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Coming Clean and Green: A Geospatial Mapping Tool for Visualizing Industrial Environmental Performance

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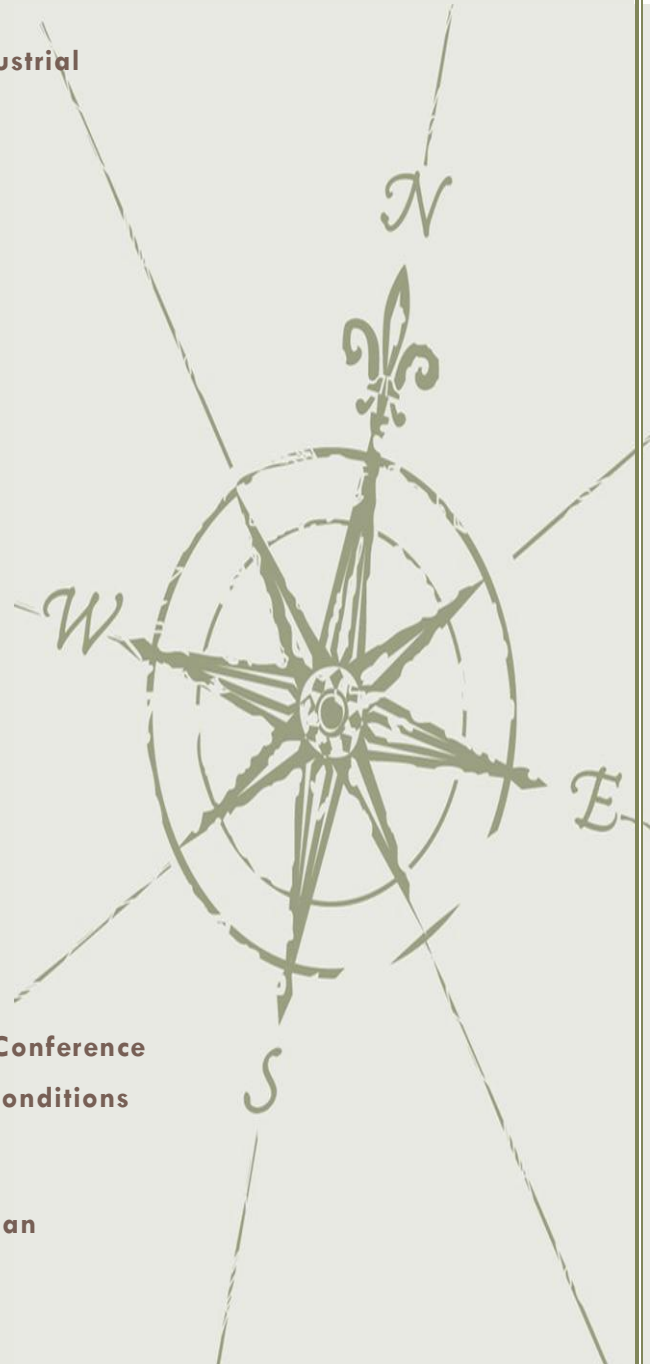
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Mapping clean and green

A geospatial mapping tool for visualizing industrial environmental performance

Research presented at the 2012 National Training Conference on the Toxics Release Inventory and Environmental Conditions in Communities

Jacob Lesser, Troy D. Abel, and Mark Stephan

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Active Minds Changing Lives

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1. ABSTRACT

The mapping of environmental data is rapidly expanding as advocates and scholars offer various platforms to display and analyze geographic environmental information. This working paper describes an online web map that displays national data from the Toxic Release Inventory (TRI), Environmental Systems Research Institute's (ESRI) ArcGIS Server platform, the Environmental Protection Agency's (EPA) Risk Screening Environmental Indicators (RSEI), and methodologies from Kraft, Stephan, and Abel (2011) to spatially display the environmental performance of more than 17,000 manufacturing facilities.

www.wwu.edu/huxley/spatial/maps/tri

The web map is supported by an online database and provides its audience with the ability to visualize facility performance over time, to individually search addresses, and display a toxic release inventory of a spatial selection for different years. TRI facilities are depicted as circles with colors that correlate to a rating system that can be accessed through the map key. Smaller circles indicate fewer pounds released; larger circles indicate more pounds released. Lighter circles represent polluters who are posing less risk to their neighbors. Users are also able to access an attribute table containing the facility name, parent company, location, identification number, pounds of toxics produced, and finally their RSEI relative risk score.

The use of color and size contrasts presents the EPA data in a way that is more accessible to an audience that may not be familiar with TRI data. Moreover, a time scale function allows viewers to perform a trend analysis between the years 1996 and 2007. The change of colors and sizes reflect increases or decreases in performance so the viewer will be able to see if a certain facility has been getting better or worse over time, or, if their neighboring industrial plants are getting safer and cleaner.

2. INTRODUCTION

Twenty five years ago, Congress passed the Emergency Planning and Community Right-to-Know Act (EPRCA) that required thousands of industrial facilities to reveal what toxic chemicals they manufactured, used in their operations, and then disposed into the environment. This 1986 legislation came two years after the world's worst industrial accident in Bhopal, India. Hundreds of thousands of nearby residents were exposed to the highly toxic chemical methyl isocyanate when a Union Carbide pesticide manufacturing plant experienced a massive leak.

The poisonous plume killed over 3,000 people on the night of December 2, 1984 while harming a 100,000 more. Many estimates put the Bhopal disaster's death toll over the following month at 15,000 while it is widely described as affecting more than 500,000 people. The disaster's aftermath lingers decades later with hundreds of tons of hazardous waste remaining at the site, high levels of pesticide residues in neighborhood wells, and a variety of chronic health problems linked to the plant's toxic emissions (Crabb 2004; Sengupta 2008).

People around the world were shocked by the Bhopal disaster and alarmed that industrial facilities could pose such risks to nearby communities and their residents. Chemical industry advocates told the U.S. Congress that the risk of a Bhopal disaster was very low. Yet one year later at factory in the town of Institute, West Virginia, a similar but smaller leak occurred.

In 1989, a report to EPA identified seventeen Bhopal-level disasters over the previous 25 years with releases in volume and toxicity equal to or exceeding the 1984 disaster. Between 1982 and 1989, according to the report, 11,048 U.S. toxic chemical
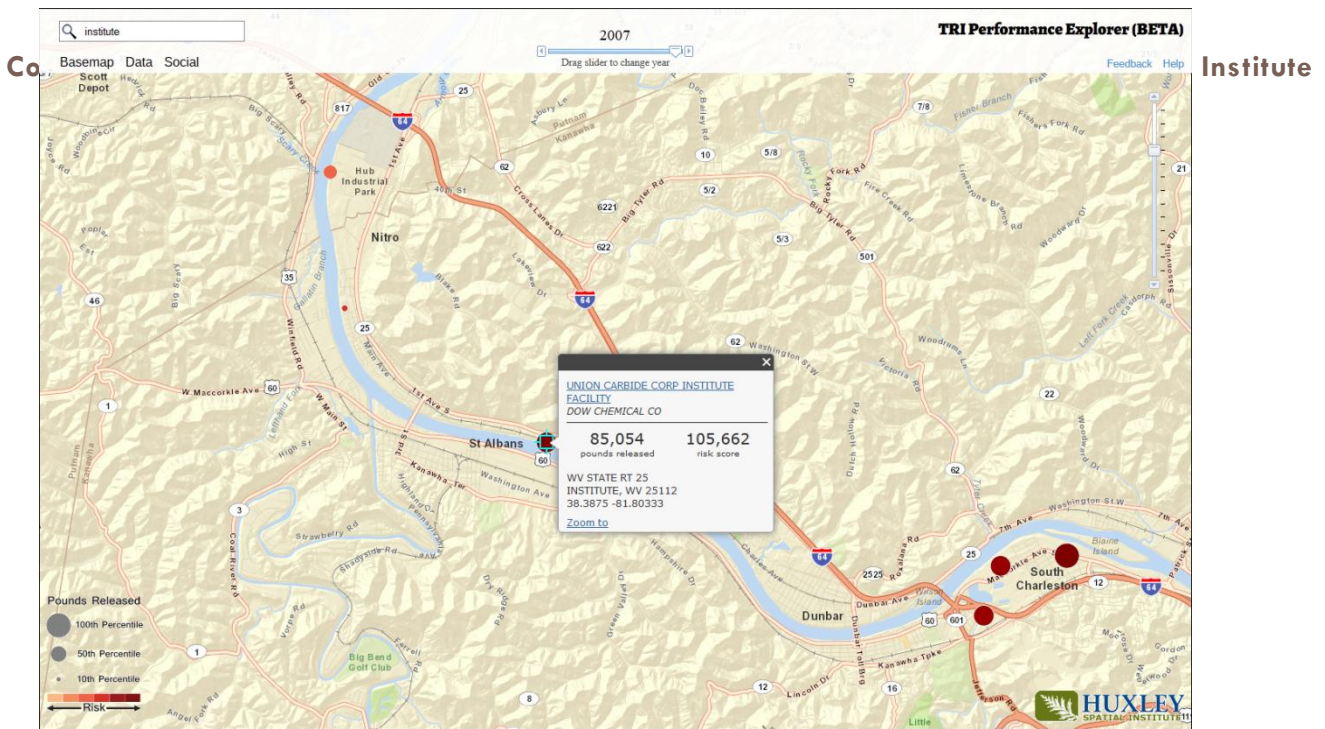
MAP 1. TRI FACILITIES IN 2007 NEAR INSTITUTE, WV.

accidents resulted in 11,341 injuries and 309 deaths (Shebecoff 1989).

2.1.   RIGHT-TO-KNOW

In the decade before the Bhopal and Institute West Virginia disasters, a push had begun for chemical right-to-know laws and by 1980, Connecticut, New York, Michigan, Maine, and California had enacted information disclosure requirements on industry to give workers -- and sometimes communities -- access to chemical releases at local manufacturing facilities. Philadelphia adopted one of the first right-to-know laws in 1981 followed by several cities in California and Cincinnati in 1982. Seventeen states and sixteen municipalities had similar laws by 1984 and by mid-1985, twenty-eight states had them (Hadden 1989; Kriz 1988). The push for the right-to-know about environmental pollution and other hazards was shaped as well by broader social forces changing the public expectations for business and governmental decision making (Eisner, Worsham, and Ringquist 2006; Hamilton 2005; Harris and Milkis 1996).

Within three months of the Bhopal disaster, several Congressional bills merged into the Superfund Amendments and Reauthorization Act (SARA) of 1984, with its new Title III, the Emergency Planning and Community Right to Know Act (EPCRA), and the new Toxics Release Inventory (TRI) program. As one observer put it, "The Bhopal train was leaving the station, and we got the kind of legislation we could put on the train" (Kriz 1988, 3008). Unable to ignore the right-to-know momentum, President Reagan signed SARA in 1986. The next year, EPCRA authorized the EPA to begin requiring companies to report the release and transfer of toxic waste from a list of priority chemicals that posed risks of acute human toxicity, chronic human toxicity, and environmental toxicity ". . . at concentration levels that are reasonably likely to exist beyond facility site boundaries as a result of continuous, or frequently recurring, releases" (EPCRA 1986).

Over the years, the EPA has added new chemicals to an original list of 300, bringing the total registry to more than 650 pollutants. The normative argument for information disclosure policies like the TRI is rooted in ideas about the public's right to access certain information and the government's responsibility to ensure the information is available so that citizens can make sensible choices. In fact, the

lack of sufficient information to foster competition or to allow consumers to make appropriate choices represents a classic market failure. Requirements for information disclosure also may be seen as essential to justice in a democratic society which requires that people be

> A third way of environmental governance would become a critical response to administrative rationalism and the concentration of environmental policy power at the national level or in subnational government agencies.

aware of the potential harms to their personal security, including their health and well-being (Stern and Fineberg 1996).

The public's right-to-know in our representative democracy can be traced to concepts in the nation's founding ideals that average citizens are entitled to know what their elected leaders are doing on their behalf. Later, and at the same time that the nation's major environmental policies were being created, public expectations grew not only for a more open and accountable government (Gormley and Balla 2008; Williams and Matheny 1995), but also for any information that a particular organization or economic sector might have a moral responsibility to share. Information disclosure, as a form of public policy, also can be understood to be what Schneider and Ingram (1997) called a capacity-building tool. By informing or enlightening people, it acts as a partial step towards empowering people to act through democratic processes.

TRI's moment in the history of environmental policy's evolution came near the end of two decades of institutional and political development. The first decade, or "epoch" of regulatory policy (Mazmanian and Kraft 1999) involved the establishment of environmental policy as a national priority in the U.S. and a series of "command-and-control" regulations (Marcus 1980, Melnick 1983, Reagen 1987). Some of the main features included a focus on human health and margin-of-safety analysis, technology forcing

standards to control end-of-the-pipe pollution, and centralized federalism. Or, as one recent appraisal put it, the initial environmental regulations were widely viewed as "heavily bureaucratic, prescriptive, fragmented in purpose, and adversarial in nature" (Durant, Fiorino, and O'Leary, 2004, 1). However, a decade of experience within this system and the emergence of new issues led to growing pressures for change (Vig and Kraft 1984).

A second epoch saw many developments towards the emphasis of either economic or risk analysis (NRC 1983; Russell & Gruber 1987; Smith 1984; Swartzman Liroff & Croke 1982). One of the notable institutional challenges faced by management at the EPA was its lack of an organic act and multiple laws pulling the agency in many directions. Moreover, vague and even conflicting legislative language resulted in multiple definitions of acceptable risks and different considerations of costs and benefits. These ambiguities spurred efforts in the executive branch to establish control over a seemingly irrational regulatory system.

In 1981, President Reagan issued Executive Order 12291 that required the Cost-Benefit Analysis (CBA) of all regulations expected to have an annual economic impact of at least 10 million dollars, raise prices, or adversely affect competitiveness (Reagan 1981). Three years later, the EPA administrator declared that risk assessment and risk management would become a primary decision making framework for the agency (EPA 1984). Both economic and risk assessment were attempts to bring a common denominator to decision making in a fragmented and adversarial environmental policy regime.

However, below this current of technocratic and rationalizing policy reforms, crosscurrents of

democratic impulses were swirling. "Beginning in the 1980s," according to Sirianni and Friedland (1995), "more participatory alternatives to top-down environmental regulation and the public lobby model of formal citizen participation . . . started to emerge in the United States" (5). The TRI's arrival in 1987 helped amplify this democratic turn away from the centralized and commanding or the technocratic and rationalizing ways of the EPA. A third way of environmental governance would become a critical response to administrative rationalism and the concentration of environmental policy power at the national level or in subnational government agencies. The resisting discourse echoed a communitarian tone and emanated from the local level. "Communitarian thought suggests ... a common public interest can be discovered if an enlightened citizenry governs directly in its own behalf" (Williams and Matheny 1995, 27). Dissatisfaction with the centralization of power led to the emergence of hundreds of locally led environmental initiatives. Several researchers call this approach civic environmentalism (John 1994; Knopman, Susman, & Landy 1999; Shutkin 2000; Sirianni & Friedland 2001).

These democratic environmental impulses strengthened across states and localities during the nineties–environmental policy's third epoch. In this period, John (1993) asserted that policy developments were progressing more in the states and communities than at the national level. He noted a doubling of state expenditures in natural resource and environmental programs since 1986 and how cases of innovation in pollution prevention, ecosystem protection, and energy conservation emerged in the states. This new environmental federalism also stimulated the attention of both scholars and practitioners (Adler 1998; Anderson & Hill 1997; NAPA 1995). In addition to the devolution of policy-making responsibility from the federal government to state and local jurisdictions, there also have been expositions on attempts to increase the influence of

citizens in environmental decisions (Abel and Stephan 2000; Layzer 2002).

At the end of the Clinton presidency, the civic environmental impulse briefly ascended to national prominence when the EPA (2000) released a draft public involvement policy aiming to enhance early and meaningful public participation and techniques to foster it in environmental decision making. Expanding environmental decision making involvement even received support at the beginning of the Bush administration. New EPA administrator Christine Todd Whitman (2001) proclaimed that the agency would ". . . launch a new era of cooperation among all stakeholders in environmental protection." She would also describe another policy priority: "We will use strong science. Scientific analysis should drive policy." Thus, U.S. environmental policy in the 1990s seemed to simultaneously emphasize more public access in decision making and scientific analysis. "But," as Abel and Stephan (2008) asked, "do these concurrent means–participation of citizens and use of technical expertise–amount to an irreconcilable tradeoff" (152)? Or, as Foreman (1998) put it, "Perhaps the most interesting and important question facing environmental scholars and policymakers as we approach the new century is how, if at all, we might achieve a more satisfying and durable blend of the technical and democratic demands that weigh so heavily on environmental policy making" (59).

Numerous researchers (Cline & Lamb 2005; Press 1994; White & Hall 2006) have applied a great deal of attention to this very tension, or what some called a "technical information quandary" (Pierce and Lovrich 1986). Likewise, a rationalizing and democratizing dissonance also echoed across the field of geography during the 1990s as the technology of Geographic Information Systems (GIS) accelerated in use.

Table 1. Terminology for the Democratization of Cartography

Cartography 2.0	Digital map design, collaboration, and access via the Web.
Citizen sensors	Spatial data collection enhanced by non-expert collaborators.
Mashup	Web-based mapping applications that mix data from two or more sources and facilitates cartographic visualization and communication.
Metadata	Data about geographic data such as descriptions about what the data represent, how the data was collected, who collected and distributed the data, the data's timestamp, and information to display the data in a coordinate system and projection.
Neogeography	The growth of non-expert geography applications, techniques, and data made available via the Web.
Open source	Software designed and developed to be freely distributed and customized by new users.
Web 2.0	Web design that enhances online data exchange, collaboration, and more equitable levels of access and participation.

2.2. DEMOCRATIC GIS

In the fall of 1993, a debate between human geographers and geographic information scientists became the focus of meetings held in Friday Harbor, Washington. These meetings became widely known as the beginning of the geography field's discussion over GIS and Society (Gatrell 1997; Nyerges, McMaster & Couclelis 2011; Pickles 2006; Sheppard et al. 1999). The beginning exchanges between human geographers and their GIS counterparts involved debates around the field's future emphasis between the technical or social. This debate, and the one in environmental policy discussed above, could be seen, as Schuurman (2000) observed, ". . . part of a broader negotiation over the value and meaning of science and technology and their relationship to the culture in which they are embedded" (571).

In one summary (Jordan et al. 2011), the democratizing turn in geography involves an array of shifts (See Table 1 above). Defined as Public Participation Geographic Information Systems (PPGIS) by one (Sieber 2006), participatory GIS (Elwood 2006) by another, and community-orientated GIS (Harris & Weiner 1998) by a third perspective; geographers faced a similar "democracy-technocracy quandary" (Steel 2000) as their counterparts in environmental science and policy. In particular, cartographers faced a challenge of doing maps with increasingly sophisticated GIS tools while simultaneously increasing transparency for, and participation by the public. On the one hand, tools like Google Earth, Wikimapia, and OpenStreetMap can be used by amateurs to produce and distribute maps that address community concerns like environmental injustice (Maantay 2002). On the other hand, "Much

of Web 2.0 is without formal metadata, or documentation about the data. Metadata should document the accuracy, authorship, and timestamp of the geospatial data" (Jordan et al. 2011, 158).

For instance, Goodchild has described several errors in Google Earth (Goodchild 2007; Schuurman 2009). Rather than take sides, several researchers instead advocate an amateur-expert alliance in efforts where GIS becomes a mediating tool for the multi-disciplinary sharing of data, knowledge, and expertise (Jordan et al. 2011; Joyce 2009). We share this perspective and designed this web mapping tool in the spirit of blending rationalizing and democratizing elements that represents a kind of "civic" cartography. We also hope that our geospatial design will help address another challenge for toxic disclosure programs: the dilemma of fostering industrial environmental performance.

3. INDUSTRIAL ENVIRONMENTAL PERFORMANCE AND INFORMATION USE

In what has become a rite of spring for environmental journalism, the United State Environmental Protection Agency (EPA) each year publishes a report of the latest data from the Toxics Release Inventory (TRI). The TRI is EPA's most well-known information disclosure program. As the data are made available, one sees a flurry of media reports that disseminate to the wider public some basic information about the nature of toxics releases. In one of the earliest release dates for the TRI program, the EPA published the 2010 national analysis on January 5, 2012. For the first time in history, the TRI recorded a double digit increase in emissions, or 16 percent more pollution than the previous year. This increase occurred despite a drop in reporting facilities of two percent. In Massachusetts, 441 TRI facilities reported a drop of 1.12 million pounds since 2009 in an

analysis by the Fitchburg city paper, the *Sentinel & Enterprise*. But in Maine, industry reported a 13 percent increase in pollution or 1.1 million pounds more than the year before (Miller 2012).

What often gets overlooked in the reporting of national summary data is that states and even facilities can vary widely in their changes from year to year. In fact, the fundamental idea behind the TRI is that requiring facilities to submit annual reports of their toxic release into the environment will stimulate efforts by companies to substantially reduce their pollution. A kind of "shock-or-shame" theory is fundamental to this presumption where one of two things may happen (Stephan 2002). On the one hand, citizens or other political actors may act to pressure the pollution output of industry when new information shocks them and reinforces concerns or fears about the risk of exposure to pollutants. On the other hand, companies may improve their environmental performance because they worry about the negative attention they may receive due to being listed as a bad performer. However, the nature of the information is critical.

If information is new and surprising, then citizens or political actors may be motivated to participate in environmental politics or policy. Once the information loses its newness in these cases, theory suggests that political actors would be less likely to be influenced by the continued provision of information. One might expect that a steady stream of information would desensitize political actors, unless there were dramatic changes in the data that suggested the need for increased attention. In fact, the structure of TRI data is essentially unchanged from the program's inception twenty-five years ago. As Kraft, Stephan, and Abel (2011) concluded, ". . . it is clear that the kind of information the TRI provides would be more useful to facility managers, public officials, and citizens if it could be presented in ways that better clarify relative public health risks and are more easily

understood, particularly for nonprofessionals at the community level" (186). In that vein, these researchers suggested a framework for illuminating the environmental performance of facilities over time. Providing the data by facility in pounds of releases has become a less meaningful metric to most citizens.

Since its inception, the TRI's skeptics have criticized its self-reported nature and many other problems with the information disclosed in the inventory. For instance, annual public releases until 2012 have lacked any risk characterizations that would allow a comparison of various toxic releases or the relative hazard of different facilities. In fact, EPA documentation on using the TRI begins by telling potential users that the database's chemicals can vary widely in their toxic effects. One's perception of and attention to high-volume releases may be misdirected when more toxic chemicals are being released at lower volumes (U.S. EPA 2002b). We avoided this limitation by utilizing the EPA's Risk Screening Environmental Indicators (RSEI) software program version 2.3.0 to characterize the relative risk of TRI facilities by air emissions. Moreover, Abel, Stephan and Kraft (2007), consider facility by facility changes in risk over time as one dimension of environmental performance. The second dimension captures the direction of a facility's performance by its change in release volume.

Together, changes in risk and releases were used to fashion a 2 x 2 matrix with directional increases and decreases coinciding or diverging into four kinds of industrial environmental performance in toxic pollution trends. When both releases and risk levels decrease; a facility becomes safer and cleaner and could be classified with a greening performance. In a second category of performance were blue facilities who reduced risk but increased release volumes (i.e., safer but dirtier). Yellow facilities populated a third category of performance by decreasing release levels to get cleaner but increasing their relative risk. In the

fourth category of performance, brown facilities became riskier and dirtier. Table 2 replicates the environmental performance characterizations for industrial facilities from Abel, Stephan, and Kraft (2007) for 1991-1995 using the latest version of RSEI (3.2.0) and adds data from 1996, 2000, and 2007.

Between 1991 and 1995, facilities decreasing releases outnumbered those increasing pollution levels by eight percent (54 to 46 percent respectively) while a nearly equal number of facilities decreased risk as those that increased risk (Table 2 above). These results suggest that the TRI program is perhaps not as successful as many have assumed it to be. Green facilities outnumbered brown facilities by only four percent. The remaining 20 percent of facilities fall into the interesting hybrid categories where release and risk performance move in opposite directions. As described in earlier work (Kraft et al. 2011):

The ". . . achievements and benefits of the TRI program are by no means uniform. They vary considerably across industrial sectors, states, communities, and individual facilities. . . The EPA and independent analysts have focused on the aggregate trends across all manufacturing industries, a practice that tends to give a misleading picture of how facilities are performing" (182).

For instance, the yellow category of our performance characterization demonstrates how substantial decreases in overall emissions can occur at the same time that facilities are increasing risk. Any new TRI presentation must help viewers take this variation into account and our mapping tool provides one kind of approach to display facility by facility performance trajectories. Above, two tables display the environmental performance of those facilities reporting in 1996, 2000, and 2001. We also omitted facilities in the bottom deciles of both risk and release to concentrate on the more significant producers of toxic pollution. From 1996 to 2000, the gaps among different levels of aggregate facility performance widened.

Table 2. Industrial environmental performance for TRI facilities.
Adapted from Abel, Stephan, & Kraft (2007).

Risk	Releases		1991 - 1995
	Increasing	Decreasing	Total
Decreasing	972 (8%)	5,095 (42.1%)	6,067 (50.1%)
Increasing	4,604 (38%)	1,447 (11.9%)	6,051 (49.9%)
Total	5,576 (46%)	6,543 (54%)	12,118

Risk	Releases		1996 - 2000
	Increasing	Decreasing	Total
Decreasing	535 (8%)	2,982 (46%)	3,517 (54%)
Increasing	1,982 (30%)	1,043 (16%)	3,025 (46%)
Total	2,517 (38%)	4,025 (62%)	6,542

Risk	Releases		
	Increasing	Decreasing	Total
Decreasing	521 (8%)	3,175 (48%)	2001 - 2007 3,696 (56%)
Increasing	1,907 (29%)	972 (15%)	2,879 (43%)
Total	2,428 (37%)	4,147 (63%)	6,575

The percentage of facilities in the five years between 1996 and 2000 getting dirtier and riskier (Brown TRIs) dropped by eight percent while greening facilities increased by four percent. Therefore, the gap between facilities in the different release performance categories increased to 16 percent; a fourfold increase from the first five years considered by Abel, Stephan, and Kraft (2007).

The most dramatic shift is discernible on releases alone, or the column totals. The difference between facilities reducing versus increasing releases in this second time period was 24 percent (Table 2 above). Conversely, there was only an eight percent gap between facilities getting safer and those getting riskier. In the next seven years, the gaps changed far less dramatically; 26 percent between release reducers and increasers and 13 percent between risk reducers and increasers. These results beg this question: Why such a divergence between pollution volume performance and risk reductions? We speculate that the greater progress in release reductions are a function of what Fiorino (2004) described as the "compliance imperative." Since facilities are required to report their releases and their volumes are disseminated annually in EPA documents and websites, environmental managers focus on improving the publicly disclosed information. The business adage, "You manage what you measure," would apply. But more broadly, these results also are consistent with Kraft, Stephan, and Abel's (2011) "performance dilemma" described next.

3.1. ENVIRONMENTAL PERFORMANCE DILEMMAS

Table three below lays out a simple heuristic that we use to better understand the dilemma that facilities and governments (federal or state) face in the area of industrial pollution management. The heuristic is grounded in the classic Prisoner's Dilemma (Rapoport and Chammah 1965), filtered through the subsequent work of Scholz's (1991) "enforcement" dilemma and Potoski and Prakash's (2004) "regulation" dilemma. Governments have two basic choices (though one can think of these on a continuum as well): focus on compliance or encourage facilities to go beyond simple compliance.

In much the same way, facilities can either meet the letter of the law or work to go beyond minimal requirements. Simply put, without outside pressures to change the payoff structure, the equilibrium position leads to less preferred outcome. The first number in each box represents the payoff for government and the second number represents the payoff for the facility. The payoffs are consistent with standard restrictions placed upon prisoner's dilemmas (Scholz 1991, 118).

No matter which approach government chooses, facilities are better off complying: $b > f$ and $d > h$. Likewise, regardless of facility behavior, government is always better off commanding: $c > a$ and $g > e$. To break out, regulators need to offer facilities benefits for superior environmental performance. One step is the creation of a mapping tool that allows users to view facility performance over time as we describe below.

Annual reports on volume and national or even state trends fall short. The performance dilemma implies that government and facilities will stick with the status quo of command-and-control rather than pushing beyond compliance. Our belief is that our mapping tool, which also includes risk performance, could serve to motivate the policy actors to reach for performance synergy. Progress towards the greening of industry is much more likely when the focus is on the ceiling of performance rather than the floor.

The performance dilemma serves as a valuable heuristic but oversimplifies what theory would predict about the influence of multiple factors (including information disclosure policies).

Table 3. Environmental Performance Dilemmas.
Adapted from Kraft, Stephan, & Abel (2011).

Government	Compliance	Facility Beyond Compliance
Encouraging	1,5 (a,b)	4,4 (e,f)
Commanding	2,2 (c,d)	5,1 (g,h)

Governments and facilities are enmeshed in a network that includes legislatures, interest groups, and citizens. The performance dilemma occurs within the context of a series of principal-agent games (see Scholz (1991) for his argument about "enforcement dilemmas"). In the real world facilities will appear in any of the four boxes in the table. As Kraft, Abel, and Stephan (2011) observe in their book:

"In cases where governments focus on encouraging facilities, but facilities focus solely on compliance, the actions of governments can be seen as weakly cheering on facility behavior while facilities themselves do just enough to meet legal requirements. When both governments and facilities focus on minimal standards, performance itself does not exceed threshold expectations. Facilities that reach beyond compliance without governmental encouragement may get a pat on the back, but no other credit is forthcoming. Finally, when both governments and facilities focus on increasing performance, the rules and regulations set only a baseline to strongly surpass" (47).

However, as Table 2 and 3 demonstrate, the dilemma is not inevitably tragic. Many facilities get safer and cleaner but risk performance lags behind volume performance. Why? We hypothesize that because the TRI has traditionally disclosed only volume information, facilities have acted accordingly. They reduce what's reported or "manage what is measured." Therefore, we have produced a geospatial tool that allows viewers to see not only the relative size of a facility's pollution emissions, but also a color representation of their relative risk.

4. DATA AND METHODS

We developed a cartographic system that allows viewers to quickly see clusters of facilities creating higher risk and volume where limited monitoring, inspection, and pollution prevention resources could be directed. We also joined the few studies (Abel 2008, Abel and White 2011, Ash and Fetter 2004, Downey 2007, Sadd et al. 2011, Shapiro 2005; Sicotte and Swanson 2007) that utilized a new exposure risk-characterization model developed by EPA's Office of Pollution Prevention and Toxics (OPPT). The Risk Screening Environmental Indicators (RSEI) tool contains records of multiple chemical releases from TRI facilities. The model accounts for local meteorology and simulates a facility' toxic air release dispersion and concentrations to produce a

comparative risk characterization of different air pollution sources (Schmidt 2003).

RSEI uses reported toxic chemical release volumes from each TRI facility as inputs into a steady-state Gaussian plume model. It then simulates downwind air pollutant concentrations from a stack or fugitive source as a function of facility-specific parameters (stack height, exit gas velocity), local meteorology, and chemical-specific dispersion and decay rates. These factors are then overlaid on demographic data taken from the U.S. Census to produce a surrogate dose estimate for the surrounding population. The final product of applying the RSEI model is an indicator value that represents a risk characterization where users can discern and compare the relative hazard being produced by different facilities.

A facility is classified as a TRI source if it conducts manufacturing operations within Standard Industrial Classification codes 20 through 39 (with a broader set of categories applicable after 1998, such as metal mining, coal mining, and electric utilities that burn coal); has ten or more full-time employees; and manufactures or processes more than 25,000 pounds or otherwise uses more than 10,000 pounds of any listed chemical during the year. TRI facilities are required to report annually to the EPA their annual toxic waste emissions into surface waters, air, land, and underground injection wells at their site or transferred off-site to landfills and wastewater treatment plants. Moreover, TRI facilities must also report if they treat, recycle, or burn toxic wastes for energy. For 2000, the TRI was expanded to include new persistent bioaccumulative toxic (PBT) chemicals, with lower reporting thresholds. The full TRI list now includes over 650 chemicals.

To facilitate the use of TRI data in our geospatial mapping tool, we transferred data from RSEI's Borland database format into our enterprise level PostgreSQL database server (8.4). In PostgreSQL,

RSEI calculations for relative risk based on the following formula were recreated for all facilities in the database. The decile for total pounds of toxics released and the decile for total risk score were calculated and inserted into new fields.

ESRI ArcSDE (10.0) server technology was installed on top of the PostgreSQL server to provide an interface between the RSEI data and the ESRI ArcGIS Server (10.0) mapping capabilities. ArcGIS Server was used to create REST service endpoints allowing web apps to access all of the RSEI data. A separate service was created for each year between 1996 and 2007. The ArcGIS API for Javascript was used to create an interactive map using our REST endpoints to access and display the RSEI data. The latitude and longitude included in the RSEI data was used to place facilities on the map. The decile for total pounds released by a facility was used to drive the size of the symbol using the equation $X^{1.8} * n/20+2$, where X is the pounds released decile and n is the zoom level. Symbol color was assigned using the RSEI risk score decile. Four colors were used to represent the first eight deciles, with each color being used for two consecutive deciles. The 9th and 10th deciles were each assigned their own color.

A cache was built for each layer year to reduce server load and reduce the amount of time the client's web browser needs to render the map. This eliminates the problem of trying to render over 17,000 facilities when zoomed out at the full extent. Instead, the cache is a series of pre-rendered tiled png images. To minimize the size of the cache, and to reduce the amount of time needed to generate the cache, tiles were only built for areas that have facilities. We also incorporated a time slider in the map interface. Changing the year on the time slider changes the cached layer displayed on the map, so that only data from facilities in the year selected are shown.

A search function was added that queries the rest service for all years of data. The search returns a list of facilities where the query matched all or part of the facility name, parent company name, federal agency name, facility id, or any part of the facility address. Clicking on one of the facilities returned by the search result zooms the map to that facility. Clicking on a facility on the map returns attribute information about that facility, including the facilities name, parent company, address, total pounds released, risk score, and the direction of that facilities performance over time.

5. Demonstration

In the following pages, we provide two screenshots from our web map to demonstrate the utility of a longitudinal performance view. Each page displays TRI locations along with representations of each facility's pollution volume (circle size) and risk (color). Following Abel (2007), we also focus on the metropolitan St. Louis region. St. Louis has been a major industrial hub for more than a century because of its mid-continental location and Mississippi river ports. In the first landscape image below, a 1996 screenshot captured more than 100 TRI facilities. In the 2007 display, less than 90 TRI facilities appear. This longitudinal comparison demonstrates several features of our performance mapping approach.

For instance, an attentive viewer could discern how the south central part of the city loses several medium sized volume and risk producers while in the north - south corridor east of the Mississippi, several large volume and risky facilities remain. In the southwest part of the map, several small risk and volume producers disappear from an industrial cluster but several big producers remain. Moreover, viewers would also benefit from quickly seeing what facilities display little to no change over a decade. For instance, several facilities in the southeast part of the map appear to improve their environmental

performance while others have no perceptible change in risk or volume. Those facilities also remain a more concentrated risk cluster near East St. Louis, an area that has raised environmental injustice concerns before.

According to the 2010 census, this city of 27,006 people was 98% African-American with 41% of households below the poverty level and 18.2% unemployment. In 2008, Abel's study of the St. Louis riskscape found that: "one-fifth of the region's air pollution exposure risk . . . was concentrated among only six facilities on the southwest border of East St. Louis" (232). He also observed that the dominant statistical methods found in two decades of scholarly publications on environmental justice relied on the statistics of averages that were blind to these extreme concentrations of risk and social vulnerability.

Also, the cartography that accompanied some of the most cited environmental justice studies depicted industrial pollution risks with a uniform point or symbol on a map (Bowen et al. 1995; Pulido 2000; Downey 2003; Maantay 2002; Mennis 2002; Pastor et al. 2004; and Campbell and Peck 2010).

Our web application's cartography avoids this limitation with symbols that change color and size. In the two maps on the previous page, a viewer could discern that while the St. Louis MSA was deindustrializing between 1996 and 2007, a significant cluster of facilities with higher volumes and more risk remained near East St. Louis. An interested viewer could then zoom in to one or two concentrated risk clusters and focus their attention on a much smaller portion of the riskscape.
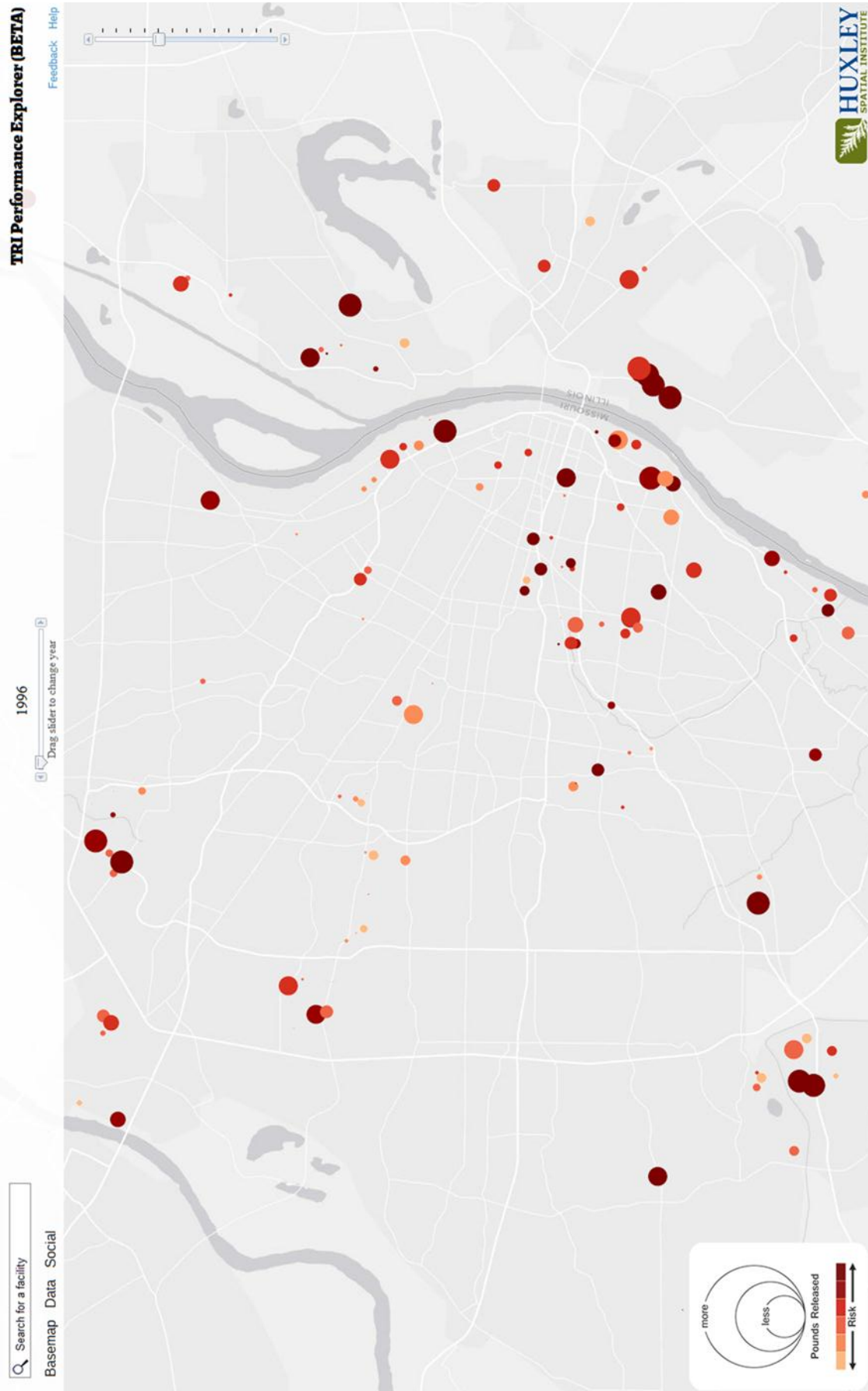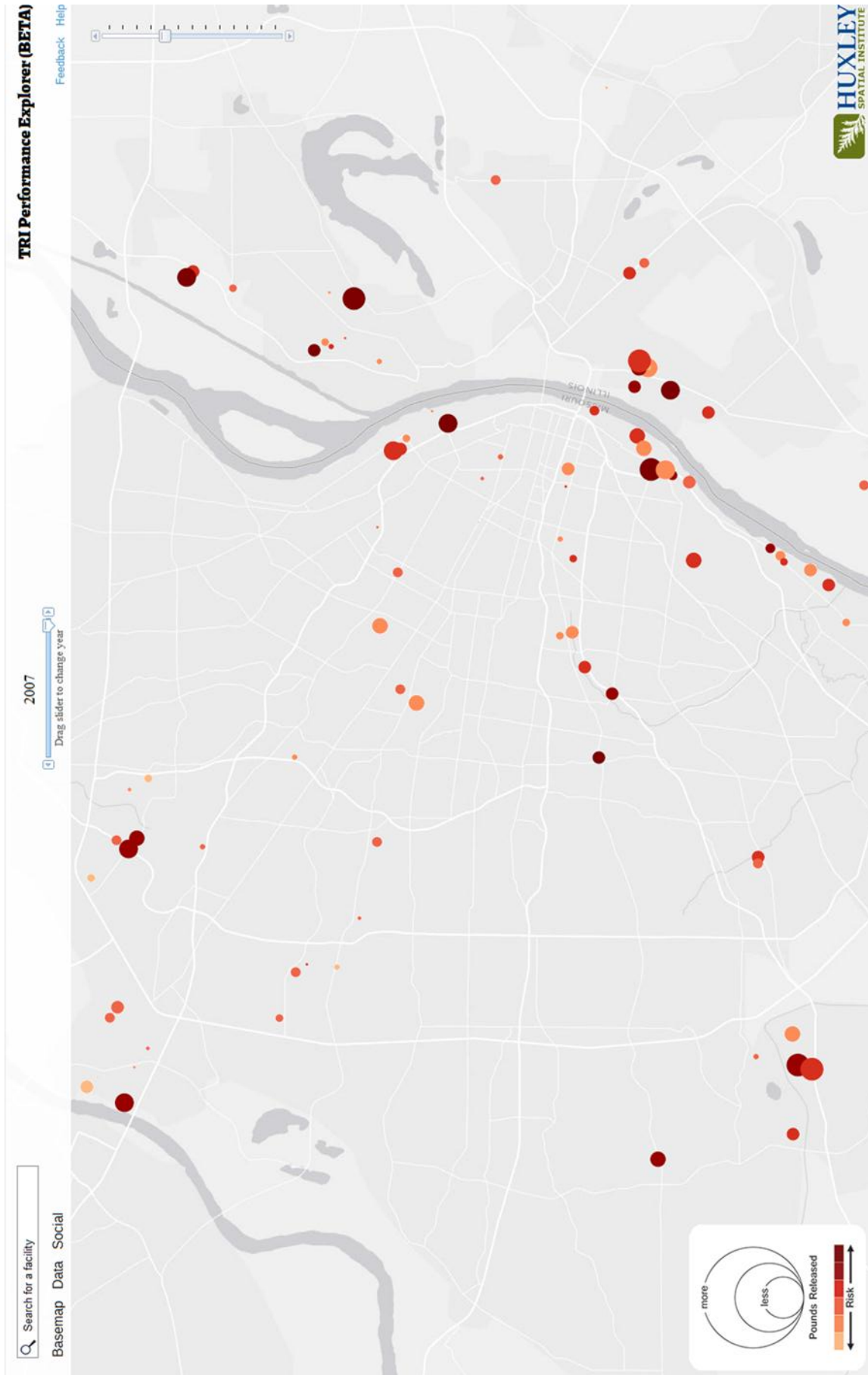
6. CONCLUSION

Since the migration of the Toxics Release Inventory (TRI) from paper reports and compact disks in 1987 to the internet, numerous mapping tools have been developed. The TRI Performance Explorer web-map joins this crowded field with several important advantages. Our tool blends the democratizing access of the internet while maintaining the rationalizing features of a symbology informed by peer-reviewed scholarship, expert cartography, and extensive metadata.

In their assessment of the TRI, Kraft et al. (2011) described several prescriptions for the next generation of environmental information disclosure. "The [EPA] could make it easy for users to find pertinent information. . . via an interactive map of facility locations, releases, and risks" (188) and our effort here offers one prototype. They also recommended that TRI data should be presented in a way that facilitates the analysis of performance over time. The symbols in our current web map for a TRI facility change in color and size to depict increases or decreases of environmental performance. This design allows a user to ascertain whether the facilities they are viewing are getting safer and cleaner, or riskier and dirtier with the addition of a time-slider. Individual facilities are also easily comparable in the viewing area. Moreover, users can select individual facilities and obtain more information on the specific amount of pollution volume and risk quantification derived with the RSEI program.

This design, we believe, offers a more practical resolution of facility-level variations and supports another important policy prescription from Kraft et al. (2011).

"The appropriate strategy at both the federal level is to target those facilities and firms that need greater incentives or technical assistance to reduce releases and risks while simultaneously encouraging, recognizing, and rewarding those facilities and firms

that are steadily improving their environmental performance" (194).

Leading and lagging facility performance is quickly discernible with the use of our web map's time slider.

We also, as Kraft et al. (2011) cautioned, recognize the potential pitfalls of easier and wider access to complicated risk and industrial output measures in a web map. "The downside of easily accessible environmental information, according to Kraft et al. (2011), is that riskscape geographies may ". . . be incorrect or subject to misinterpretation, leading to unfounded public fears and inappropriate actions" (187). One standard concern is that any map projection or facility characterization is a very limited view of reality and poses significant problems for decision making. We would argue that the pros and cons of incomplete information are a bit more complex.

On the one hand, it's true that information used to mislead, manipulate, or obscure true conditions on the ground can lead to faulty reasoning and therefore bad decision making. On the other hand, incomplete information based on good intentions and in properly managed contexts has the ability to motivate better information, which in turn can mean good information that leads to, or adds transparency to solid reasoning, good decision making, and a strong alignment between values and behavior.

Certainly policy actors want good information and while there are other actors, with the best intentions in mind, who would argue against faulty information being used to drive policy action; incomplete or "bad" information is better than no information. Many level just such a critique at the TRI and its self-reported nature that is used for estimating the surrogate inhalation doses driving RSEI's risk characterization. Our argument instead is that contested information, properly mediated, opens a window for deliberative processes that will lead to increasing the quality of

information and fostering collective rationality. In fact, this is why we have advanced our effort as a kind of "civic cartography."

Does our mapping tool rest on assumptions that some may understand as faulty? Certainly. Does it draw the journalist's, analyst's, or activist's attention to the "wrong" conclusions? Quite possibly. But at its heart, we have created the mapping tool not as a be all, end all; but as a tool that may foster a broader conversation and motivate a rethinking of some basic premises we find to be faulty, e.g., how focusing on releases only and ignoring risk can be very misleading.

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