Synapse
Energy Economics, Inc.

The Real Costs of Cleaning Up Nuclear Waste

Appendix C:

Potential Uncontrolled Release of Radioactive Waste from the West Valley Site and Contact with Water Utilities

June 23, 2008

AUTHOR

Michael Wilson, PhD

108 Houghton Hall

SUNY Fredonia, Fredonia, NY 14063

Purpose

The U.S. Department of Energy (DOE) prepared an Environmental Assessment for the West Valley (New York) Demonstration Project (WVDP) for on-site radioactive waste disposal in April 1986, and on that basis issued a finding of no significant impact (FONSI) on August 6, 1986. In 1987, DOE agreed to construct an Environmental Impact Statement (EIS) addressing citizen concerns about waste disposal. The Draft EIS was released for public review in 1996, subsequently reviewed, and revised, with a new DEIS completed in 2005. In an effort to extend and improve the DEIS analyses of closure scenarios, an independent Full Cost Accounting (FCA) study of waste disposal economics at the WVDP site is being conducted. The purpose of this report is to contribute to the FCA an analysis of potential radioactive waste release and possible impact on water supplies.

Waste Release Factors

There are numerous factors affecting possible release of radioactive contaminants from the WVDP site. Threats to water supplies (Table 1) emanate from possible combinations of: causes of escape (Table 2), forms and rates of release (Table 3), general and specific paths of migration (Table 4), and related factors such as retardation. I have used experience and professional judgment to identify a realistic worst case scenario to see what level of danger exists. This worst case scenario evolved from consideration of outcomes in my investigations of other sites in other past projects: municipal, agricultural, industrial, hazardous, non-point and other wastes; studies of erosion and sedimentation of streams, lakes and reservoirs; measurements of contaminate movements through watersheds and into longshore transport; and familiarity with the West Valley site and its regional context.

While at first it may seem improbable that radioactivity could escape from the West Valley site, there already have been three breaches of containment (smoke stack, pipe leakage under a building, and bath-tubbing). Table 2 lists numerous future possibilities for causes of escape of radioactivity, specific to the WVDP site. While considering rad-waste escape mechanisms, one also thinks of the form and rate of release (Table 3) as well as paths of migration (Table 4). Thinking about the interplay of factors in these tables helps to envision worst or best case scenarios.

Worst Cases

It is tempting to assume that speed equates to worst case scenario, such as: gully erosion leading to landslide breaching of a trench during storm flow of creeks, with consequent rapid transport of contaminants into strong, eastward longshore transport in Lake Erie. However, worst cases may contain slow processes as well, and be combinations of point and non-point sources and multiple events, seen and unseen by human observers. Worst case scenarios are:

Scenario 1:

Expanding desiccation allows slow or intermittent escape or exchange of trench-water leachate into Erdman Brook or Franks Creek which binds to clays or silts or oxide coatings on coarse sediments; then liquid and sediment migrate to Buttermilk and Cattaraugus Creek stream bed and point bars, and is also taken-up by bacteria and food-chain; lastly, a 10 or 100 year storm event flushes the system, including gullies and desiccation cracks. The time frame for scenario 1 could be less than a century.

Scenario 2:

Worse yet, after centuries, several trenches containing leachate are exposed by a landslide at the end of the trenches. This flush is added to scenario 1. Because of the need to have conditions that promote landslides, this scenario may take centuries or longer.

Joshi (1988a, 1988b) made a case for radioactive waste migration from the WVDP site through the Buttermilk-Cattaraugus-Erie-Niagara route, with consequent deposition in the Niagara River delta in Lake Ontario. His analyses argued for non-deposition in Lake Erie in order to account for an apparent large quantity of radionuclides in the Niagara delta. However, he need not assume lack of deposition in Lake Erie. Even during one or a few years, stream bed and stream bank storage with a subsequent storm flush might account for both deposition in the Niagara delta and losses to Lake Erie bottom sediments. That he accounted for only 36% of Pu, which has a lower retardation than some other radionuclides, suggests Pu losses occurred to Lake Erie, or to Springville Reservoir, or water for the Niagara Power Project, or community water supplies.

The Lake Erie Connection

As part of this study, the apparent connection of Cattaraugus Creek to the Niagara River was investigated. The dominant circulation in the Eastern Basin of Lake Erie was measured during 1979-80 as eastward along both south and north shores by Saylor and Miller (1987), with these currents meeting in the north east part of the Eastern Basin and flowing westward down the north center of the Eastern Basin. Beletsky, Saylor and Schwab (1999) described and mapped summer currents as westward, winter as eastward, and annual average currents as eastward in the Eastern Basin of Lake Erie. However, they had limited data for the Eastern Basin and left most of the map area blank in their report. These reports emphasized discussion of the major currents rather than details of longshore sediment transport.

Hawley and Eadie (2007) investigated sediment re-suspension in Lake Erie. They looked at extensive data at one deep site in each of the Central and Eastern Basins of Lake Erie. They concluded that the site in the Central Basin was subject to repeated sediment re-suspension with little net accumulation, while the deep site in the Eastern Basin had no local re-suspension and was subject to deposition of bluff-eroded sediment or shallow-water re-suspended sediment. They further concluded that the site in the Eastern basin was subject to receiving sediment by infrequent, large storms because during their study they did not observe significant transport to the site by small or modest storms. They did not discuss or take account of streams supplying sediment to longshore transport and currents, which is likely a critical process.

The author has observed sediment transport along the southeast coast of Lake Erie sporadically for 40 years, and continuously during the ten years from 1984 to 1993, when living on the coast two miles west of Dunkirk, NY. He also measured stream discharge, stream and lake ice growth and decay, and stream and coastal sediment transport for several studies of the southeast coast of Lake Erie. Sediment transport in longshore drift was wholly responsive to wind direction and consequent wave direction, frequently reversing (east-west-east-west, etc.) as weather fronts passed (eastward transport dominated).

Approximately 568 three-hour periods of NOAA wind measurements and modeled current directions for several Aprils and Mays were checked, which included dates of imagery selected for discussion in this report. Longshore currents adjacent to the southeast coast of Lake Erie were eastward approximately 78% of the time, westward approximately 18% and in transition at least 4% of the time. While this review was not exhaustive and did not cover all seasons, it does agree with the author's routine observations and provides a general idea that longshore transport of Cattaraugus Creek sediment will be generally eastward toward the Niagara River but reverses direction toward the west about 18% of the time and for periods of hours up to a day.

Using Satellite and Related Imagery

Several factors confound image interpretation. The presence and movement of winter ice cover is a consideration. In Figure 1 (3-12-1999) melting ice has moved southward against the south shore of Lake Erie. The ice boom at Buffalo, NY kept the ice form entering the Niagara River. In Figure 2, ice has moved north eastward into the Buffalo end of Lake Erie (3-28-1995). On the one hand, interpretation is helped by ice because it is easy to see how surface currents have moved ice, on the other hand it is difficult to perceive how ice cover has altered or prevented incoming stream sediments from being distributed in the lake.

Figure 3 (5-4-2002) shows a "whiting event," which is the brightening of surface water color due to elevated quantities of calcium carbonate sediment. This sediment is from chemical precipitation of supersaturated calcium carbonate triggered by water temperature change. The sediment appearance on the image could be confused with suspended sediment from coastal erosion or streams. Imagery for this study of Cattaraugus outfall was chosen to avoid confusion with “whiting” by observing direct linkage of sediment plumes to the mouth of Cattaraugus Creek.

Another factor affecting interpretation of sediment transport from imagery is the frequent reversal of wind directions (and consequent reversal of longshore transport) as atmospheric warm and cold fronts pass over the region.

Interpretation of Selected Images

Figures 4a and 4b, both images taken on April 18, but three years apart, give a comparison of Cattaraugus Creek sediment load and impact on Lake Erie. In Figure 4a, winds were consistent for many hours from west or southwest, creating a well-defined, eastward, longshore sediment pattern, and streams, including Cattaraugus Creek, were heavily charged with sediment. In Figure 4b, winds were somewhat weak and changed during the course of the day from out of the west and then from north toward shore, creating complex sediment dispersal. The sediment load of Cattaraugus Creek is lighter (less) in Figure 4b, and the eastward longshore transport was being reversed at the time of the photo. If radioactive dissolved or suspended loads were being carried in either of these cases, there would be considerable dilution. Dilution in case 4a by mixing with other stream’s loads, and dilution in 4b by mixing into the lake.

In Figure 5, Cattaraugus Creek was carrying sediment into Lake Erie on a day when winds were changed from west-to-east to east-to-west and back to west-to-east. North-eastward sediment transport dominated at the time of the photos, as does north-eastward movement of the remnants of ice cover.

In the image in Figure 6, there are clouds and jet airplane contrails, but the sediment plumes of both Cattaraugus Creek in Lake Erie and the Niagara River into Lake Ontario can be easily seen. NOAA wind data for the date of the image fit the appearance of the sediment plumes: eastward transport of both Cattaraugus Creek sediment in Lake Erie and Niagara sediment into Lake Ontario was redirected westward. The Cattaraugus plume was detached from the shore at Buffalo; the more recent plume of Cattaraugus Creek was stretched westward to just past Dunkirk harbor; the Niagara River was light in tone due to being deprived of the Cattaraugus plume (longshore transported sediment); in Lake Ontario the Welland Canal and Niagara River plumes had drifted westward; and the water at the mouth of the Niagara River was clear. NOAA wind data suggested a brief return to eastward sediment transport at or just before the image was acquired.

Figures 7a and 7b are overlapping images showing the outflow of the Welland Canal and Niagara River into Lake Ontario (north toward top; Lake Ontario). Winds were from the northwest and very-strong, eastward, longshore sediment transport is seen.

In conclusion, the satellite and air plane images, taken together with information on winds and currents, clearly indicate that Cattaraugus Creek sediment is the most important source of sediment to the south coast of the Eastern Basin of Lake Erie, and a critical source of sediment to the Eastern Basin of Lake Erie and to the Niagara River and its delta in Lake

Ontario. At times, Cattaraugus Creek is linked directly to the Niagara River by longshore transport, but sometimes its connection is interrupted by westward drift and then Cattaraugus sediment finds its way into the depths of the Eastern Basin.

Dilution

As the radioactive waste is released from the WVDP site dilution may or may not occur. The foregoing sections of this report present a conceptual model for movement of radioactive wastes from the site to public water intakes along the Lake Erie shore and the Niagara River. Table 5 presents a schematic diagram for changes in flow rates along the conceptual path. A storm that flushes the system, liberating stored radioactivity from gullies, point bars, stream beds and banks, beaches and bays, and occurs when there is a longshore transport that is continuous from Cattaraugus Creek to public water intakes needs to be considered. The worst case would be a "first flush" storm, one that follows a period of slow radioactive release and environmental accumulation. It is common scientific knowledge that concentrations of pollutants often rise (rather than diminish or dilute) during first flush events. Such an event combined with partial trench or structure collapse will be a "worst case." The worst case would include eastward longshore current and beach sediment movement that involves minimum mixing of lake sediments or other stream waters.

So far, an extensive literature search has returned little about actual measurements of currents within Lake Erie. The estimates here are from personal qualitative observations, the quantitatively modeled currents by NOAA, and our studies of the qualitative appearances of remote sensing imagery. Regarding plume mixing, Figures 4-7 show how that takes place.

When wind is weak or when winds are shifting, then Cattaraugus Creek will have its best ability to flow unimpeded into the lake and make plumes perpendicular to the shore and outward into the lake. We found no images that showed such a condition, so Cattaraugus flow directly outward into the lake is likely very temporary (my estimate was 4% of the time, based on NOAA models of currents).

Volumes of near-shore currents vary greatly through time, similar to creeks and rivers. Any creek or shore zone will mix within themselves fairly rapidly, over the distance of a few bed or bar forms or after a couple of eddies in currents. Dilution thus will be simply a function of relative volumes that mix. So, if Cattaraugus Creek is flowing at 1,000 ft^3/s and the near shore current is 10,000 ft^3/s, then dilution is an order of magnitude.

Some utility intakes have been lengthened in recent years to improve water quality by avoiding mussel colonies or avoiding the shore currents. For example, Erie, PA has an intake located over 3 miles off shore. If utility intakes are far enough off shore, then they tap only highly diluted flow. Unfortunately knowledge of the exact locations of most of the intakes is limited due to homeland security issues. It is important to note though that the water supply intakes themselves cause neither dilution nor concentration; intakes sample whatever passes by.

The Niagara River utility intakes receive whatever portion of shore currents that enter the Niagara River. Those intakes sample quickly-mixed river water and their position in the river seems of little importance. If Niagara flow is 200,000 ft^3/s and shore currents flow at 10,000 ft^3/s, then dilution is 20 times. An exception to this kind of simple mixing might occur when the

Niagara River splits around Grand Island. Some remote images indicate more turbid water in the east branch of the river that appears to emanate from south shore currents.

In conclusion, dilution using changes in flow in cubic-feet-per-second is approximately an order of magnitude for each transition from Erdman (1), Franks (10), Buttermilk (100), Cattaraugus (1000), Lake Erie Shore (10,000), to Niagara River (200,000). If ten-times flow increase occurs at the Cattaraugus-shore confluence then multiply Cattaraugus concentration by 0.1 for shore utility intake; and if twenty times flow increase occurs at the shore-Niagara confluence then multiply Cattaraugus concentration by 0.005 for Niagara river utility intake.

REFERENCES

Beletsky, D., J. H. Saylor and D. J. Schwab. 1999. Mean Circulation in the Great Lakes. J. Great Lakes Res., 25: 78-93.

Hawley, N. and B. J. Eadie. 2007. Observations of Sediment Transport in Lake Erie during Winter of 2004-2005. J. Great Lakes Res., 33: 816-827.

Joshi, S. R. 1988a. West Valley-Derived Radionuclides in the Niagara River Area of Lake Ontario. Water, Air and Soil Pollution, vol. 37, p. 111-120.

Joshi, S. R. 1988b. West Valley Plutonium and Americium-241 in Lake Ontario Sediments Off the Mouth of Niagara River. Water, Air and Soil Pollution, vol. 42, p. 159-168.

Saylor, J. H. and G. S. Miller. 1987. Studies of Large-scale currents in Lake Erie, 1979-1980. J. Great Lakes Res., 13: 487-514.

ACKNOWLEDGEMENT

Ms. Dawn Shermet, Senior Research Support Specialist, State University of New York, Fredonia, NY, was retained to aid this study. She conducted literature, records, and imagery searches and selected most of the imagery.

TABLE 1. Drinking Water Intakes Related to Cattaraugus Creek by Longshore Transport

A. Eastward Longshore Transport

- Erie County Water Authority
    - Sturgeon Point (*source:* Lake Erie)

    - Van de Water Treatment Plant in Tonawanda (*source:* East branch of Niagara River)

- Buffalo Water Authority
    - Buffalo Water Intake Crib (*source:* Lake Erie, near head of Niagara River)

- Niagara County Water District
    - Near West River Rd. in Town of Grand Island (*source:* West branch of Niagara River

- Niagara Falls Water Board
    - Michael C. O'Laughlin Water Plant (*source:* East branch of Niagara River)

- Regional Municipality of Niagara, Ontario, Canada
    - Niagara Falls Water Treatment Plant (*source:* Niagara River via Welland River Channel)
    - Welland WTP (*source:* Lake Erie via Welland Ship Canal & Welland Recreational Waterway)
    - Rosehill WTP, Fort Erie (*source:* Lake Erie)
    - Port Colborne WTP (*source:* Welland Canal)
    - DeCew Falls WTP (*source:* intake canal from Welland Ship Canal, Lake Erie)

B. Westward Longshore Transport

- City of Dunkirk, Lake Erie

- Erie Water Works, PA
    - Chestnut Water Treatment Plant, 17,500ft into Lake Erie
    - Sommerheim Water Treatment Plant, 8,700ft into Lake Erie

TABLE 2. Ten "Natural" Causes for Escape of Radioactivity from the West Valley Site

In order for there to be an off-site release of radioactive contamination there must be a means to initiate that escape from trenches, tanks or lagoons:

1. Erosion breaches the walls or base of containment feature.
    A. Gully head advance into feature
        1) drain plugging

        - a) hail
        - b) litter, such as leaves during storm
        - c) snow
      - 2) failure of edge of seal
      - 3) undercutting
        - a) sapping
        - b) desiccation

  - B. Meandering adjacent to containment feature
    Franks Creek or Erdman Brook

  - C. Down-cutting adjacent to containment feature
    Franks Creek or Erdman Brook

2. Landslides

3. Desiccation cracks
   - A. Dewatering of soil by barriers, wells, erosion, etc.
   - B. Climate change with increased droughts

4. Expulsion by fluid pressure
   - A. Methane from wastes or shale gas
   - B. Radioactive contaminated gas release from breaching of seals
     - 1) natural or artificial covers
     - 2) barriers or trench walls

5. Burrowers
   - A. Ants
   - B. Plant roots

6. Corrosion
   - A. Metals
   - B. Soils

7. Bath-tubbing

8. Impact (e.g. meteorite)

9. Combinations of events or processes

10. Other- processes or events not yet perceived

TABLE 3. Form and Rate of Release of Radioactive Material

Pent-up fluid as liquid or gas
- slow release
- rapid release

Solid particles
- slow release

- rapid release

Solid particles
- clay minerals
- non-clay minerals
- organics
    - active microbes
    - other

TABLE 4. General Pathway of Migration After Release

Air
- gas
- dust

Water
- base flow
- storm flow

Food Chain

TABLE 5. Dilution?

Flow Path	Average Flow*	Storm Flow*	Data Source
Buttermilk Creek	1.3 (46)	111 (3,900)	1996 DEIS
Cattaraugus Creek	20.7 (750)	170 to 940 (6,000 to 34,000)	USGS; Joshi, 1988
Lake Erie Shore**	100s to 1,000s (10,000s)	100s to 1,000s (10,000s)	------
Niagara River	5,500 (197,000)	5,500 (197,000)	Joshi, 1988; USGS

* m^3/s (ft^3/s)

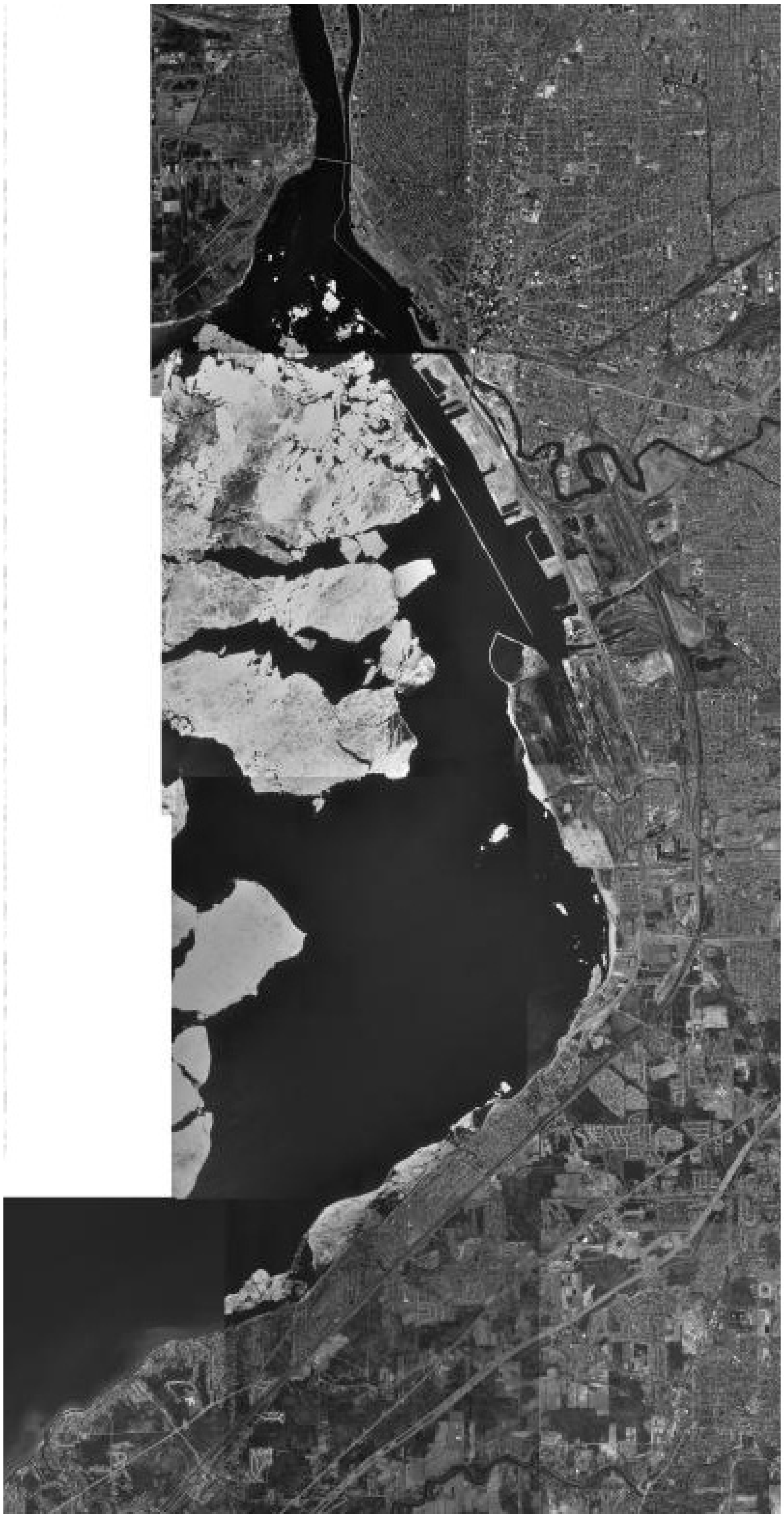
**For purposes of this discussion, estimate the longshore transport as similar to surface currents modeled by NOAA for the figures in this report, 0.2 m/s (0.7 ft/s). Cross-section of the surface current estimated as 1,200 m (4,000 ft) wide, averaging 3 m (10 ft) deep. Thus the shore current flows at 720 m^3/sec (26,000 ft^3/sec) in Figure 4a. While the calculation is a rough estimate, it gives a sense of order of magnitude.

Additional Information on Cattaraugus Creek:
- Between 1940 and 2007 the largest annual peak flows were from 6,000 to 34,000 ft^3/s.
- The highest TSS concentrations were likely above 1,000 mg/L during storms.
- The average discharge was 750 ft^3/s; the highest months average flows are March with 1587 ft^3/s and April at 1457 ft^3/s. Lowest is August at 250 ft^3/s. May average flow is 757 ft^3/s, nearly matching the annual average (750 ft^3/s).

FIGURE 1.

3-12-1999 *http://visibleearth.nasa.gov/*

FIGURE 2.



3-28-1995 *TerraServer Image courtesy of USGS*

FIGURE 3.

5-4-2002 *http://visibleearth.nasa.gov/*

FIGURE 4a.

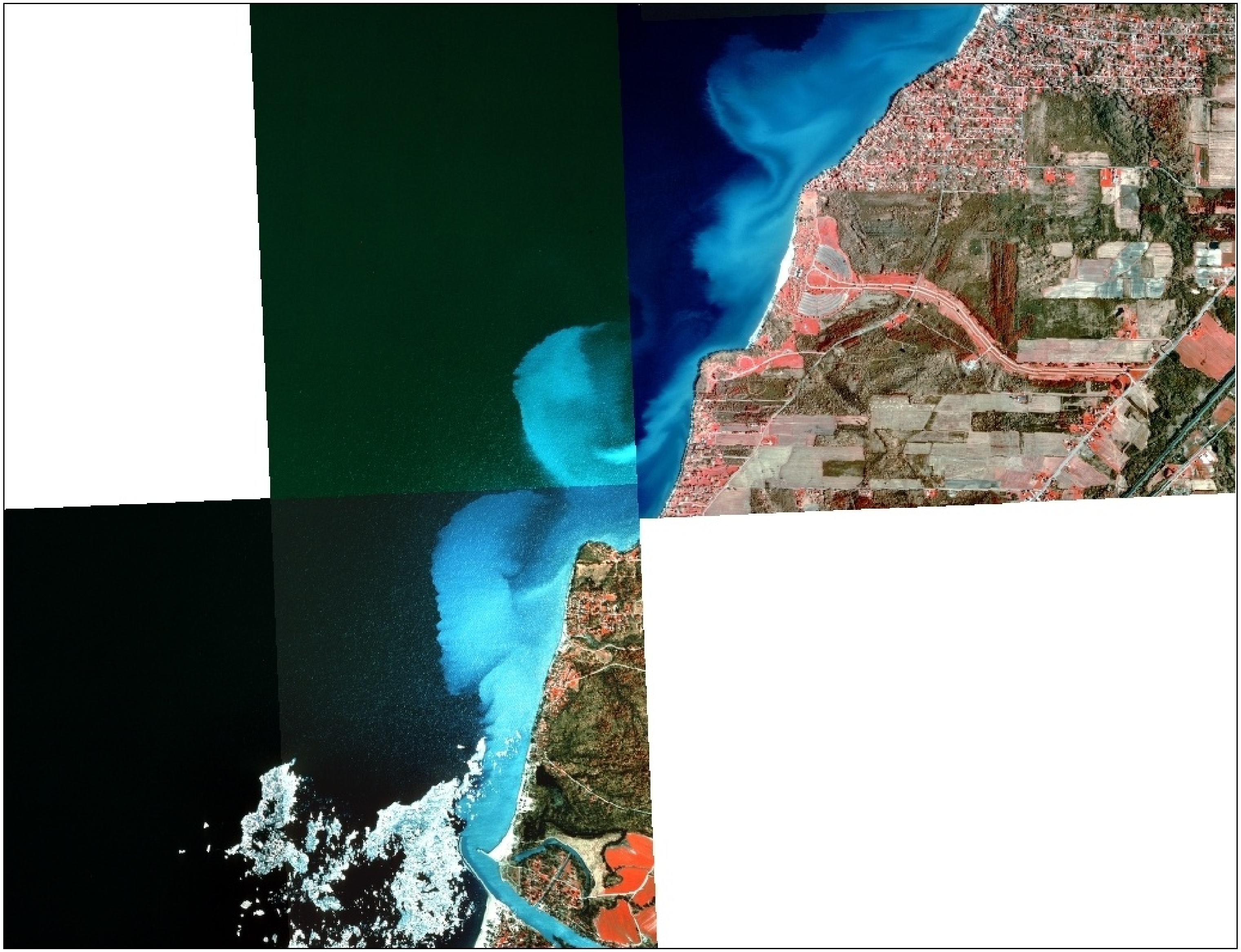
4-18-02: Panchromatic

FIGURE 4b.

4-18-05: Panchromatic

http://www.nysgis.state.ny.us/

FIGURE 5.

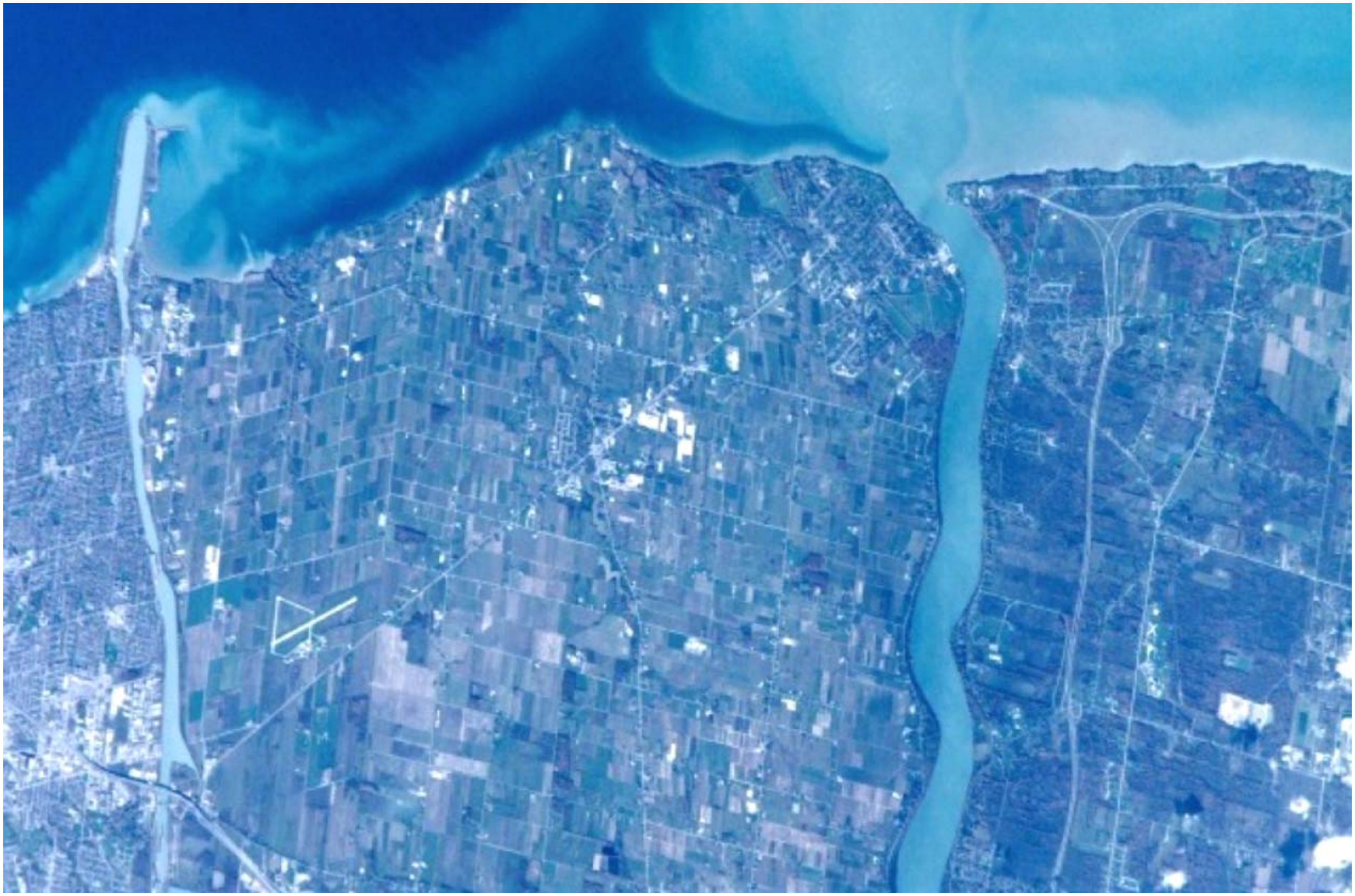


4-21-1994: 1-meter Color IR tile *http://www.nysgis.state.ny.us/*

FIGURE 6.

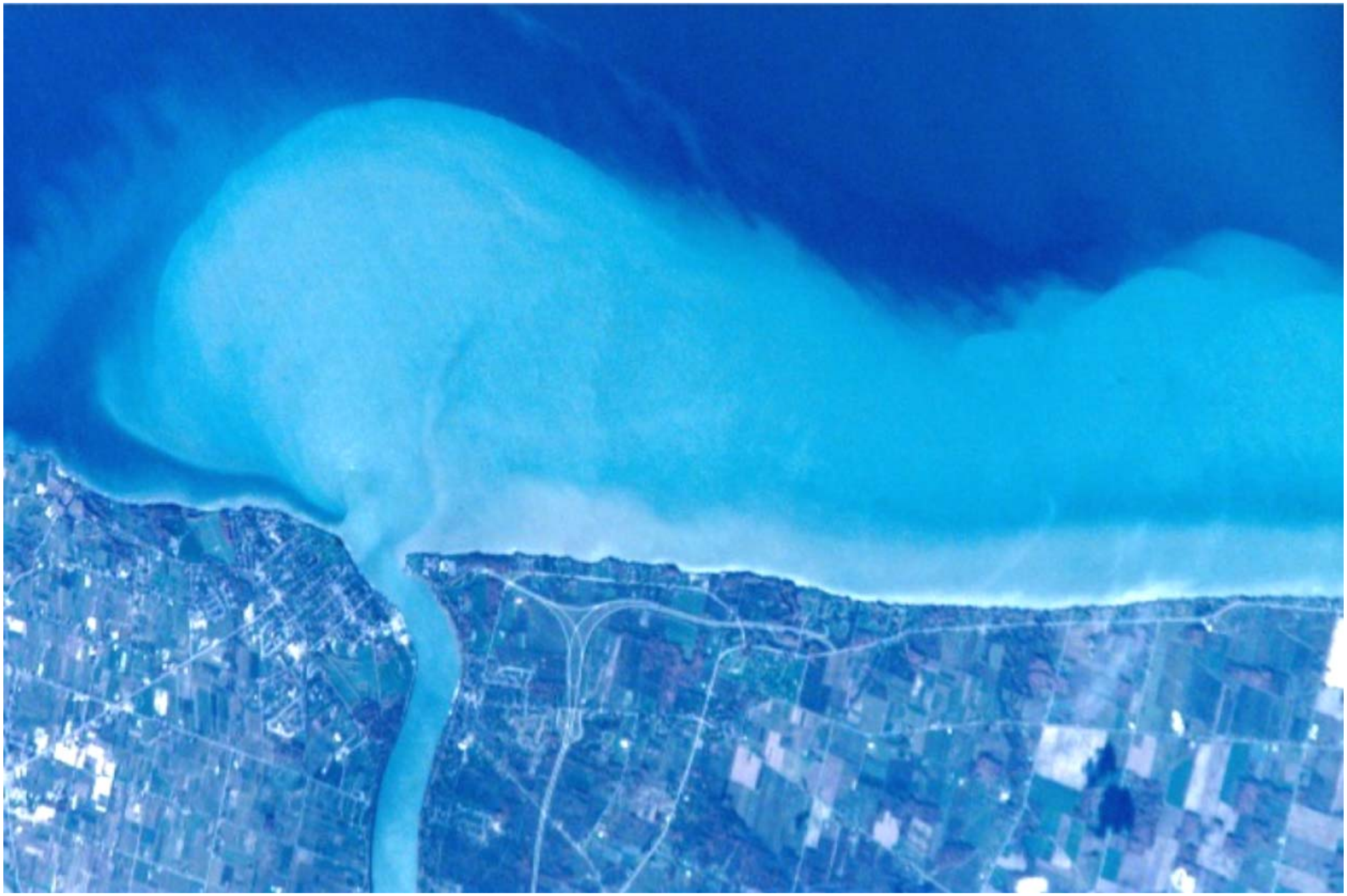
6-22-1984: Landsat 4-5 MSS

FIGURE 7a.



11-5-2001 *NASA Astronaut Photography*

FIGURE 7b.



11-5-2001 *NASA Astronaut Photography*

Lake Erie Currents and Longshore Sediment Transport

Data Collection

• Digital Orthoimagery

NYS GIS Clearinghouse (http://www.nysgis.state.ny.us/): provides aerial imagery without distortion for all of NY.

- downloaded orthos of the shoreline of Lake Erie, including most of Chautauqua County to the Niagara River (Erie County).
- reviewed a combination of: 1-meter resolution Color IR tiles (1994), 2-foot resolution Panchromatic (2002 & 2005), 1-foot (2005) and 2-foot (2004) resolution Color IR, and 1-foot (2005) and 2-foot (2004) resolution Digital Color

• Satellite Images

Visible Earth (http://visibleearth.nasa.gov/): a catalog of NASA images

- reviewed close to a hundred images of the Great Lakes to find any that showed sediment transport

USGS Global Visualization Viewer (http://glovis.usgs.gov/): a catalog of satellite images at the Earth Resources and Observation Science Center (EROS)

- reviewed over a hundred images of the Lake Erie-Lake Ontario region to find any that showed sediment transport
- reviewed images were from various satellites including Landsat 7 ETM+, Landsat 4-5 TM, Landsat 4-5 MSS, Landsat 1-3 MSS, Landsat Decadal Collections, Landsat Science Collections and Terra ASTER.

• Astronaut Photos

The Gateway to Astronaut Photography of Earth (http://eol.jsc.nasa.gov/): online catalog of astronaut photographs of the Earth from 1961-present.

- reviewed hundreds of photographs taken in the Lake Erie-Lake Ontario region to find any that showed sediment transport

• Models

NOAA Great Lakes Coastal Forescasting System (http://www.glerl.noaa.gov/res/glcfs/)*:* provides maps for various parameters of all the Great Lakes (for the past 48 hours), including surface temps, surface currents, temp transects, temp profiles, water levels, winds, waves, air temps, and ice cover

- downloaded maps of recent currents and winds modeled for Lake Erie and Lake Ontario for 5/31/08 to 6/5/08. Individual maps were produced for each parameter, for every third hour of the day, for a total of 39 maps for each. Maps displayed both speeds and directions of said parameter.

- reviewed modeled output of available winds and currents for the dates depicted in Figures 3-7.

Comparison

After reviewing all aerial photos and satellite imagery collected, specific images were selected from each category based on clarity and distinctiveness and variety of apparent sediment transport. Some images were also chosen for their apparent lack of sediment transport or for other reasons, such as varying ice covers. When corroborative information could be found, images were compared to known wind directions or currents. Some images were compared to modeled output to relate sediment transport observations to wind and current patterns. About 40 images or mosaics, as well as recent model maps of currents, were discussed between Shermet and Wilson when choosing the images referenced in the text of this study.

Acknowledgment

Gregory Lang, NOAA GLERL Physical Scientist, provided modeled output of available winds and currents for the dates depicted in Figures 3-7.