An Integrated Assessment of Torch Lake Area of Concern: Summary

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Beached remains of Quincy Dredge #2, Mason, Michigan. Photograph by Todd Marsee, Michigan Sea Grant, 2012. Calumet & Hecla operations in Lake Linden ca 1940. In the foreground are the Calumet and Hecla stamp mills with the stacks of the power house. Photo provided by the Michigan Technological University Archives and Copper Country Historical Collections.

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Ruins of Quincy powerhouse. Photograph by Todd Marsee, Michigan Sea Grant, 2012.

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SUMMARY

Left to right: Beached remains of Quincy Dredge #2, Mason, Michigan. Photograph by Todd Marsee, Michigan Sea Grant, 2012. Photograph of Calumet and Hecla dredge with Hecla stamp mill in background. Photo provided by the Michigan Technological University Archives and Copper Country Historical Collections.

INTRODUCTION

Torch Lake has been a USEPA Superfund site and Great Lakes Area of Concern for over thirty-five years. Remediation has been slow and incomplete. The industrial site of copper ore processing that produced stamp sands (tailings), slag, chemical pollutants such as polychlorinated biphenyl compounds (PCBs), and dramatic ecosystem changes during 100 years of mineral processing and reclamation, Torch Lake remains a polluted environment. Remediation has focused upon coverage and vegetation of the stamp sands that extend into Torch Lake and a few emergency actions to remove metals, asbestos, and PCBs at specific locations. What remains to be remediated are the lake sediments rich in copper and trace metals that prevent a healthy benthos, the sources of mercury and PCBs to the fish, and the western shoreline of Torch Lake where many processing facilities once existed. The purpose of the Integrated Assessment is to document the history of pollution at Torch Lake and to make available the findings of ongoing research and data collection in a form that benefits the community, government agencies, and researchers who continue the work of improving the Torch Lake ecosystem and eliminating exposure to major pollutants. This document summarizes the much lengthier Integrated Assessment in which may be found all references and documentation of facts; the full document may be downloaded from the Sea Grant website (michiganseagrant.org/torchlake) or requested from the authors.

In 2011 Michigan Sea Grant funded researchers at Michigan Technological University (MTU) to perform an Integrated Assessment of the Torch Lake Area of Concern (TL AOC). The original objectives of the project were: 1) to gather and to summarize existing information regarding conditions in the AOC; 2) to communicate with stakeholders about the status of the site as well as stakeholders' ideas for and visions of future conditions in the AOC; and 3) to identify and to begin to evaluate potential remedial actions that could mitigate any remaining undesirable conditions. The Integrated Assessment summarizes the project findings related to the first objective and the actions taken to meet the second objective. The third objective was dropped as the project evolved, and no evaluation of potential remedial

actions was performed. The Integrated Assessment covers actions through December, 2014, and an Epilogue gives a brief summary of important events after that date. This Summary does not summarize each chapter, but rather discusses the key points from the Integrated Assessment of most benefit to community members and those needing an overview of the status of Torch Lake pollution and remediation.

INDUSTRIAL HISTORY

Conditions at Torch Lake today are the result of over 100 years of mining-related activities and the subsequent 45 years of remedial actions. The mining industry released wastes to the atmosphere, to the lake and its tributary streams, and to the land around the lake. A unique feature of this project was the application of research into the industrial history to clarify the genesis of, the specific components of, and the spatial and temporal distributions of the "problems" at the site. The historical research included extensive review of materials from the MTU archives as well as interviews with local residents with memories of the industrial activities and the post-industrial period of reclamation. This investigation uncovered a complex picture of copper milling and processing along the western industrial shoreline of Torch Lake. The multiple sub-processes involved in copper production resulted in differing waste streams. Additionally, as technology changed during one hundred years of ore processing, the character, size, and location of waste streams changed.

The western shoreline of Torch Lake provided a site for milling facilities for the mines of Calumet and Hecla (C&H) and Quincy mining companies. The first mills, located in Lake Linden, had access to water (needed to produce steam and to separate metal-rich and –poor components of the ore) and to a water body for deposit of waste tailings. When the US government established harbor lines that prevented further dumping from mills operating in Portage Lake, several companies moved their mills to Torch Lake. A total of eight mills operated at different times along the shoreline between 1860 and 1970, producing the large volume of stamp sands that were deposited into the lake (~1.5×10^8 m^3 or ~200 million metric tons). These stamp sands became the object of reclamation beginning in the 1910s and continuing through the 1950s, adding a new dimension to processing in the district. The original stamp sands were dredged, re-ground, and then treated in leaching and flotation units installed in Lake Linden and Tamarack City, and a flotation unit at Mason; this processing used chemicals including ammonia and xanthates, and created new wastes in the form of metal-rich sludges and finer tailings that were re-deposited into the lake. Electrical power replaced steam power such that by 1940 most industrial facilities along the western shoreline were powered by a single coal-fired power plant located in Lake Linden, augmented by steam. A smelter located in Hubbell was operated by Calumet and Hecla for nearly one hundred years, and two large coal-handling facilities were built at Hubbell (C&H) and Mason (Quincy). Auxiliary buildings such as sub-stations and chemical laboratories added to the infrastructure and potential waste disposal in and around the lake. The original sole focus on production of copper metal was broadened to include production of secondary copper chemicals, and this also brought new waste streams.

Photograph of Ahmeek stamp mill located in Tamarack City, Michigan. Photo provided by the Michigan Technological University Archives and Copper Country Historical Collections.

MINERAL PROCESSING AND THEIR WASTE PRODUCTS

Two types of ores, amygdaloid basalt and conglomerate, were processed near the lake with only conglomerate ore being processed at the north end of the lake (Lake Linden), only amygdaloid basalt at the south end (Mason), and both types in the middle. Only some basalt ores contained arsenic, and hence arsenic enrichment is not found in stamp sands processed at the northern end of the lake. Conglomerate-derived stamp sands were easier to reclaim, and reclamation included both flotation and ammonia-leaching; all leaching was performed at the Lake Linden and Tamarack reclamation plants, and the metal-rich slimes/sludges produced by this process are likely confined to these areas.

Composition of slag, a major byproduct of smelting, changed tremendously as technology developed. Early slags (pre-1914) were generated at lower temperatures, and had higher metal content and probably higher leachable metal content. The locations where these slags were deposited remain to be clarified. Use of coal pulverization (beginning around 1914) increased the efficiency of metal separation from slag and resulted in a more vitrified slag; these slags are less likely to leach metals than the earlier slags. Beginning in 1929, slag was ground and subjected to flotation to extract copper; in the 1930s and 1940s, slag was granulated (fractured by depositing in water) and then pumped to be re-extracted.

Photograph of C&H smelter and concentrate storage building in Hubbell, MI about 1950. Photo provided by the Michigan Technological University Archives and Copper Country Historical Collections.

These later slags are likely to have lower metal content and to pose less environmental hazard than earlier slags. Beginning in 1905, amendments were added to the smelters to draw arsenic from the molten copper into the slag. In the late 1940s, arsenic-rich slags were reground and leached (Lake Linden reclamation plant) to extract the arsenic; it remains unknown what was done with the arsenic-rich leachate, but arsenic enrichment is observed in north basin lake sediments and soils in the Calumet and Hecla processing areas.

Vast amounts of coal burning were required to support the mills, smelter, and electricity generating facilities, a dimension that has not been considered previously. Considerable quantities of fly and coal ash were generated; the coal ash was deposited with the stamp sands into the lake, although for some period after World War II, the coal ash was subjected to metal reclamation. The leaching plant at Lake Linden produced metal-rich sludges/slimes as a by-product. The complete extent of this material remains to be determined, although some was identified and removed in a Superfund emergency removal in 2007. Reclamation of scrap materials resulted in additional toxic waste generation in the area. Specifically, lead- and zinc-rich wastes were produced, and PCBs were volatilized and deposited in soils through burning of copper wire insulation. The present-day distribution of lead-enriched sediments and soils shows the locations of disposal of reclamation wastes.

Electrification of the mining industry was accompanied by use of PCB-containing transformers along the length

of the shoreline. The specific locations of installation of many of these transformers have been identified. However, the fate of the transformers and PCBs following demolition of sites has not been determined. One significant insight from our historical investigation of mineral processing is that many of the contaminants that remain in the landscape today originated from specific locations and industrial processes. The types of waste remaining at the site and their disposal locations identified by this type of research are guiding ongoing remediation efforts.

REMEDIATION HISTORY

When copper processing and mining facilities shut down in 1970, pollution concerns surfaced a few years later when residents noticed the presence of fish tumors. For the next 15 years, Michigan DNR and MTU researchers investigated these tumors in an attempt to locate the cause. Evidence pointed to the mining environment, but no causative agents were definitively identified. Meanwhile, in the 1980s, the US EPA and the International Joint Commission each designated Torch Lake and surrounding sites as significantly contaminated and listed them on the National Priorities List (Superfund) and as an Area of Concern (AOC) under the Great Lakes Water Quality Agreement.

Most remedial actions of the Torch Lake Superfund program focused on one waste stream, the stamp sands around the lake above the lake water level. The fish tumors that were one of the major causes for concern originally have disappeared, presumably as a result of cessation of release of carcinogenic compounds into the lake. Remediation efforts did not focus on removing sources of PCBs or mercury (Hg), and fish in Torch Lake still have elevated concentrations of these pollutants that result in fish consumption advisories/guidelines for multiple fish species. No concerted effort was made to remediate the soils at the sites of industrial activity, and hence localized areas of soils highly contaminated with metals, PCBs, and asbestos still exist. No effort was ever made to examine the extent of soil and lake sediment contamination by plumes emitted from the boilers and smelters; the extent and degree of contamination from these sources remain unknown. The lake water is safe for contact recreation, and supports a healthy ecosystem with several notable exceptions including a highly depauperate sediment community (benthos), restricted shoreline wetlands and macrophyte beds, and possibly limited fish spawning within the lake due to sediment toxicity to eggs.

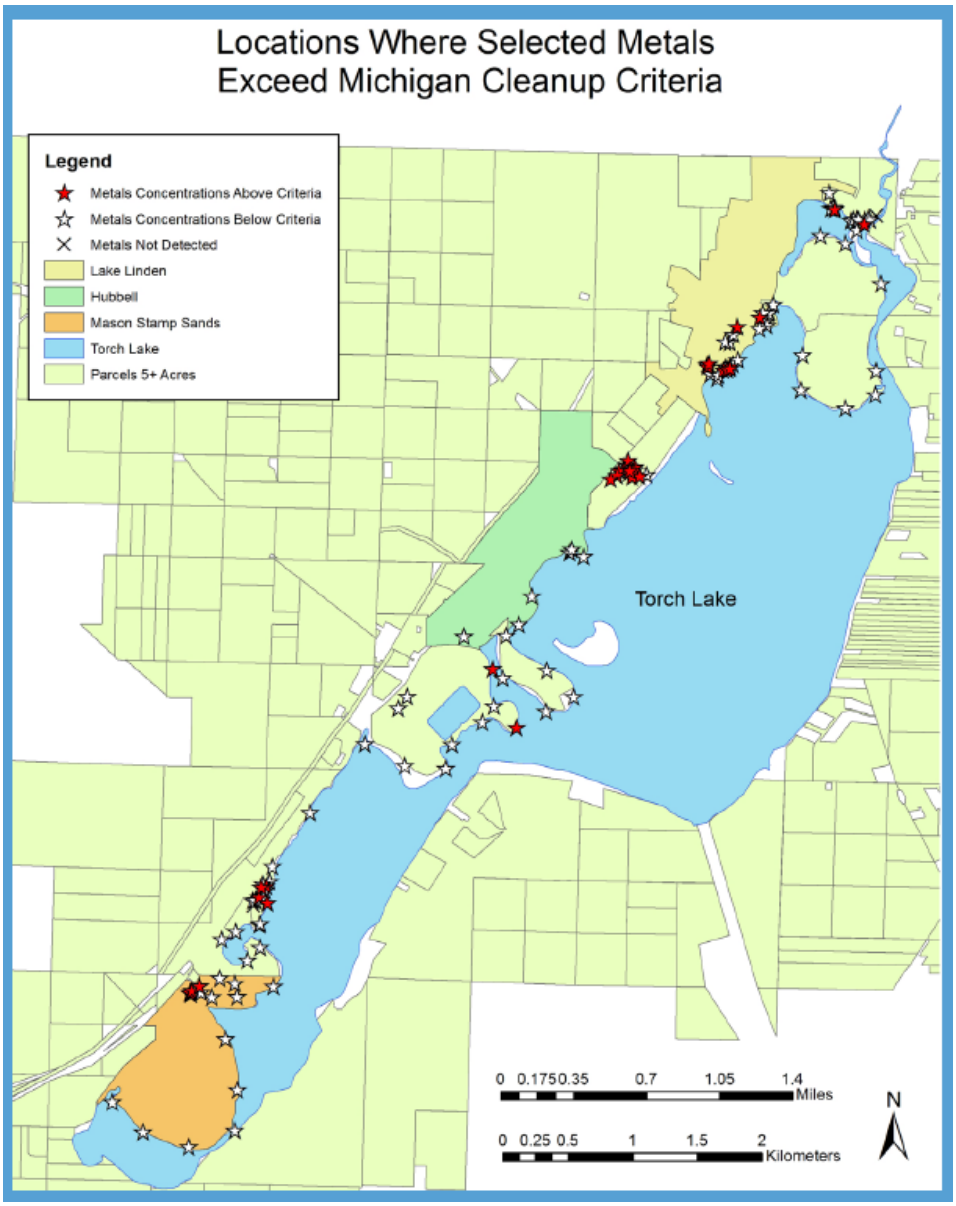
LESSONS FROM ONGOING REMEDIATION AND CITIZEN INVOLVEMENT

Our research also included historical analysis of federal and state involvement in the environmental history of Torch Lake (including the remediation details under Superfund) as well as an evaluation of citizen interest in pollution issues and involvement in ongoing remediation. Several lessons emerge from this research.

The historical context is always important. Actions on the national level were important to both the polluting of the lake and to its remediation. Close scrutiny of these actions helps to clarify why remediation remains incomplete after 45 years. Torch Lake was specifically exempted from restrictions on dumping of materials into the lake in the 1899 Rivers and Harbors Act; because of the importance of copper production to the war effort, pollution restrictions were again waived from 1940 through 1965. These waivers allowed roughly 50% of the lake volume to be filled with stamp sands (not 20% as commonly stated). Even more than at other sites throughout the U.S., pollution was unchecked by national laws and anti-dumping policies in navigable water bodies. Local concern and local studies coincident with the environmental awareness and associated national legislation in the 1970s were instrumental in listing Torch Lake as part of the Superfund and Area of Concern programs in the mid-1980s.

The historical research identified four problems that have impeded the complete remediation of Torch Lake by either Superfund or the AOC program: lack of funding, the narrowing of focus on a complex contamination problem, polarization of local and official viewpoints, and finally the failure of agencies to re-examine early conclusions as new knowledge and remediation tools became available.

Lack of funds within the AOC program led to little action under this program after completion of the first Remedial Action Plan (RAP) in 1987. Funding within the



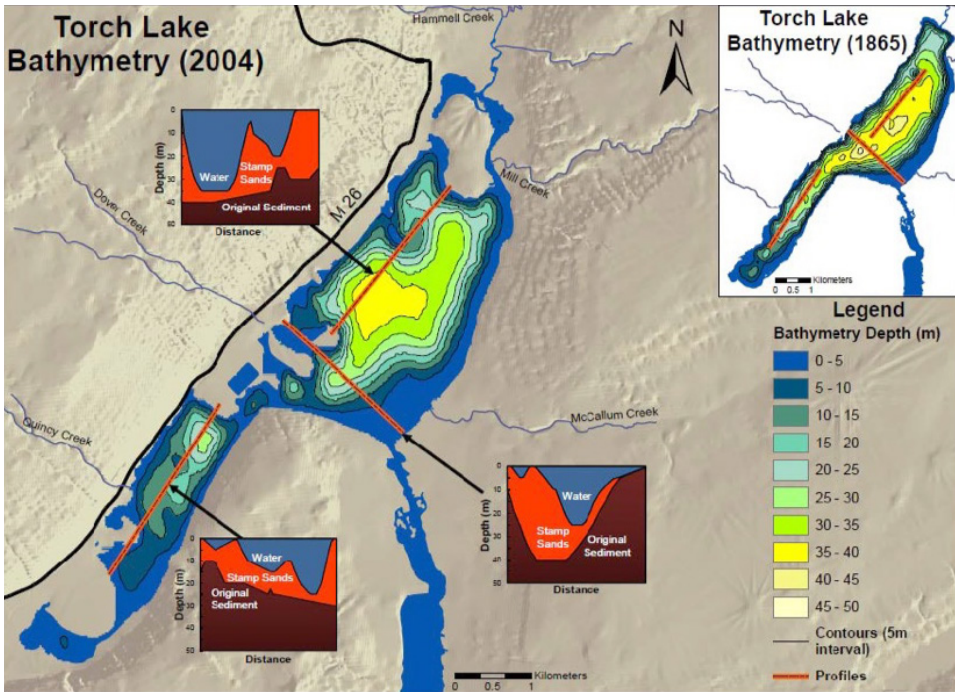
Michigan Dept. Environmental Quality and U.S. EPA data compared to Michigan Part 201 Residential Soil Direct Contact Criteria. Red stars indicate sampling sites where one or more of tested metals (As, Cd, Cr, Cu, Pb, Hg and Zn) were above the Part 201 criteria. Many areas of high metal concentrations were at industrial sites not addressed by the Superfund clean-up activities.

Superfund program was adequate for a remedial investigation (1988-1992) that led to a plan of action (Record of Decision, ROD) in 1992. However, it took six years before funds became available for remediation of stamp sands around Torch Lake (Operating Unit I). In the meantime, the sediments in the lake (OU II) were delisted without remediation. This meant that the lake itself and its sediments received little attention. Later, despite an influx of funds into the AOC program through the Legacy Act (2002) and Great Lakes Restoration Initiative (2010), the lack of an action plan (i.e., the lack of a remedial investigation within the AOC program) has rendered acquisition of these funds for Torch Lake unsuccessful to date.

A second impediment has been the narrow focus of all government agencies involved at Torch Lake, but notably of the Superfund and AOC programs, on a subset of the problems present in the lake. This is further complicated by the lack of any entity capable of integrating all efforts. During the Remedial Investigation of the Superfund program (1988-1992), a sampling design not informed by knowledge of historical industrial activities led to failure to identify many of the hazards present in the area, especially those at upland sites surrounding the numerous industrial facilities and residential communities. As a result, focus shifted from the entire industrial area and the contaminants associated with industrial activities to only hazards from airborne dust from the large stamp sand deposits on the lakeshore. This meant little or no attention was paid to the PCB-contamination of soil and lake water, high metal and asbestos contamination of soils around industrial facilities, deposition of toxic substances from smelter and boiler smoke stack plumes in residential soils, and the mercury release from mine discharges and tailings. The AOC's major focus on problems within the lake led to restricted efforts to determine the out-of-lake sources of materials (mercury, PCBs, copper) causing those problems as well as exclusion of other problems on land (e.g., soil contamination). Within both programs, the predominant focus on fish tumors as a potential human health threat was accompanied by

a failure to recognize the threat from mercury and PCBs despite documentation of the presence of these contaminants starting in the 1980s. Not until the update of the Remedial Action Plan (RAP) in 2007 did MDEQ formally conclude that the BUI associated with restriction on fish consumption should remain in place because of PCB contamination. It decided that mercury contamination was a regional problem, not specific to Torch Lake. The Michigan Department of Health and Human Services (MDHHS) did recognize the multiplicity of potential concerns, but it had no legal authority or funding to collect data to determine if the risks were significant. The Michigan Department of Environmental Quality Water Division (MDEQ) and U.S. Environmental Protection Agency (EPA) focused on the water quality violations associated with high copper and mercury concentrations in the tributaries, but did not work in conjunction with Superfund or AOC programs to ensure that remediation efforts would solve these problems. While the law governing Superfund does mandate some inter-agency coordination (Applicable or Relevant and Appropriate Requirements), it has been ineffective at this site.

A second issue arose from the focus of each remediation program on narrow, and different, subsets of the total program. The differences between the two programs eventually created confusion among citizens as to the types of problems created by mine processing waste, and further complicated citizen understanding as to what might be appropriate



Depth of stamp sands in Torch Lake. The original (1865) bathymetry of the lake (inset at upper right) shows a much larger area of deep water than the current (2004) bathymetry indicates. Both bathymetric maps are digitized reproductions of NOAA navigational charts. Comparison of the 1865 and 2004 bathymetries across specific transects of the lake are shown in the small insets; the difference in water depths between the two maps is colored in red and represents the thickness of stamp sand deposits within the lake. The north-south transect in the northern basin indicates that about 5 m of stamp sand underlay the deepest area of the lake. The transect running northwest to southeast indicates that nearly 40 m of stamp sands filled in this formerly deep area of the lake. Subtracting the 2004 lake volume from that in 1865 indicates that 50% of the lake was filled with stamp sands.

remedial solutions. This confusion and the complexity of problem definition and remediation has likely led to a diminishment of citizen involvement. The USEPA Superfund program focused on human health and ecological risk, whereas the AOC focus is on lake beneficial use impairments. Both programs require remediation to reduce or eliminate risks or use impairments before a site can be delisted. While there can be overlap between these two foci (e.g., the health effects behind the restrictions on fish consumption), they can also lead to different definitions of the problems at a site. At Torch Lake the Superfund program identified blowing stamp sands as the primary human health threat, and degradation of the benthic community as the primary ecological health problem. The AOC program, however, focused on restrictions on fish consumption (originally due to the presence of tumors in fish) and the degradation of the benthic community as the two major beneficial use impairments (BUIs). By creating differences in the definition of the contaminant problem at Torch Lake, progress toward remediation was limited. Superfund moneys were spent exclusively on capping and revegetating the sands. The AOC program witnessed little

progress in resolution of its defined problems due to lack of funding. From the view of local residents, it appeared that, with the more visible and active work on covering stamp sands and the eventual delisting of the Superfund site, all problems were resolved. This confusion persists today in the local population. The difference in problem definition has enabled much of the Superfund site to be delisted despite the persistence of two BUIs that the local residents are just now beginning to realize.

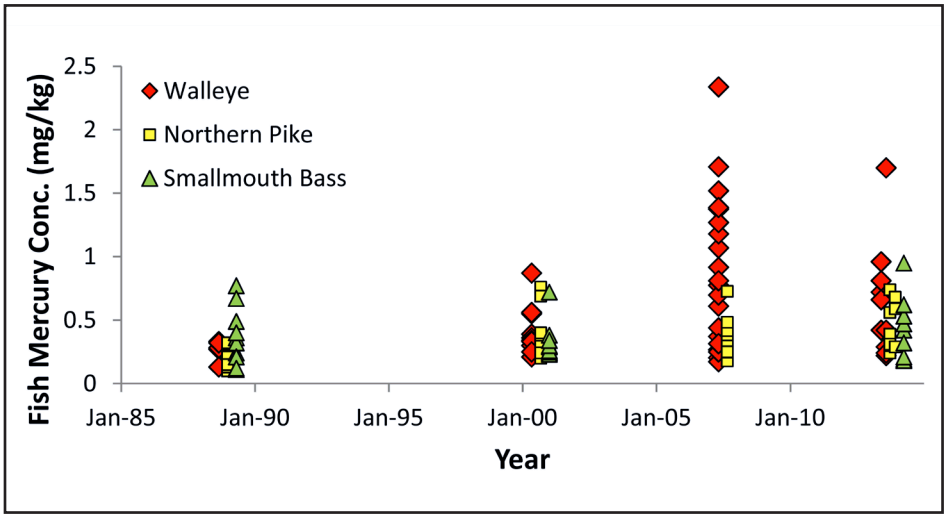
Third, from the outset, a polarization of viewpoints has existed with one party claiming that no serious problems exist and therefore advocating for immediate delisting of the site, and a second party advocating for more thorough investigation and remediation. These polarized parties have included government agencies (some of whose viewpoints have switched over time) and local groups of citizens. When Michigan Department of Natural Resources (MDNR) completed the first Torch Lake RAP in 1987, the tug of war began between MDNR who favored elimination of the AOC site and the EPA and IJC who advocated more study and eventual remediation. Eventually, EPA's progress in stamp sand remediation led to the delisting of Torch Lake from the National Priority List and the appearance that EPA work at the site was completed. However, upon transfer of operation and maintenance of remedial actions to the State of Michigan, the MDEQ recognized the existence of several critical remaining problems. As a result, since the early 2000's MDEQ has been an advocate for continued research and remediation at Torch Lake—a reversal of the early state position. Multiple emergency removals were conducted by EPA's Superfund Division after the delisting of portions of the Superfund site; these again raised questions in the public mind as to the safety of the site and the efficacy of the prior remediation. The changing positions of state and federal agencies over several decades and the illogical sequence of emergency clean-up after remediation was completed has confused the general public about the actual state of affairs, leading to the impression that different government units are polarized in their conclusions. From the government's perspective, the often vitriolic public criticism of remediation efforts or plans combined with other public calls for more thorough clean-up have left the impression that the local public is divided and lacks a clear vision for the lake's future.

Finally, a few conclusions reached early in the site investigation that may have been justified based on available knowledge at the time were never re-evaluated as new knowledge and tools became available. For instance, the enormity of the problem engendered a pessimistic attitude on the part of government officials from the outset. It resulted in no effort to remediate the lake sediments that would resolve the problem of degradation of the benthic community. The enormity of mining waste in the Keweenaw peninsula and the complexity of the pollution located at the mineral processing sites along Torch Lake made it difficult to characterize clearly the health and environmental hazards facing the region. Early signs of pessimism are found in AOC and Superfund documents. The 1987 RAP spoke of the impossibility of remediating the massive amounts of stamp sands (200 million metric tons) covering the entire lake bottom. The 1994 ROD for Superfund Operating Unit II (the lake sediments) picked up on this theme and used it as the reason for not evaluating alternatives for remediation. Self-recovery of the lake through natural sedimentation processes was proposed and viewed as the only feasible option, but it was never quantitatively evaluated. This pessimistic outlook created a force for inaction, became embedded within the remediation plan, and allowed the EPA to claim Superfund programmatic progress even in the absence of progress towards recovery of the ecosystem. In addition, because the "remediation" involved no action on the part of EPA to restore the benthic (sediment) community, the agency decided that no monitoring of the sediments for effectiveness (of inaction) is required.

Another early and erroneous conclusion was that fish contaminants were not from local sources. This conclusion led the DNR to advocate for removing the site from the AOC program in the early 1990s. Despite the development of analytical tools that can identify sources of PCBs, these were not applied in Torch Lake for 15 years after they became available. Tools (stable isotope analyses) are now available for identifying sources of mercury, but they have not yet been applied in Torch Lake. Similarly, devices (passive samplers) widely used for over 20 years to trace the sources

of contaminants have not yet been utilized for this purpose in Torch Lake. Mass balance modeling is a tool that has been used for identifying sources of contaminants since the 1980's, but it was never applied by government agencies at Torch Lake. The long duration of the remediation guarantees that knowledge and tools will evolve during that process. At least at Torch Lake, the two remediation programs seem to have repeatedly reiterated decisions made early in the process rather than continuing to apply the best tools available to re-evaluate early decisions.

The multiplicity of governmental agencies and nongovernmental groups working on Torch Lake is potentially bewildering, and without integration also can be an impediment to progress. Federal agencies include the U.S. EPA (Superfund program, AOC program), the Agency for Toxic Substances and Disease Registry (ATSDR) of the U.S. Dept. Health (health assessments required as part of Superfund), the Dept. of the Interior (National Park Service), the U.S. Geological Survey (hydrologic monitoring), and the National Oceanic and Atmospheric Administration (bathymetric mapping). State departments include the MDNR (fish stocking and assessment, contaminant monitoring); Michigan Dept. of Health and Human Services (contaminant monitoring, fish consumption advisories, public health assessments for ATSDR); the State Historical Preservation Office (SHPO); and multiple offices within the MDEQ including the Office of the Great Lakes (AOC program); the Superfund, Compliance and Enforcement, and Program Support sections of the MDEQ Remediation and Redevelopment Division (Superfund operation and maintenance, Part 201 compliance); and the MDEQ Water Division (Clean Water Act requirements). Each office or agency looks at their narrow legal mandates, and there is no requirement for integrated management at the site.



Mercury in Torch Lake fish has been high (> 0.3 mg/kg) since at least 1988. There is no evidence of a decline in mercury content in northern pike or smallmouth bass. Changes in mercury content of walleye likely result from fish community changes resulting from stocking.

The four points discussed above and the bewildering array of government entities involved have had a significant effect upon citizen engagement in the four-decade search for solutions at Torch Lake. Citizen involvement has varied over time. Citizens shifted from being substantially involved in monitoring research and early government actions toward general inattention and seeming disinterest. Local efforts, particularly in Lake Linden and Hubbell, drove the research and listing process in the 1970s and early 1980s. The official listing of Torch Lake as a Superfund site and AOC, while encouraging citizen engagement, seemed to dampen actual participation. The initiation of the Superfund process (hazard ranking and remedial investigation, 1985-1992) resulted in a one-way communication system where EPA assumed the role of educating the public on the problems present and the options for remediation, and local residents became less active and inattentive. Release of the Record of Decision (1992-1994) brought more interest and scrutiny to Superfund processes. Community response split into two diverging positions: some community members called for a "No Action" decision that would remove Superfund listing. Others called for a thorough remediation plan and more investigation. The founding of the Public Action Committee (PAC) for the AOC process (1997) marked a turning point in local engagement, as it allowed a local citizen's committee to work with both Superfund staff and the AOC program at Torch Lake. For the next 15 years, the PAC would be the face of the local citizenry to the government

agencies. In this time, the PAC was actively engaged in facilitating progress of the Superfund remediation. The prolonged process of delisting from the Superfund program (2002-present) that happened concurrently with the AOC program's push for further study of the causes of the BUIs led to confusion within the PAC and the local community as to what problems remained and what could be done about them. As this confusion was allayed, partly through the information dissemination by the IA team as well as by MDEQ's Abandoned Mine Waste Program, the PAC once again became active in seeking to clarify what actions could be taken to solve the remaining problems. The interaction of the PAC and the governmental agencies contained elements of mistrust and dislike of government "intrusion" into local affairs, but also an eagerness to solve the contamination problems so that local communities could safely develop and use their resources.

PROBLEMS THAT REMAIN AT TORCH LAKE

Several problems with ore processing wastes still remain at Torch Lake that have not been resolved by either the Superfund or the AOC programs. They pose risks to both human and environmental health. There remain two Beneficial Use Impairments under the AOC listing that should be addressed. Further, there is evidence of contamination in locations on the shoreline and in sediments along the water's edge that have surfaced and need remediation.

1. Fish Contamination.

Although the fish tumors reported between 1970 and 1986 have disappeared because the causative agent likely disappeared, issues of fish contamination remain in Torch Lake. The Beneficial Use Impairment related to fish tumors under the AOC program was removed in 2007. However, re-evaluation of evidence of high levels of mercury and PCBs in the fish prompted fish consumption advisories in 1993 (mercury) and 1998 (PCBs) that still persist today. The BUI related to restrictions on fish consumption remains in effect today. The Superfund program never responded to the evidence evaluated in their early risk assessment for local sources of mercury and PCBs. This report assembles all monitoring records by EPA, MDEQ, and MDNR and discusses the history surrounding the identification of PCBs and mercury contamination. We conclude that contrary to MDNR assessments which argue for a decline in concentrations of PCBs and mercury in Torch Lake since the 1980s, that in fact there is evidence of increased concentrations in Torch Lake fish. This report provides a thorough historical comparison of fish consumption advisories in Torch Lake and its control sites, and demonstrates that consumption advisories for both contaminants in fish have consistently been stricter in Torch Lake than in the control sites. As a result, we argue that there is no basis at present for removal of this BUI. In fact, mass balances for both substances point to continued local inputs of mercury and PCBs to Torch Lake that were caused, indirectly, by mining. Archival research on industrial buildings and processing practices documents the sites where PCBs were used in electrical transformers. The types of PCBs present as well as mass balance calculations clearly point to ongoing inputs of locally-derived PCBs. Similarly, mass balance calculations suggest that mercury inputs from mine drainage, uncovered over a decade ago by the MDEQ, may contribute significantly to the total input to Torch Lake. Identification of these local sources is a prerequisite for clean-up and ultimate removal of the second BUI associated with fish consumption restrictions.

2. Benthic Community.

Similarly, there is little evidence of an improvement in the condition of the benthic community, and hence this AOC BUI still persists in the lake. A surprising finding of this Integrated Assessment was that there has been no effective monitoring of the benthic community; only four historical benthic surveys were identified over the past 45 years, and no two visited the same sites or used the same protocols. In contrast, the toxicity of the sediments has been thoroughly established. Toxicity to macroinvertebrates, bacteria, fish, and zooplankton has been shown. Toxicity to fish eggs and effects of the sediments on spawning success have not been adequately evaluated. While trends in benthic populations have not been monitored, the combination of mapping of the extensive historical measurements of copper in the lake sediments, recent studies showing high copper concentrations in near-surface sediments, and the

extensive toxicity testing of the lake sediments give little reason to expect improvement in the benthic community.

An impediment to action in the AOC program has been the uncertainty regarding the source of metals in the sediments. To what extent are metals eroding from shoreline sites, being brought in by tributaries from the catchment, or diffusing upwards from the massive stamp sand deposits in the lake? This project reviewed the available evidence and concluded that the sediments within the lake are the largest source. Sediment traps placed throughout the lake clearly showed that erosion of shoreline material was not responsible for high copper concentrations in recent sediments. Tributary monitoring, while sporadic, does not indicate that the catchment is the major source. Sediment cores along a transect from the eastern shore to the center of the lake showed profiles that would be created by upward movement of metals in the sediment porewaters. The cores also revealed very slow rates of accumulation of new sediments, and suggested that hundreds of years might be required for copper toxicity in the sediments to be naturally attenuated. Despite this recent evidence, the EPA has dropped its requirement for continued monitoring of sediments and benthic organisms. The sentiment expressed in the 1987 Remedial Action Plan that sediment contamination in this lake is a problem too big to remediate prevented any assessment of remedial alternatives. This report suggests that alternatives worth evaluating do exist.

Underwater photograph of marine debris in Torch Lake. A white sucker (*Catostomus commersonii*) is shown adjacent to a corroded metal barrel in this photograph taken with Michigan Tech's Remotely Operated Vehicle (ROV) in 2014.

3. Problems outside AOC scope and never addressed by Superfund.

The Integrated Assessment provides a cursory examination of a variety of problems that have received little attention during 35 years of remediation. Not all of these problems lie within the purview of the AOC program, yet were never fully investigated or were ignored by the Superfund program. They include contamination of soils, sediments, and water in and surrounding Torch Lake. These problems include:

- Widespread soil contamination from airborne contaminants released from the numerous industrial smokestacks;
- Deposits of metal-rich sludges such as found in 2007 at the Lake Linden beach;
- Other waste streams (coal ash, slag) and contaminants (arsenic, PAHs) that were never adequately characterized;
- Concentrations of several trace metals in lake water above the state's water quality criteria;
- Physical hazards from derelict buildings, machinery and refuse;
- Contamination in Boston Pond and Calumet Lake – the latter drains into Torch Lake and the former is included in the larger Superfund area;
- An abundance of marine debris on the bottom of Torch Lake including 800 barrels, some of which may contain industrial wastes;
- Sections of the lake at both the north and south ends that were isolated from the rest of the lake by stamp sands such that water quality, habitat quality and aesthetics have been impaired.

Beached remains of Quincy Dredge #2, Mason, Michigan. Photograph by Todd Marsee,

CONCLUSIONS

The Integrated Assessment indicates that the prolonged time required for remediation at this site has resulted from failure to consider the historical record, programmatic issues within government agencies, and the inability of a local group of stakeholders to coalesce and remain engaged in the remediation process. The Integrated Assessment illustrates how an understanding of historical activities can help to explain (and to predict) what wastes are present and where they are most likely to be located. Remediation of a complex site such as Torch Lake would benefit from an initial investigation of historical industrial activities. Review of the remediation history at this site identified several programmatic obstacles that have hindered progress including lack of funding, too narrow definitions of the problems, and failure to continue to use new tools and knowledge to evaluate what could be done. While the multitude of agencies involved at the site could have resulted in a diversity of viewpoints and options being considered, that did not occur here in part because only one agency at a time had funding for supporting site investigation. A clearer mandate for inter-agency cooperation and integration of effort might have helped both to provide diversity of ideas and to promote use of new knowledge and tools. Public engagement varied considerably over time in response to the clarity of information available, the changing perceptions as to whether the problem was solved, and the degree to which such engagement was promoted by the agencies. Public engagement was instrumental in drawing attention to this site initially, but waned once government programs assumed control. The history of public engagement suggests that involvement of a diverse group of local stakeholders could play an invaluable role in achieving remediation and help to circumvent some of the agencies' limitations.

Photograph of last standing steam stamp at the remains of the Ahmeek stamp mill in Tamarack City. (1990).

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