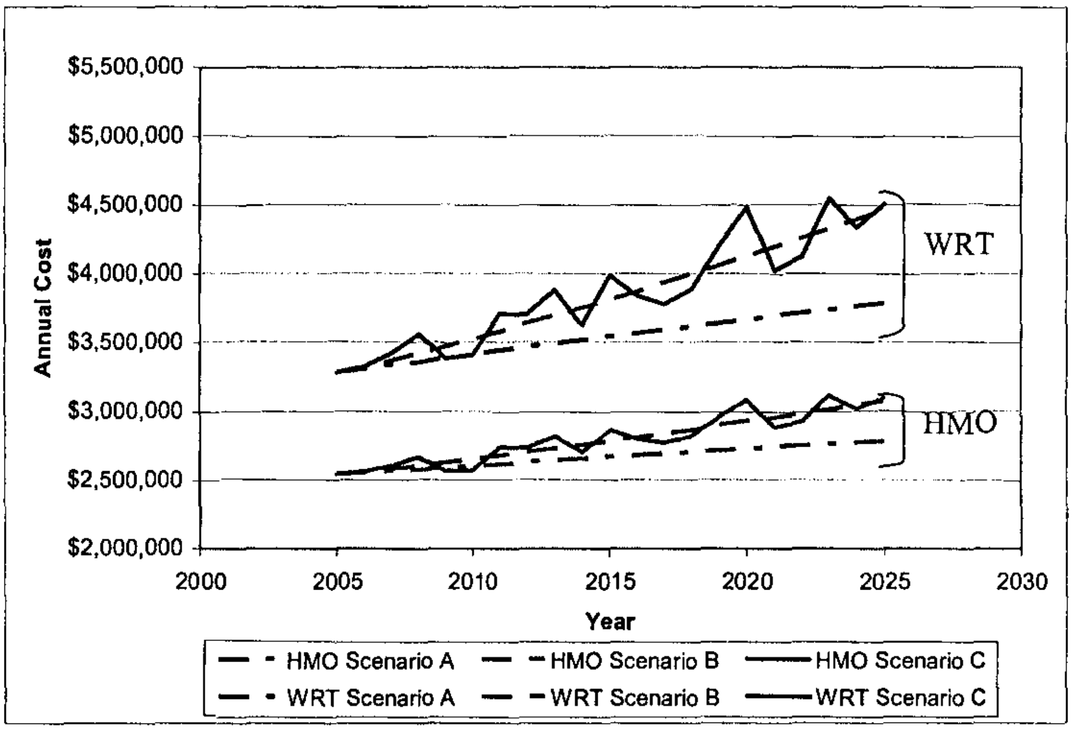

Figure 7 Cost Analysis Of WRT vs. HMO With Radon Removal

The actual dollar difference between the two technologies ranges from $739,450 for all three scenarios in the first year to between $1,003,000 and $1,407,000 in the final year of the 20-year study period, depending upon scenario.

Table 4 shows the percent difference between WRT and HMO annual costs with radon-removal equipment. For all three demand scenarios, WRT is 29 percent costlier than HMO in the first year. By the final year of the 20-year study period, the cost differential for WRT increases to 36 to 45 percent greater than HMO, depending upon demand scenario.

Year	Percent Diff In Cost (WRT higher than HMO) Demand Profile		
	Scenario A	Scenario B	Scenario C
2005	**29.0%**	**29.0%**	**29.0%**
2006	**29.4%**	**29.4%**	**29.7%**
2007	**29.8%**	**30.3%**	**31.2%**
2008	**30.2%**	**31.1%**	**33.3%**
2009	**30.5%**	**31.9%**	**31.7%**
2010	**30.9%**	**32.7%**	**32.5%**
2011	**31.3%**	**33.5%**	**35.5%**
2012	**31.6%**	**34.3%**	**35.3%**
2013	**32.0%**	**35.1%**	**37.9%**
2014	**32.3%**	**36.0%**	**34.1%**
2015	**32.7%**	**36.8%**	**39.3%**
2016	**33.0%**	**37.6%**	**37.2%**
2017	**33.4%**	**38.4%**	**36.3%**
2018	**33.7%**	**39.2%**	**37.8%**
2019	**34.1%**	**40.1%**	**41.9%**
2020	**34.4%**	**40.9%**	**45.2%**
2021	**34.7%**	**41.7%**	**39.5%**
2022	**35.1%**	**42.5%**	**40.8%**
2023	**35.4%**	**43.2%**	**45.9%**
2024	**35.7%**	**44.1%**	**43.3%**
2025	**36.1%**	**44.9%**	**45.4%**

Table 4 Percent Difference in Cost For WRT Treatment, Compared With HMO, With Radon Removal

In past draft agreements, WRT has proposed disposing of spent media at Envirocare of Utah, Inc.'s Clive, Utah, facility at a cost of $78.75 per cubic foot. Recent correspondence from WRT indicates that it is basing the Joliet contract on a different disposal site with lower disposal costs, resulting in a stipulated disposal cost of $35 per cubic foot. Should WRT contract with Envirocare instead of this alternative disposal site after contractually agreeing to the lower stipulated cost, actual disposal costs charged to Joliet could be significantly higher. Figure 8 shows annual costs for WRT and HMO treatment options should this situation arise and also includes costs for radon removal to present a high-range likely annual cost. The sudden jump in annual costs between 2005 and 2006 for WRT occurs because there is no media disposal the first year, since the first media change-out is projected to occur in year two.

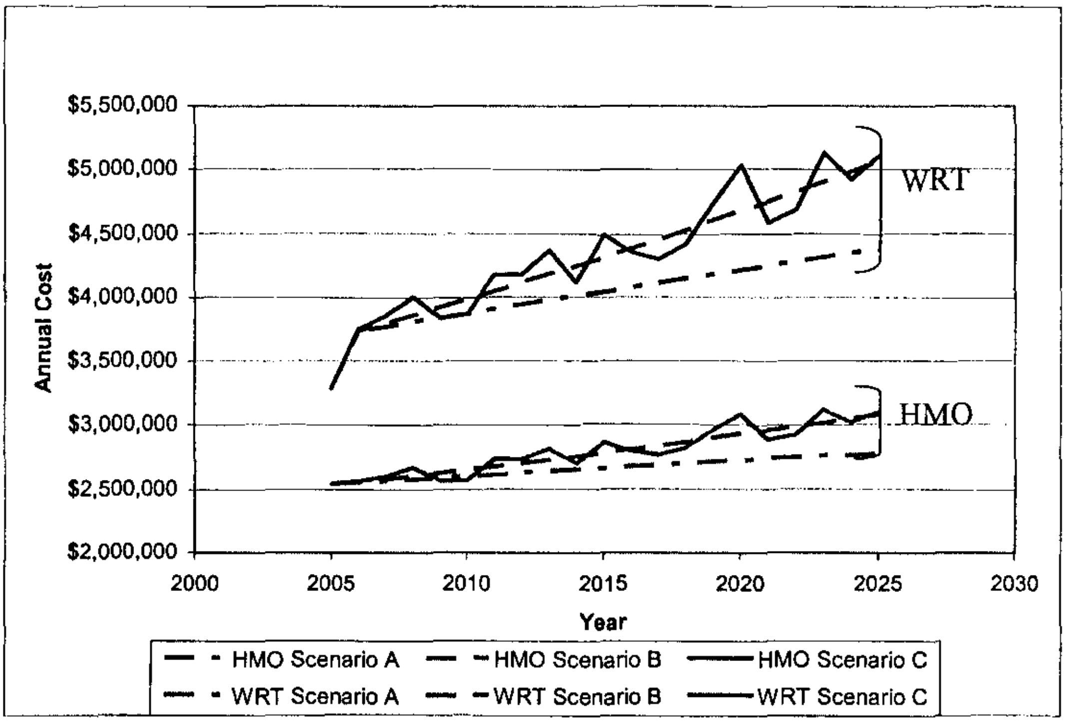

Figure 8 Cost Analysis Of WRT vs. HMO With Radon Removal and Excess Disposal Fees

The actual dollar difference between the two technologies ranges from $739,450 for all three scenarios in the first year to between $1.60 million and $2.00 million in the final year of the 20-year study period, depending upon scenario.

Table 5 shows the percent difference between WRT and HMO annual costs for this condition set. WRT is 29 percent costlier than HMO in the first year and climbs to between 57 and 65 percent greater than HMO by the final year of the 20-year study period, depending upon demand scenario.

Year	Percent Diff In Cost (WRT higher than HMO) Demand Profile		
	Scenario A	Scenario B	Scenario C
2005	**29.0%**	**29.0%**	**29.0%**
2006	**46.0%**	**46.0%**	**46.2%**
2007	**46.6%**	**47.0%**	**47.8%**
2008	**47.3%**	**48.0%**	**49.9%**
2009	**47.9%**	**49.0%**	**49.3%**
2010	**48.6%**	**50.0%**	**50.4%**
2011	**49.2%**	**51.0%**	**52.6%**
2012	**49.8%**	**52.0%**	**52.8%**
2013	**50.5%**	**53.0%**	**55.2%**
2014	**51.1%**	**54.0%**	**52.5%**
2015	**51.7%**	**55.0%**	**56.9%**
2016	**52.3%**	**55.9%**	**55.6%**
2017	**52.9%**	**56.9%**	**55.2%**
2018	**53.5%**	**57.8%**	**56.7%**
2019	**54.1%**	**58.8%**	**60.3%**
2020	**54.7%**	**59.7%**	**63.1%**
2021	**55.3%**	**60.6%**	**59.0%**
2022	**55.8%**	**61.6%**	**60.2%**
2023	**56.4%**	**62.4%**	**64.5%**
2024	**57.0%**	**63.4%**	**62.8%**
2025	**57.5%**	**64.3%**	**64.6%**

Table 5 Percent Difference in Cost for WRT Treatment, Compared With HMO, With Radon Removal And Excess Disposal Fees

Figure 9 depicts the cumulative difference in cost over the 20-year study period between WRT and HMO technologies. This figure shows the cumulative difference between the two technologies using the linear demand scenario (Scenario B) under all three analysis alternatives. Cumulative cost differences at the end of 20 years range from $14.5 million when no radon removal is required for WRT to $32.4 million when radon removal and excess disposal charges are incorporated.

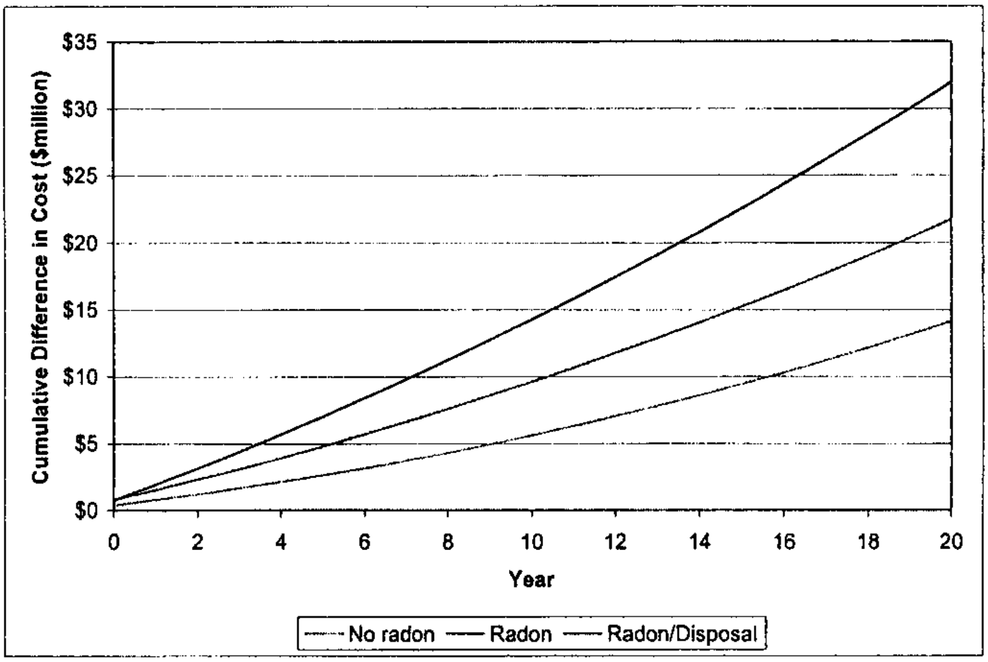

Figure 9 Cumulative Difference in Cost (WRT More Than HMO) Over 20-Year Study Period Between WRT and HMO Technologies

Cost Risk vs. Time

For this analysis, consideration is given to converting an HMO technology to RSM due to regulatory restrictions. Only Demand Scenario B, using straight-line growth in demand over the analysis period, is used for this evaluation.

The materials and equipment not included in initial capital costs of a convertible system are shown in Table 6, along with an opinion of their probable costs. Table 7 shows an opinion of lost value for the initially installed HMO equipment and materials that would be unnecessary upon conversion to RSC. It should be noted that the cost of backwash blowers at the Fairmont and Garvin plant is not included in the lost value, since blowers at this facility could be salvaged for reuse in an iron-removal plant. This cost also is factored into the opinion of probable cost to build a new iron removal plant at Fairmont and Garvin.

Item	Opinion of Probable Cost
Remove and dispose of HMO Filter media	$100,000
Purchase RSC media and install	$3,200,000
Build Iron Removal Plant at Fairmont and Garvin	$5,700,000
TOTAL	$9,000,000

Table 6 Opinion of Probable Costs to Convert Facilities from HMO to RSC

Several changes in operational costs result from a conversion to RSM treatment. If HMO facilities are converted to RSM, the radium-selective media will require disposal in a licensed low-level radioactive waste facility, similar to WRT media in previous analyses. The estimated annual cost for RSM media disposal and replacement is $1,270,000 in 2005 dollars.

Item	Opinion of Lost Value
HMO chemical mixing and feed equipment	$1,500,000
Backwash Blowers	$25,000
Granular Filter Media	$30,000
TOTAL	$1,555,000

Table 7 Opinion of Lost Value in Converting Facilities from HMO to RSC

A graph of the depreciation schedule for the lost value is shown in Figure 10. Depreciation is calculated using a straight-line formula, with a $0 salvage value assumed at the end of 20 years.

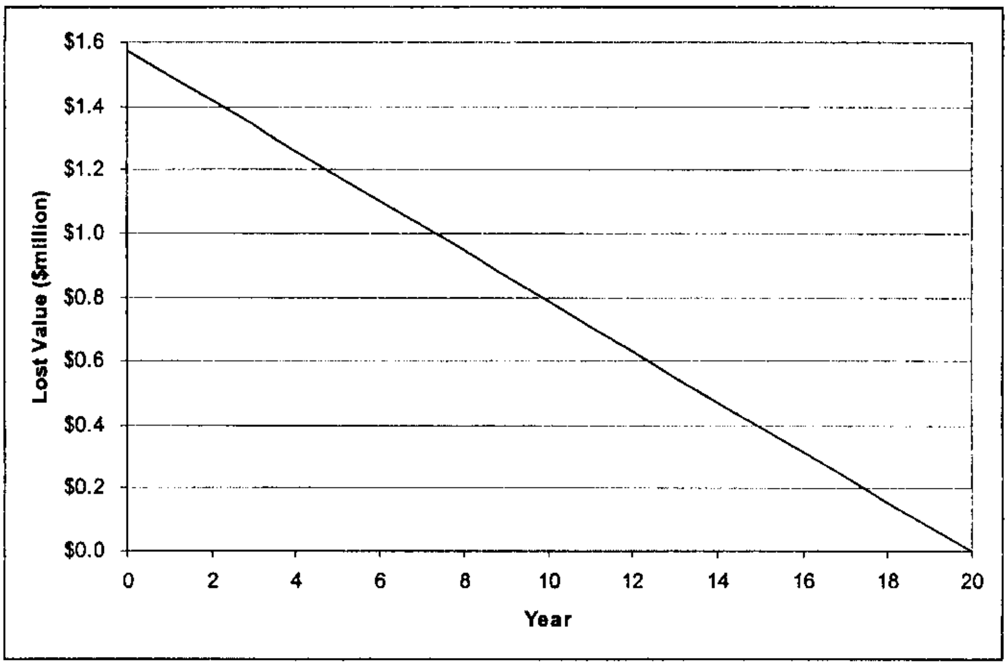

Figure 10 20-Year Depreciation Schedule of Lost Value in Converting Facilities from HMO to RSM Technology

Figures 11, 12, and 13 show the running difference between the depreciated lost value of HMO equipment and the cumulative WRT vs HMO cost savings per year, as shown in the previous analysis. These figures do not include any changes in operating expenses due to the conversion to RSM technology from HMO, nor do they include any capital expenses that may be incurred initially if a convertible HMO-to-RSM treatment system is installed at each facility rather than an HMO-only system.

Figure 11 depicts the running difference for the no-radon-removal alternative. The figure indicates that the depreciated lost value is offset by savings before year four.

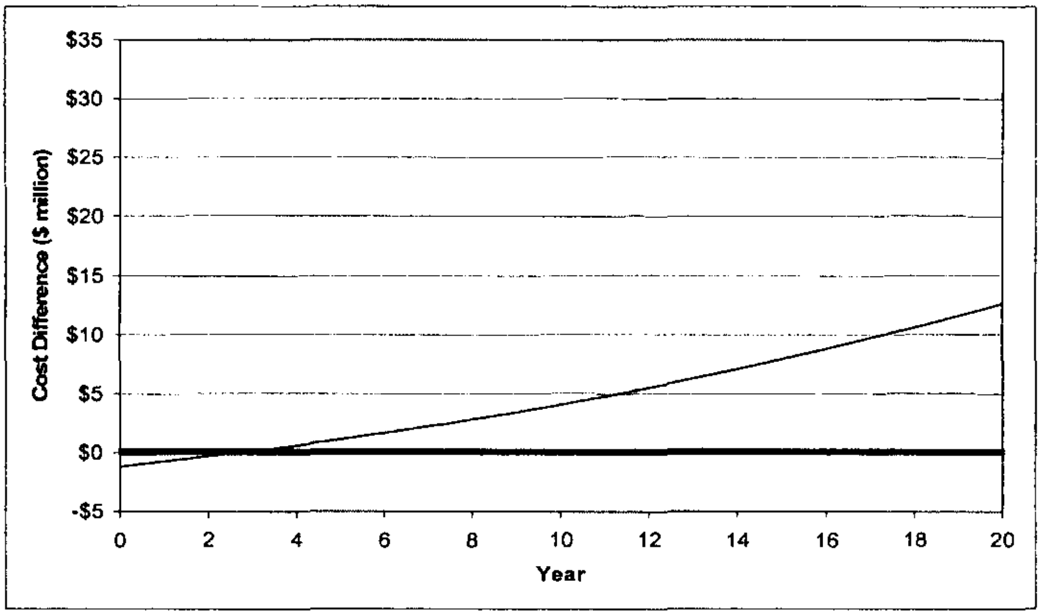

Figure 11 Difference Between Lost Value and Cumulative Cost Savings of HMO vs. WRT Technology With No Radon Removal

Figure 12 depicts the running difference assuming radon removal for WRT facilities only, and does not incorporate costs should radon removal be needed for RSM treatment.

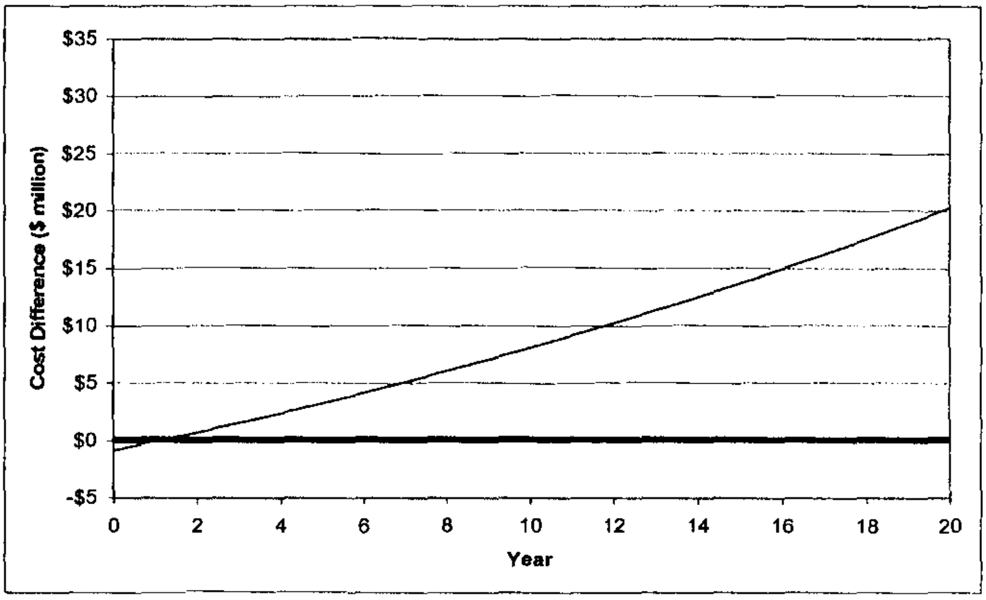

Figure 12 Difference between Lost Value and Cumulative Cost Savings of HMO vs. WRT technology With WRT Radon Removal

Figure 13 depicts the running difference assuming radon removal for WRT and excess disposal fees for WRT spent media. As noted above, operating expenses such as spent media disposal for RSM are not included in this analysis.

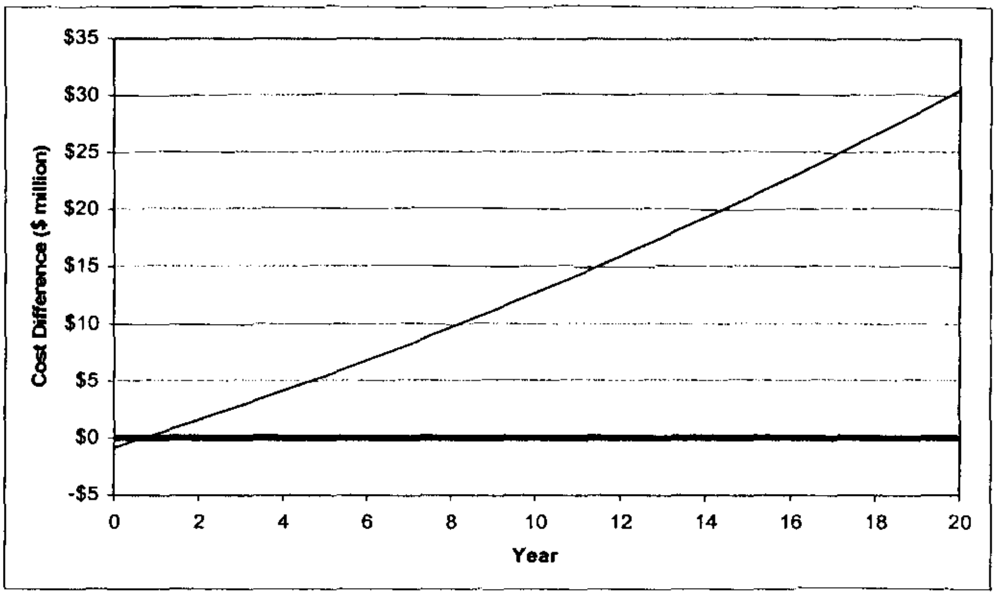

Figure 13 Difference between Lost Value and Cumulative Cost Savings of HMO vs. WRT technology With WRT Radon Removal and Excess Disposal Fees

Extended Period Analysis

Additional cost analysis of the HMO and WRT technologies was performed using a 30-year study period for Scenario B only. Possible conversion to RSM is disregarded for this analysis.

In this analysis, all physical costs (building and equipment) are fully depreciated at the end of year 20. Also, all HMO injection equipment is replaced at the end of the 20 year period and is financed using identical interest and time-period conditions as the initial purchase. The cost of the replacement equipment has been adjusted based on the Consumer Price Index to reflect inflation. Building construction costs for WRT, then, are fully paid in the year 2025, while construction costs for only the HMO chemical feed equipment are renewed after 2025. HMO building and filter equipment are fully depreciated after the year 2025. In addition, the estimated depreciation cost for WRT filter vessels and piping is subtracted off annual WRT operating costs after the year 2025. This presumes that WRT will renew its 20-year contract with the City of Joliet without incorporating capital expenses into its annual fees. Thus, amortized costs of more than $666,000 for filter vessels and process piping are eliminated from WRT annual fees beginning in the year 2026.

Figure 14 shows the annual difference in cost between the two technologies during the 30-year period for Scenario B under all three analysis alternatives. The initial cost difference between HMO and WRT is greater for alternatives in which radon-removal equipment must be built. When excess disposal charges are not incorporated into the analysis, the cost difference between the two processes is identical once capital expenses are fully depreciated. Annual cost differences range from $376,000 to $1.98 million over the course of the 30-year study period, depending upon year and analysis alternative selected.

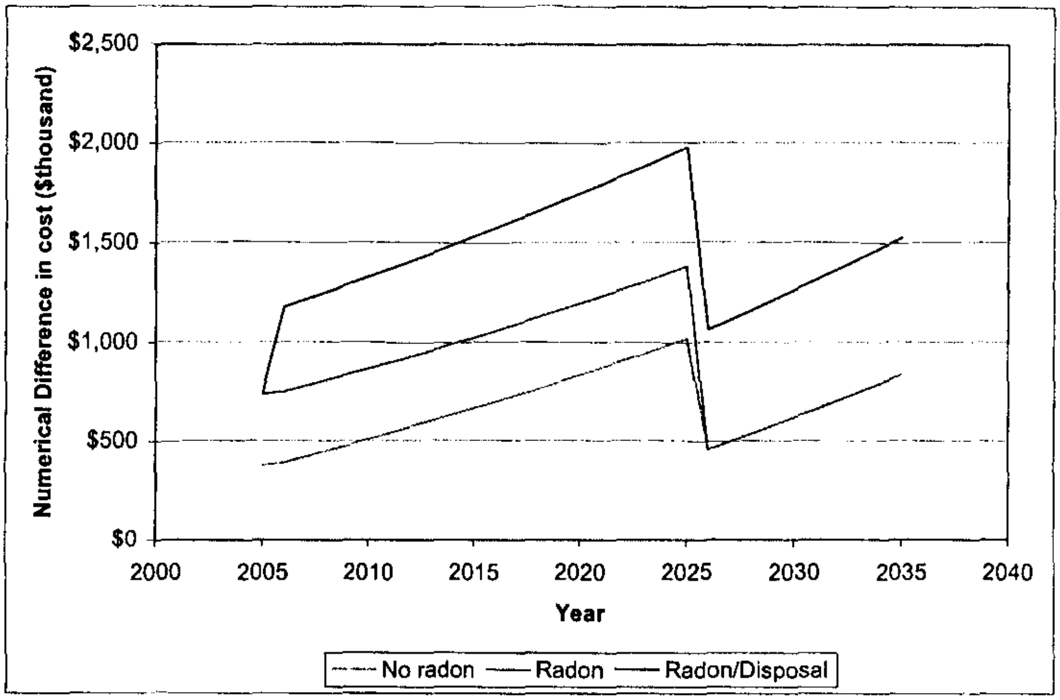

Figure 14 Annual Difference in Cost Between WRT and HMO Over a 30-Year Period for Linear Demand Scenario (Scenario B)

Figure 15 depicts the cumulative difference in cost over the 30-year study period between WRT and HMO technologies. This figure shows the cumulative difference between the two technologies using the linear demand scenario (Scenario B) under all three analysis alternatives. Cumulative cost differences at the end of 30 years range from $20.6 million when no radon removal is required for WRT to $44.9 million when radon removal and excess disposal charges are incorporated.

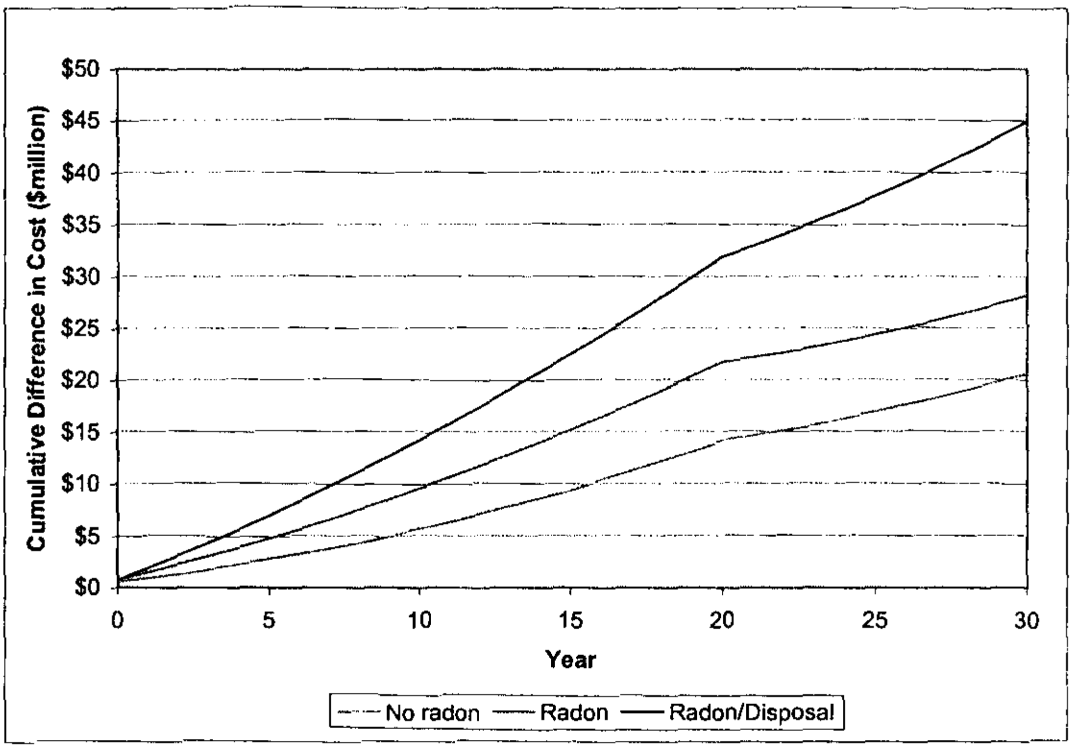

Figure 15 Cumulative Difference in Cost between WRT and HMO over a 30-year period for Linear Demand Scenario (Scenario B)

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Summary

The cost analyses performed indicate that cumulative costs over a 20-year period are significantly lower with HMO than with WRT. If a convertible HMO/RSC system is installed, the technology will be cost effective in comparison with WRT as long as conversion occurs at least six to 13 years after start-up, depending upon conditions. That conversion time frame could be shorter if additional fees and financial requirements associated with WRT are instituted. Those additional fees and financial requirements are not evaluated in this analysis, since their value cannot be determined at the present time. While conversion from HMO to RSC results in more capital expenditures, operational expenses associated with either technology are lower than operational expenses associated with WRT.

Extended-period analysis indicates that the HMO technology continues to generate lower annual costs than WRT using the assumptions described above, even after equipment is fully depreciated and replaced where appropriate.

It should be noted that these cost evaluations for all technologies should be considered a baseline range only. Please contact us to discuss further at your convenience.

Sincerely,

STRAND ASSOCIATES, INC.

Mark G. Oleinik, P.E.