SHOULD THE UNITED STATES ENVIRONMENTAL PROTECTION AGENCY'S POLICY ON THE TECHNICAL IMPRACTICABILITY WAIVERS BE CHANGED?

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James Michael Tarr

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Charles Town, WV

ProQuest LLC.
789 East Eisenhower Parkway
P.O. Box 1346
Ann Arbor, MI 48106 - 1346

DEDICATION

This thesis is dedicated in memory of my deceased parents Clyde and Mary Tarr and my late wife Diane Selleck Tarr. Without their encouragement throughout my younger years, support, and most of all, love, my dedication to the field of Geology and ultimately becoming a professional Geologist would not have occurred. Their reinforcement made the development and completion of this work possible.

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ABSTRACT OF THE THESIS

SHOULD THE UNITED STATES ENVIRONMENTAL PROTECTION AGENCY'S POLICY ON THE TECHNICAL IMPRACTICABILITY WAIVERS BE CHANGED?

By

James Michael Tarr

American Public University System, May 11, 2014

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Professor Elizabeth Crosier, Thesis Professor

This research tests and answers the main question: Should the Environmental Protection Agency's Policy on the Technical Impracticability Waivers be changed? This research uses public and private databases for collecting information on the Comprehensive Environmental Recovery and Liability Act sites with Technical Impracticability Waivers and examines the process the Environmental Protection Agency uses to make Technical Impracticability Waivers evaluations. Existing data demonstrates the Environmental Protection Agency has been very conservative and has granted few Technical Impracticability Waivers over the last 30 years. Several arguments for changing Environmental Protection Agency's policy are made. A comparison of approved Technical Impracticability Waivers sites and sites that meet the criteria for approval but have not been submitted for the waiver are used in this research. The results indicate that the policy should be changed. A policy change would be beneficial to appropriate funds to the more complex and critical sites. A change in policy would also save taxpayers funds instead of being spent on experimentation on sites that are impracticable to clean up, these funds would go to more critical sites. The research also shows a need for collecting a database of sites that Environmental Protection Agency has rejected for a Technical Impracticability Waiver.

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LIST OF ACRONYMS AND ABBREVIATIONS

AEC	United States Army Environmental Center
Air Force	United States Air Force
ARARS	Applicable or Relevant and Appropriate Requirements
ASTDR	Agency for Toxic Substances and Disease Registry
BRAC	Base Realignment And Closure
CERCLA	Comprehensive Environmental Response, Compensation and Liability Act
CFR	Code of Federal Regulations
CLEAN	Comprehensive Long-Term Environmental Action, Navy
DOD	United States Department of Defense
DOE	United States Department of Energy
DNAPL	Dense Non-Aqueous Phase Liquid
EPA	United States Environmental Protection Agency
ESTCP	Environmental Security Technology Certification Program

FRTR	Federal Remediation Technologies Roundtable
FY	Fiscal Year
FUDs	Formally Used Defense Sites
IC	Institutional Controls
IRP	Installation Restoration Program
LUCs	Land Use Controls
MCLs	Maximum Contaminant Levels
MNA	Monitored Natural Attenuation
NAPL	Non-Aqueous Phase Liquid
NAVFAC	Naval Facilities Engineering Command
Navy	United States Department of the Navy
NRC	National Research Council
NCP	National Oil and Hazardous Substances Pollution Contingency Plan
NPL	National Priorities List
MCLs	Maximum Contaminant Levels

OSWER	Office of Solid Waste and Emergency Response
PCBs	Polychlorinated Biphenyls
PCE	Tetrachloroethene
PRPs	Potential Responsible Parties
RAOs	Remedial Action Objectives
RCRA	Resource Conservation and Recovery Act
ROD	Record of Decision
SVOCs	Semi-Volatile Organic Compounds
TCE	Trichlorothene
TIW	Technical Impracticability Waiver
SARA	Superfund Amendments and Reauthorization Act
VOCs	Volatile Organic Compounds

I. INTRODUCTION

Statement of the Problem

According to the United States Environmental Protection Agency (EPA) the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA), groundwater cleanup levels are established by applicable or relevant and appropriate requirements (ARARs) water quality standards EPA (2011a). The water quality standards in this study are the drinking water standards or Maximum Contaminant Levels (MCLs) which are legally enforceable. Therefore, one must meet these cleanup standards in order to achieve closure at a CERCLA site. Although there are many different approaches to reaching site closure, this research focuses on one method. According to a study conducted by Malcom Pirnie, (2004) for the Army Environmental Center (AEC), under the CERCLA regulations there are six exceptions to meeting the ARARs. One of the categories for exceptions, are known as waivers, one of the six waivers, specifically the "Technical Impracticability Wavier" (TIW) is the subject of this research. Malcom Pirnie (2004) found that the EPA has not actually defined the term "Technical Impracticability" as it applies to groundwater cleanup (p. 2-2). They point out that the EPA decided to define the process for the determination of meeting the cleanup goals for polluted aquifers based on being impracticable from an engineering point of view Malcom Pirnie (2004). The National Research Council (NRC, 1994) noted that the word "policy", is not limited to laws for the cleanup of groundwater but to other documents used to enforce the regulations as well. In this document the TIW process is used in the context of policy. The difficult process of obtaining a TIW is the object of discussion in this paper. Specifically, this research looks at the EPA's policy of granting so few TIWs over the last 30 years. It also examines why progress of the cleanup of many Superfund sites has slowed. The problems with the EPA approving TIWs are not new. One paper by Quarles and Steinberg (2004) points out that there is a need for EPA to be flexible in the policy matters for cleanup. Quarles and Steinberg (2004) state the "national policy and regulatory practices are severely flawed". They further indicate that the current practices are costly, and have many deficiencies that have led to wasting tax payer funds for cleanups. These authors believe that EPA should have a new policy for groundwater cleanup. Another paper by Laskey, Deeb, Hawley and Kell, (2007) acknowledged that even though EPA documented the use of the TIW, it is underused. An additional article by Yohannan, (2014) claims industry has urged the EPA to change its policy by allowing more use of the TIW. A recommendation also was also made by the Committee on Environment and Public Works to the United States Senate, (2007) that the TIW be reconsidered and expanded in order to advance the process for cost effectiveness. Yohannan (2014) also considers that the EPA has unfeasible beliefs concerning the use of the TIW. Yohannan (2014) notes that the industry group's position on which the article was based goes as far as stating "EPA has resisted and discouraged the use of TI waivers from the outset" (p. 2). This author believes that Yohannan (2014) summarizes the current status of the EPA policy TIW explicitly well. The article by Yohannan went on to say EPA's policy for restoration is basically not representative of the current situation. As a result of the current policy, not only are we failing to progress on cleaning up these sites, but the EPA and others have funds diverted less critical sites. Funds should be appropriated to more urgent sites needing immediate remediation of contamination impacting drinking water supplies. A shift in the TIW policy in maintaining one of EPA's main tenets would still be protective of human health and the environment. The current policy is examined in greater depth with case studies and is the focus of this research. This research tests the question of whether the EPA's policy on TIWs be changed?

Background

One of the most significant pieces of legislation of our time is CERCLA of 1980 also known as Superfund. According to the EPA, the name "Superfund," was given to the environmental program and the fund that was established to pay for cleanup and enforcement activities at sites dealing with hazardous substances that may pose a threat to human health, welfare or the environment EPA (2011b). This fund also pays for the cleanup of sites that have been abandoned and where no potentially responsible parties (PRPs) have been found. Some of these sites are discussed in this paper. The CERCLA statute was designed to cleanup these hazardous wastes sites. CERCLA was later amended by the Superfund Amendments and Reauthorization Act (SARA) in 1986. Prior to 1980, few regulations were in place that provided the safeguard or depth that CERCLA does for the protection of human health and the environment.

This law was developed based on occurrences in 1970s such as the unearthing of notorious toxic waste sites such as New York's Love Canal EPA (2011b). Love Canal and others like it precipitated public outcry and eventual action by the Federal government. It is worth noting that like many other legacy Superfund sites, Love Canal is still not entirely cleaned. Like many CERCLA sites, this may cost millions of dollars and take hundreds of years to reach regulatory drinking water standards. CERCLA provides the EPA the authority to cleanup such sites and to require those identified PRPs to implement remedial action or compensate the government for EPA lead cleanups.

According to EPA (2012a) the 40 Code of Federal Regulations (CFR) 300.430 (a) (1) (iii) (F), in order to conduct response actions, one must follow the regulation established by the National Oil and Hazardous Substance Pollution Contingency Plan (NCP). The NCP is the regulation that provides administrative structure and processes for dealing with various contaminants EPA (2012a).

Based on research by Charsky (2007) the majority of the TIWs that have been approved are for groundwater restoration. The issue of groundwater has long been recognized, and has been discussed over the years. One of the well-known studies by the NRC (1994) noted at that time, there were some 300,000 waste sites around the country that involve groundwater contamination and with a potential cost of at least a trillion dollars for cleanup. Since this time numerous changes have occurred in both numbers of sites as well as cost.

One of the most important aspects of CERCLA is the restoration of groundwater contaminated sites across the nation. Since the majority of Superfund sites involve groundwater contamination, it is a major topic of discussion of this research. According to the EPA (1993) approximately 85 percent of the Superfund sites have groundwater contamination problems. Because of the high percentage of Superfund sites involving groundwater contamination there has been many articles written on the topic. A study conducted by Deeb et al. (2004) for the Environmental Security Technology Certification Program (ESTCP), points out the fact that aquifer restoration success in achieving drinking water standards is hardly ever achieved Deeb, et al. (2004). This research investigates how these sites are addressed under CERCLA. According to EPA (1993) "EPA expects to return usable groundwater to their beneficial uses wherever practicable, within a timeframe that is reasonable given the particular circumstances of the site. When restoration of groundwater to beneficial uses is not practicable, EPA expects to prevent further migration of the plume, prevent exposure to the contaminated groundwater, and evaluate further risk reduction," (p. 1).

This is the EPA's main tenet and provides the foundation for corrective action under the current regulations and is the subject of much debate.

Deeb, Hawley, Kell, and Laskey (1990/2011) write that according to the NCP Preamble "by stating 'expectations' rather than issuing strict rules, EPA believes that critical flexibility can be retained in the remedy selection process." Because of this expectation, several barriers-issues arise in the TIW process. The one problem is the restoration of groundwater use "where practicable" and covers a wide spectrum that is subject to interpretation. Another concern is what is "reasonable timeframe," is not well-defined and has created numerous glitches in determining the appropriate methods for cleanup based on expected time to achieve meeting the groundwater standards. The authors also believe the timeframe definition can be interpreted many different ways over a wide range of time anywhere from 30 to 600 years. They go further, Deeb, et al. (2011) states "there is no standard definition of reasonable timeframe", (p. 40). They also note, the EPA 1993 guidance document generally accepts the use of the 100-year timeframe as being reasonable. Furthermore, the EPA acknowledges (Federal Remediation Technologies Roundtable (FRTR), in their FRTR (2012) opinion, a reasonable timeframe is not defined in outright terms but rather subject to interpretation by EPA on a case-by-case basis and sites specifics. The results have many variations and lack of consistency in the policy throughout the various EPA regions. The Interstate Technology & Regulatory Council (ITRC) indicates that cleanup site timeframe ranging from as few as 50 years to as much as several hundred ITRC (2012) can impact the approach to remediation of these sites. The extension of cleanup time, results in significantly increased costs associated with cleaning up these sites. This author believes the EPA should set time frame of 50 years as the justifiable timeframe for setting cleaning up sites.

These are contributing factors in the lack of progress as well as the determination of cleanup goals and standards as applied within the TIW process. While there are significant and well known studies on the general topic of TIWs by Malcom Pirnie, the NRC, the Department of Defense (DOD) and others, there is a general lack of published research that questions the EPA's policy on TIWs, specifically, why so few have been granted. It should be noted there are other alternative end point methods for cleaning up groundwater for closure other than the temporary use of TIWs, these include: institutional controls, such as pump & treat systems, monitored natural attenuation (MNA), and well head protection, EPA (2011c) to name a few.

Purpose Statement

One of fundamental objectives of this research is to assess why such a low number of sites have been approved for a TIW. This research questions the EPA policy for evaluating the TIW applications. Specifically this research examines the criteria EPA uses to evaluate TIWs. EPA approves TIWs is the main emphasis of this research investigation. This research tests the following question: Should EPA's policy for TIWs be changed? In addition, secondary questions such as how and why granting more TIWs will be beneficial economically and socially will be discussed.

Thirty years since Congress enacted CERCLA, many sites have been cleaned up and closed; however, the difficulties and failures such as a lack of closure at numerous NPL sites around the country is apparent. According to Steinberg (2002) the major and most menacing sites are those of the federal government. Hence the majority of sites discussed in this paper are those of the federal government. EPA issued several documents for the improvement and clarification of the TIW process. Even after several guidance documents were issued the issues of groundwater restoration and the use of the TIW remain a lingering and costly problem throughout most of the country. These issues are investigated along with how billions of dollars have been expended but very few sites have achieved the EPA tenet goal of groundwater restoration to drinking water standards. This research investigates specifically how EPA approaches and approves TIWs and what criteria are used to judge TIW evaluations.

There have been numerous studies that have looked at the investigation and remediation of complex sites. A recent study by the NRC (2013) recognized that the technology has not been able to keep up with stakeholder requirements for investigation and restoration of many complex sites. Furthermore the NRC understands that there is lack of both funding, as well as research at federal agencies on how to deal with these complex sites NRC (2013).

II. LITERATURE REVIEW

Overview

Like many of the existing federal regulations, it is apparent that the review and approval process is an iterative one as evidenced by the EPA's history of some of the guidance and directive documents. As the understanding of a complex environmental issues and advancement in technology increase, many regulations are amended or modified to adjust for the new conditions that have been discovered. In conducting the literature search for this paper multiple sources were reviewed. The EPA issued several TIWs documents to address the difficulties and failures associated with the TIW process. These documents are briefly discussed in order of the year they were issued.

The first of which is the only guidance document introduced in 1993. The Office of Solid Waste and Emergency Response (OSWER) issued the directive 9234.2-25, the document entitled "Guidelines for Evaluating the Technical Impracticability of Ground Water Restoration", provides a framework for the EPA's approach for groundwater cleanup goals, and institutes alternative protective cleanup strategies if restoration is technically impracticable EPA (1993). Furthermore, the document provides clarification of how the EPA determines if the restoration is technically feasible and what actions will be required to ensure that the alternative is protective of health and environment EPA (1993) (p. 9). It is worth noting that the EPA (1993) states "This guidance does not signal a scaling back of EPA’s efforts to restore contaminated groundwater at Superfund sites and RCRA facilities” (p. 4).

In 1995 the EPA, issued a second document (OSWER, 9200.4-14) the “Implementation of the FY 1993 Guidance on Technical Impracticability of Ground-Water Restoration at Superfund Sites” EPA (1995). This directive document describes and spells out in detail what the role of the EPA headquarters plays in the review of the TIW process. EPA (1999a) issued a third reference document (OSWER, 9200.1-23P, 1999) entitled “A Guide to Preparing Superfund Proposed Plans, Records of Decision, and Other Remedy Selection Decision Documents”. This document according to (EPA, 1999a) provides guidance for submitting records of decision (RODs) and clarifies the responsibilities of EPA and others that issue documents. It also provides an explanation for the changes. This was yet still followed by a memorandum, “Clarification of OSWER’s 1995 Technical Impracticability Waiver Policy” EPA (2011d) this was intended to provide additional clarification to the original 1995 document. Specifically, it reiterates that EPA is not to approve TIWs based on DNAPL presence alone EPA, (2011d). According to Perellis (2011), this document represents a change in EPA’s policy on groundwater treatment and TIW criteria. Perellis (2011) believes this EPA document represents a reversal and the EPA now is saying not to grant TIWs because of dense non-aqueous phase liquids (DNAPLs) presence. What the EPA actually said was not to grant TIWs based on DNAPL presence alone. DNAPLs can be generally defined as a separate phase liquid including chlorinated solvents, PCBs, creosote, and coal tars. These DNAPLs are frequently found at Superfund sites, due to widespread use of chemicals such as solvents and other products. The remediation is complicated by the chemistry (immiscibility) characteristic in water DNAPLs are heavier than water; therefore, DNAPLs tends to sink. Because of this DNAPLs tend to sink, DNAPLs migrate into the deeper portions of an aquifer as well as in some case absorbing into soil and-or rock matrix. These DNAPLs found in complex geological settings are hard to remediate because of the lack of technology capable of destroying the DNAPLs. They may continue to be a source of groundwater contamination for a great period of time.

In 2009, EPA issued the "Summary of Key USEPA CERCLA Policies for Groundwater Restoration, OSWER directive 02893.1-33. According to Deeb et al. (2011) this directive reinforced EPA's policy for groundwater restoration. One of the more recent documents issued is (OSWER 9230.2-24), this directive "A Summary of Technical Impracticability Waivers at National Priorities List Sites," EPA (2012a), was published like the former documents to address and clarify various issues associated with TIW policy and process. The document shows the number and distribution of TIWs by Region and years and rational for granting the TIWs.

Basis for Granting a TIW

According to Malcom Pirnie (2004) the EPA's justification of granting a TIW is based on "one of two criteria needs to be met in order to be granted for a TIW: (1) engineering infeasibility, and (2) unreliability EPA (1993)" (p. 2-2). This means a cleanup action can be determined to be infeasible if current engineering methods cannot meet the intended ARARS. Unreliability simply means that if the cleanup method is unlikely to be considered to be protective of human health and the environment, then it is unreliable. The Malcom Pirnie (2004) study indicates that these "two criteria define the term technically impracticable from an engineering perspective" (pp. 2-3). This is a critical metric that must be met in order to obtain the approval of a TIW by EPA.

One of the more pertinent and comprehensive research documents that looks at cleanup issues is the National Academy of Science (NAS, 2013) study "Alternatives for Managing the Nation's Complex Contaminated Groundwater Sites," which indicates that over the last four decades, hundreds of billions of dollars have been spent attempting to cleanup hazardous waste sites NAS (2013). To put the problem into perspective, the overall extent of contamination according to the NAS (2013) report indicates that as many as 126,000 other non CERCLA sites exist across the country that have some form of legacy contamination NAS (2013). It should be noted, that the numbers and cost associated with cleanup has changed over the years. As of 2013, the NAS (2013) report estimates the future cleanup cost of these sites alone is over a $110 billion dollars.

Generally speaking the NAS is a recognized authority and has published numerous articles over the years on the topic of groundwater remediation and has documented the associated difficulties in achieving drinking water standards NAS (2013).

Database of Approved TIWs

In order to understand the TIW process, one must first look at the CERCLA sites. According to the latest information, EPA (2014a) as of February 2014, there are 1,319 NPL sites, and 375 deleted sites, and 53 newly proposed sites. One research study by Malcom Pirnie (2004) study found that there is no specific database for listing of Superfund sites with TIWs. The lack of TIW data makes research a challenge and therefore, one must find the information on TIWs by indirectly by reviewing RODs within the EPA database. The research of these various databases is the method for identifying these sites. This research has determined that a lack of information exists for listing TIWs that have been applied for and or rejected by EPA. Furthermore, one must realize that the TIW only applies to a restricted and defined zone; all other areas are expected to achieve MCLs.

In addition to TIWs, there are several alternative endpoints to reach closure of sites. Many of these sites use common practice tools of implementing “Land Use Controls” (LUCs) which limit the use of the properties for current and future use. LUCs can prevent human and environmental exposure and therefore are considered protective measures. LUCs however, are not intended to be a method of closure. Studies show that many of these sites likely will not reach groundwater cleanup goals as defined by EPA. The TIW is one of the endpoint methods that can be chosen. If a TIW is granted it is only for a temporary period of time until a better technological remedial alternative is found. Furthermore, an approved TIW does not mean no further action and continued monitoring is required to ensure that human health and the environment is protected.

Since the beginning of CERCLA, thousands of sites have been identified and many have been successfully cleaned up and delisted from the NPL. This research is not suggesting that the EPA has not been successful at remediation of the CERCLA sites, but is proposing that more TIWs be applied to the more complex sites. Even though more recent data indicate that the number of TIW approvals have decreased from 2000 to 2011 compared to prior years (1988-1999). The question of why relatively few TIWs that have been approved remains. The following figure from the EPA (2012a) shows the total numbers of TIWs that have been approved by the EPA each year since 1988 to 2011.

The low numbers of TIWs granted in any given year as well a spike in the data for 2006 is noteworthy. Perhaps more significantly for 2008 and 2010, no TIWs were approved. On the average 3.95 TIWs per year over 23 years were approved. No additional data on the number of approved TIWs from 2011 to 2014 were available at the time of this research. No TIWs were granted during 1980 to 1988. Although based on history, it may be reasonable to assume that a few more TIWs have been approved since the 2011 time.

Figure 1: EPA's TIWs By Fiscal Year (FY 1988 - 2011)
(Source: EPA, 2012a)

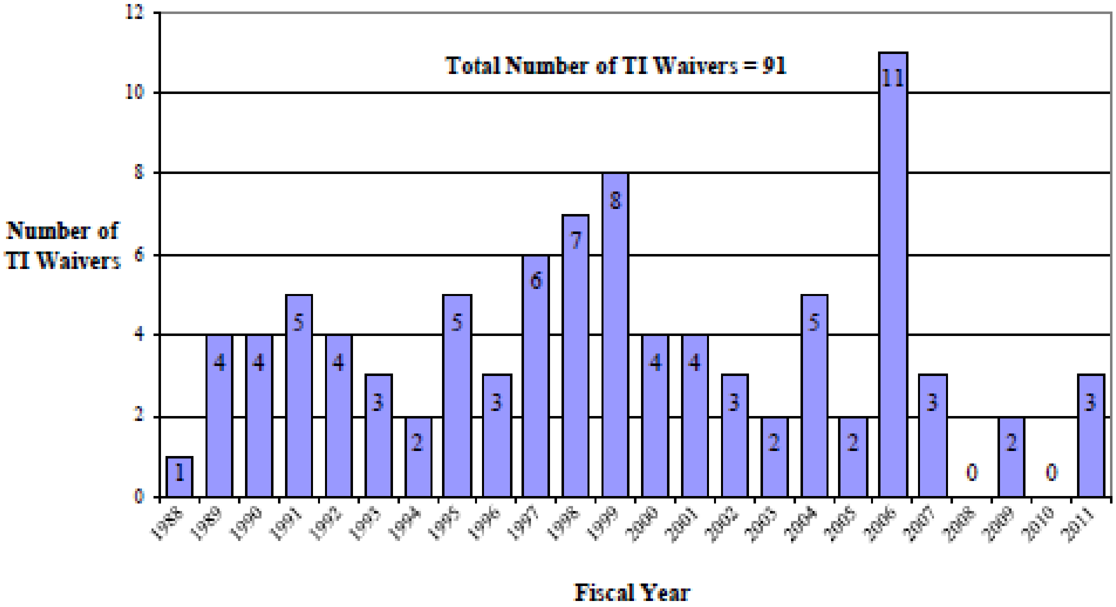
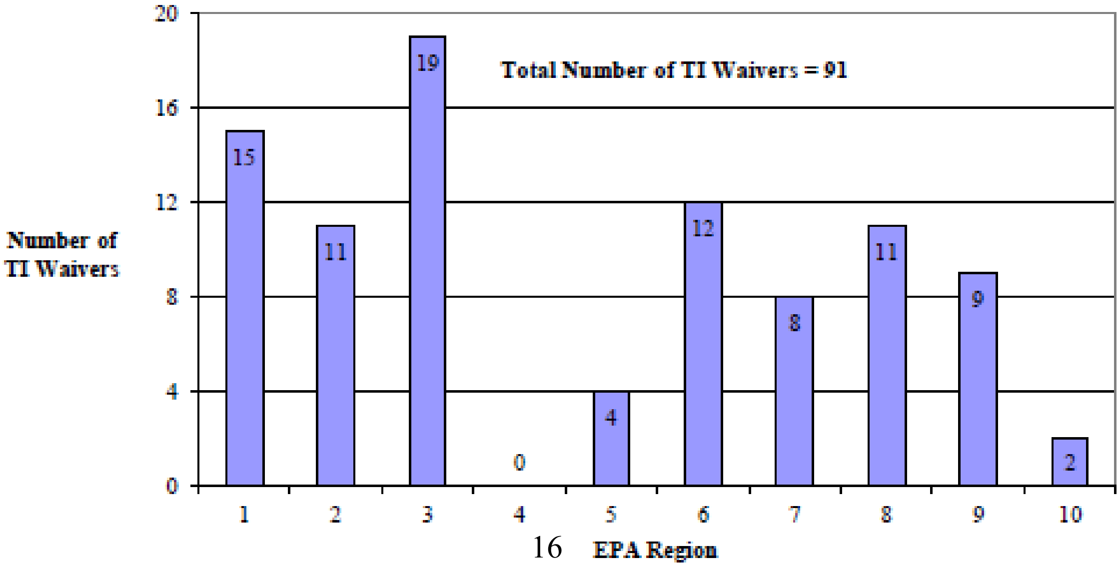


Figure 2 below also from the EPA (2012a), depicts the total number of TIWs approved by region. The data clearly shows Region three and one lead the other regions in approving TIWs. Region four recorded no approvals, followed by regions: ten, five and seven with other regions having recorded somewhere between eight and twelve TIWs. It is clear from the data that wide disparities of TIWs that are approved vary significantly between the EPA regions. In reviewing the data no explanation by EPA is made to account for why region four has no approved TIWs. As equally important is why region three had as many as 19 approved TIWs, this is also not explained. One may find these reasons may be based on criteria such as the degree of complexity of geology as well as other technical issues in the various TIW sites that creates this variation in the data sets. Perhaps another reason that could account for the range is policy-interpretation differences amongst the project managers and supervisors within the various regions. This is further analyzed by looking at several case studies and is described in a later section of this paper. A report by the NRC (2013) does suggest that a "Better Decision Making during the Long Term Management of Complex Groundwater Contamination Sites" be used, (p. 11). The NRC (2013) report goes further and discusses that when a sites reaches a point where the return on the investment has reached its maximum, then it may make sense to look at a better long term strategy.

Figure 2: EPA's TIWs By Region (FY 1988 - 2011)
(Source: EPA, 2012a)

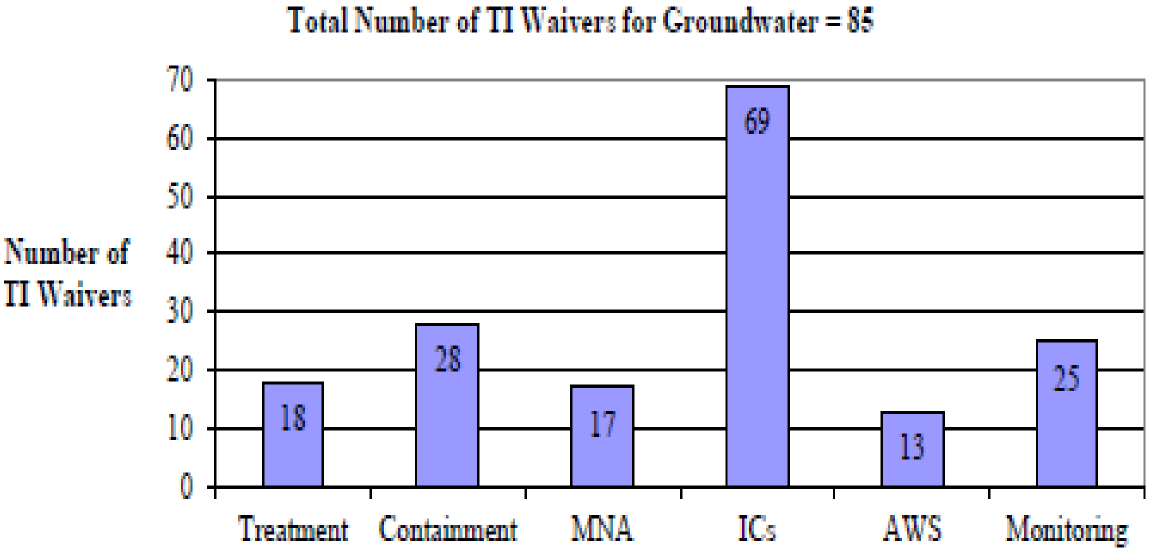


EPA (2012a) data show a total of 91 TIWs have been approved as of 2011. Overall, there is also a lack of research as to why so few TIWs have been granted, although several articles discuss TIWs in some fashion or another.

The next figure from EPA (2012a) shows 85 TIWs have groundwater issues and the type of remedy that was implemented to address the situation. The graph plots the number of waivers and associated treatment strategy for groundwater restoration.

The figure depicts the various categories including treatment, containment, MNA, institutional controls, alternate water supply, well head treatment, and monitoring. EPA (2012a) points out that source action is the most common strategy at approximately

Figure 3: Groundwater Remedy Components with TIWs to Ensure Protectiveness (Source: EPA, 2012a)



36 percent of the sites. Institutional controls leads the TIW at 69 sites, followed by 28 with containment, and 25 sites with monitoring, 18 with treatment and 13 with alternative water supplies.

III. THEORETICAL FRAMEWORK-APPROACH

Overview

One of CERCLA programs goal is the establishment of reasonable and attainable cleanup levels. Under CERCLA a TIW can be used in lieu not meeting ARARs. Within the TIW framework, as noted by the DOE (1998), the EPA (1993) requires that specific criteria such as a proposed TIW zone (area of contamination) be delineated horizontally and vertically. This is to be determined from an engineering perspective in order for groundwater to be not restored and to not meet ARARs. These and other barriers prevent TIWs from being approved. This research examines the structure of the criteria within the TIW requirements. In addition, this research examines several case studies by individual EPA Regions and reviews the EPA policy and general criteria for granting TIWs.

It has been long recognized by many that the preservation of the nation's groundwater is of vital concern. The issue of groundwater contamination is not new. As far back as the 1980s and later in the 1990s a leading authority, Kavanagh (1996) believed that the cost of restoration would exceed one trillion dollars and stated that the management and restoration process would be challenging and costly. He also recognized that technology at that time was limited in its success at reaching cleanup standards. He further stated that policy at that time was shifting away from fixed framework to a more progressive risk based decision making process Kavanaugh (1996).

While some technology for groundwater restoration has progressed and the use of risk-based approaches have grown, the more complex contaminated sites remain a challenge and are now perhaps more costly to investigate and cleanup. In addition, compounding the problem many government funding programs have been reduced. This reduction in funding occurs at a time while the demand for clean water only increases with the growing population, land use expansion for agricultural purposes, negative impact from climate changes, and increased drought conditions. The current policy challenge for the restoration of groundwater is the proper management. Decisions to clean up the most contaminated sites in a cost-effective manner must be found. The need for appropriating-directing funds in the most critical sites is required. Even then, because of complexities one can expect only modest gains for the cleanup of many sites.

The literature shows at least one Department of Defense (DOD) agency, the U.S. Department of the Navy (Navy) in the beginning of the decade (2000) supported the NRC to study the issues mentioned above. The Navy has common issues associated with remediation of various media NRC (2003). Like many other agencies the more complex sites that now remain are a challenge because the complex geological conditions, or in some cases sheer size and volume of contamination. The Navy apparently understood these issues and the purpose of the NRC study was to help the Navy find a better management-strategy tool for dealing with these complex sites. Many technological as well as regulatory issues are present at these sites that have not achieved the intended cleanup goals. The NRC (2003) decided to use an approach called "Adaptive Site Management" (ASM), this is described as a wide-ranging and flexible approach for dealing with the problem sites. ASM had been used in other applications, the NRC (2003) proposed that the concept be used and applied to hazardous wastes sites. The idea is to change and adjust as knowledge on a site increases and changes. The NRC (2003) report pointed out that at many sites once the asymptotic affect of contaminate concentrations is reached, the intended remedial design no longer is able to reduce contamination to the regulatory standards. This is where current technology is lacking the capability to reduce contaminates to MCLs; therefore, alternative cost- effective strategy must be employed to address these situations. The NRC (2003) report, suggests a wider approach is needed to address these situations and by using ASM for site management.

According to NRC (2003) the use of ASM provides advisement on how to manage and interpret data as well as which technology to consider for selection to best accomplish cleanup.

Perhaps even more significant and important, based on the Malcom Pirnie (2004) report, the process of obtaining approval of a TIW is based on effective communications with the regulatory agencies, as well as other stakeholders like the public. The report further recommends proper management within the process so issues are dealt with in advance. The Malcom Pirnie (2004) report notes that EPA views the TIW process as site specific and EPA recommends the use of quantitative tools such as computer modeling to improve the TIW evaluation. The Malcom Pirnie (2004) report indicates that the Army's 127 installations are required to achieve groundwater cleanup, and it is estimated over $3 billion dollars will be needed to reach closure. In addition, many of those sites are located in karst or fractured bedrock aquifers that are further complicated by the presence of DNAPL, this is recognized by the EPA as one of the major site- specific criteria for granting a TIW. The report by Malcom Pirnie (2004) points out that many of the Army sites should be eligible for TIW assessments. This author believes that many DOD sites should conduct similar assessments like the Army, to determine if there are sites that might be qualified for a TIW. In many organizations barriers prevent the TIWs from being approved because of management unwillingness to pursue the TIW or lack of funding. These issues are not limited to these two DOD agencies.

According to the DeVenoge, Soloyanis, Vogel, and Kavanaugh (2006a), in a United States Air Force (Air Force) study, the Air Force found while their total cost for environmental restoration is increasing, the budgets for cleanup are decreasing. Furthermore, they like other DOD agencies that follow the regulations and guidelines pertaining to TIWs are faced with making decisions based on economics while still remaining protective of human health and the environment. DeVenoge, et al. (2005/2006b), points out that “TIWs are appropriate if remedial action objectives (RAOs) cannot be met by any feasible approach” (p. 9). Like the Malcom Pirnie findings, DeVenoge, et al. (2006b) also found similar results and concluded at many Air Force sites, the TIW could be suitable (p. 14). The study by DeVenoge, et al. (2006b) determined the Air Forces uses the approach of determining which individual sites are suitable for TIWs. The Air Force reached similar conclusions that other DOD agencies have reached that the cooperation between various stakeholders and regulators is required in order to get a TIW approved. This may account for the disparities in data found in the various ten EPA Regions. In reviewing the EPA policy, it is apparent that the EPA prefers aggressive treatment of contamination and not monitored natural attenuation (MNA) EPA (2013a).

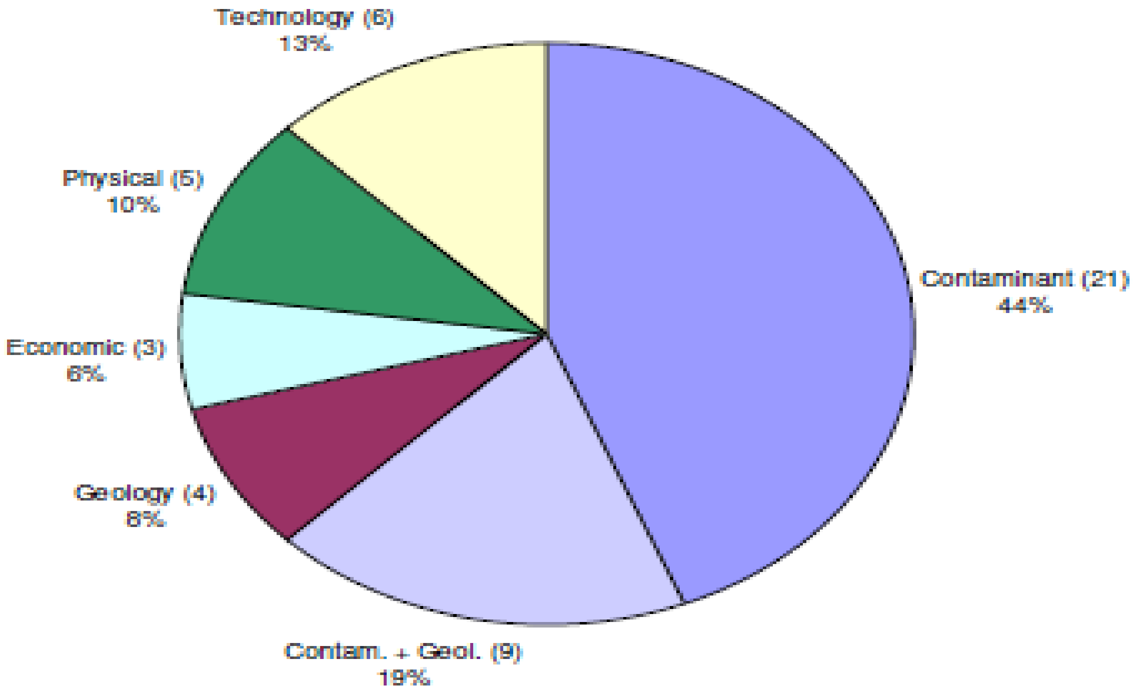
Summary of Theory

The evidence of the very few and varied TIWs approved since CERCLA began suggests that the EPA TIW process has been restrictive, antiquated, ineffective, costly, and inconsistent at granting TIWs within various EPA Regions. Such disparities within the structure of the EPA create an impression in the environmental industry of not only poor management, but are counterproductive for PRPs to seek a TIW and PRPs may consider it a waste of time and funds. This research tests the following questions: Should the EPA's policy on the Technical Impracticability Waivers be changed? In addition, secondary questions are investigated: What is the process for granting TIWs? And how and why granting more TIWs will be beneficial. The answers to these questions demonstrate the need for changing the TIW policy and how it will be beneficial for society.

Data Gaps

This study included reviewing existing databases of the EPA and other agencies as well as documents produced by the private sector. The following figure demonstrates justifications for 48 TIWs at the time the study was completed by Malcom Pirnie (2004). The pie chart divided into various segments depicts the various reasons for justification of a TIW. These reasons range from economic to contamination type. A review of the data indicates a potential data gap now exists. Since the 2004 report, the number of TIWs have increased to 91, and there may be a difference in the reasons compared to what the Malcom Pirnie (2004) study found. The Malcom Pirnie report is one of the first studies that asked the question whether more TIWs could be granted be as identified by their research? The study found that there could in fact be more TIWs granted. The Malcom Pirnie study found the majority or 44% of TIWs had contaminant specific justification. Followed by contaminants in a complex geologic conditions at 19%, the other categories were determine to lessor extents included; technology at 13%, physical at 10%, geology at 8%, and economic site specific conditions at 6%, Malcom Pirnie (2004).

Figure 4: Primary Reasons For TIWs At 48 CERCLA Sites
(Source: Malcom Pirnie, 2004)



IV. RESEARCH DESIGN

Overview

The following case studies look at some the examples of sites that have approved TIWs and also several case studies of potential sites that could be eligible for TIWs. The Malcom Pirnie (2004) report points out that many TIWs are denied because of a variety of reasons, including a poor understanding of the process by various parties, a lack of enthusiasm of the regulators to accept the TIW process a belief that the TIW process is too expensive, a lack of support that the TIW is a genuine alternative, a fear of negative perception by various stakeholders, and a lack of understanding the potential benefits of a

TIW Malcom Pirnie (2004, p. 3). There may be a perception with PRPs that if EPA approves too many TIWs, then the public may perceive that EPA is not doing its job. At least one case study suggests that this is indeed the case.

For each case study listed below an analysis was performed using the EPA criteria for determining factors affecting ground water restoration. While it is understood that many factors are considered for the TIW evaluation process, each case study was reviewed and compared using the EPA criteria. These criteria are summarized on Table 3. A comparison between the approved TIW sites and the potential TIW sites is made.

Case Studies of Approved TIW Sites

The following discussion is a review of select sites one from each EPA Region that have an approved TIW, it should be noted, Region four has no case study of an approved TIW. These sites are summarized in Appendix 1.

1) Former, Pease Air Force Base, Portsmouth, New Hampshire (EPA, Region One)

This case study involves the former Air Force Base located in Portsmouth, New Hampshire. The history of this site includes VOCs and DNAPLs in the soil and groundwater EPA (2014a). RODs issued for the base indicate a long history dating back to the 1950s of the use of solvents and other contaminants. According to the EPA database, complex hydrology and the presence of DNAPLs at site 32 warranted the use of the TIW. The Air Force Civil Engineering Center (AFCEC, 2013) estimates that over $166 million has been spent and another estimated $20 million will be required to reach cost to complete the cleanup.

2) GE Moreau, Saratoga, New York (EPA, Region Two)

This site is located in the Town of Moreau, Saratoga Country a former General Electric (GE) owned property from 1950s it was used for disposal of industrial waste EPA (2011e). Groundwater and soil are impacted by PCBs and VOCs. According to EPA (2011e) approximately 100 residences were placed on public water supply. The expected time according to EPA (2011e) to reach cleanup standards is estimated at 200 plus years; therefore, EPA issued a TIW for the site in 1994 because the groundwater would not meet the standards and could not be completed in the reasonable time frame.

3) Rodale Manufacturing Co. Inc. Emmaus, Pennsylvania (EPA Region Three)

The EPA (1999b) issued a ROD for this site in 1999 and as an alternative selected a TIW for part of the chosen remedy. The ROD addressed VOCs in groundwater namely TCE and Tetrachloroethene (PCE) a small site consisting of approximately 1 acre. The company produced wiring and electronic devices dates back over several decades. The geology is considered to be complex and is highly fractured bedrock. The site has contaminates ranging from: heavy metals, VOCs, PCBs, and semi volatile organic compounds (SVOCs). Receptors included; springs, surface water of streams, sediment, and both public and private drinking water supplies. DNAPL was considered to be probable based on groundwater concentrations. Groundwater contamination extends through the overburden to the bedrock and is from 60 feet to 400 feet below grade.

Based on the ROD EPA (1999b), the TIW is cleanup cost was estimated at $4.2 million with groundwater pump & treat system natural attenuation over 30 years. The TIW was granted for TCE in the probably DNAPL zone. The research on this case study shows the EPA defined the TIW zone very loosely and appears to be limited in the ROD to one figure depicting the horizontal extent of "Probable DNAPL".

4) Continental Steel Corporation, Kokomo Township, Indiana (EPA, Region Five)

According to the EPA (2005) this case study sites history dates back to the 1800s and was used for manufacturing of wire and nails. The site was first became an NPL site in 1989. The site consisting of approximately 183 acres is situated in a glacial drift deposits. Aquifers are have been impacted and there is approximately 20 feet of overburden overlying bedrock. As many as 1,000 55-gallon drums of various materials were discovered. The site is contaminated with PCBs, metals, and VOCs. Source removal and other forms of remediation have occurred since it was first listed. Several areas have been remediated as a result of the corrective efforts. A TIW was approved, and is in place because it was estimated that it would take at least 200 years for the groundwater contamination groundwater to reach MCLs EPA (2005).

5) Crystal Chemical Company, Harris County Texas (EPA, Region Six)

This site is located in Harris County, Texas southwest of Houston. Based on the EPA (2014b), site information update, the site history dates back to the 1960s where Crystal Chemical manufactured pesticides and herbicides until the early 1980s. The site was abandoned when the company went bankrupt. The site has poorly drained soils with a deeper sandy aquifer. Arsenic-based herbicides according to the Agency for Toxic Substances and Disease Registry (ASTDR, 1988), is the primary compound of concern (COC). Source removal actions were completed in the 1980s. A TIW was granted in the 1990s because areas of groundwater were thought to be technically impracticable for cleanup.

6) Missouri Electric, Cape Girardeau, Missouri (EPA, Region Seven)

According to the EPA (2012b) this site is located in Cape Girardeau, Missouri and is the site of the former Missouri Electric company that started operations in the 1950s until the early 1990s. The plant was in the business of repairing and servicing electric equipment. The site is contaminated with PCBs, waste oils, and VOCs. The soil and sediment in wetlands and groundwater are contaminated. In 2005 EPA (2012b) a TIW was approved to address contamination in the bedrock since ARARs could not be met with groundwater contamination extending into the bedrock. The bedrock characteristics make this site difficult to remediate. NAPL was not reported detected for this site. Source removal of over 30,000 tons of soil has been completed. Other methods of cleanup continue to address contamination in the various media. It is estimated that cleanup standards may take in excess of 30 to 100 years to reach.

7) Silver Bow Creek, Butte, Montana (EPA, Region Eight)

This case study was chosen for review and discussion because it was one of a few studies that depict one scenario that shows a negative reaction to the EPA granting a TIW. In this case study, the Public Employees for Environmental Responsibility (PEER) advocated against the approval of a TIW. Based on the report from PEER (2005) the TIW zone covers several miles. The article by PEER claims Atlantic Richfield Company now known as British Petroleum-ARCO (PEER, 2005) would be granted a TIW. The article entitled "Cut and Run: EPA Betrays Another Montana Town" PEER (2005) challenges the EPA approval of a TIW for what is known as the Butte Priority Soils Operable Unit (OU) site. The report claims the site is the largest Superfund site in the country PEER (2005, p. 6). This site consists of mostly heavy metal contamination from arsenic, cadmium and copper mine wastes. Investigation indicates the bedrock is contaminated with these compounds. The group goes on to state that because the PRPs left millions of tons of mining wastes over an area of several miles the protection of human health and the environment is in danger of impact from contamination. The group concluded that this impacts groundwater and ultimately the headwaters of the nearby rivers PEER (2005). The article by PEER (2005) claims that the “Of course, it is completely inappropriate for EPA to be working towards a TIW while purportedly going through the public process of selecting a preferred alternative because of the six alternatives, three of which involve significant removal” (p. 9).

The authors discuss an example of where the TIW was applied an at least in one case, and support the findings where one site the Berkley Pit operable unit was granted the TIW because of its sheer size PEER (2005). Even though a vast area of impacted soil exists, the article called for the removal of mine tailing waste. The authors found that the work was lacking proper scientific merit PEER (2005) such as inadequate delineation of the contamination and recommended additionally that an independent group be appointed to further investigate and advise the EPA and their consultant on the matter PEER (2005). This site is a case study where the TIW was approved. The group of concerned scientists have expressed concern that the TIW should not have been granted. The PEER article noted there is no data on the estimated time for cleanup to meet regulatory standards. This case study does exemplify the negative reaction to the EPA approving a TIW and may be a prevalent attitude amongst the public and perhaps other interest groups in some instances around the country.

8) Schofield Barracks, Oahu, Hawaii (EPA, Region Nine)

According to Harding Lawson Associates (HLA, 1996), because of site complex volcanic geological site conditions ARARs for restoration of groundwater to MCLs could not be achieved and; therefore, TIW was implemented under the ROD HLA (1996). The ROD indicates that the Schofield is an important aquifer. Using the EPA's criteria for TWI evaluation, this aquifer has hydrogeological characteristics such as high transmissivity and hydraulic conductivity classifies this site in the complex or difficult end of the spectrum for restoration.

Another measurable factor listed is contaminant distribution, and in this case according to HLA (1996), the contaminated groundwater at the site is approximately 600 feet deep. Such a depth makes restoration of the aquifer very challenging and expensive. The ROD called for an ongoing groundwater monitoring program will be applied to evaluate varying aquifer conditions over time. A TIW is in place because of complex geology, contamination in groundwater at depth, and length of time estimated to reach groundwater cleanup standards.

9) Eielson Air Force Base, Alaska (EPA Region Ten)

According to the EPA (2007a) Eielson Air Force Base is located just outside of the City of Fairbanks, and it's site history dates back to 1944 for providing tactical support.

Based on the EPA information this site has PCBs, metals, and VOCs that have contaminated soil and groundwater. Lead was found in the groundwater which the Air Force was granted a TIW for waiving the action level for lead. The site also reported the presence of NAPL in some portions of the site. The geology consists of glacial outwash with high hydrogeological characteristics. The TIW zone for this site extends to approximately 30 feet deep, which is actually relatively shallow. On-going monitoring is conducted on an annual basis. Land Use Controls remain in place as well. The Air Force estimates that it may take over 100 years to reach groundwater cleanup standards.

Worth noting in the literature review this author found that the EPA documents pertaining to the TIW process indicate one of the primary requirements for obtaining a TIW is the defining of the TIW zone of contamination for the TIW. One source from Laskey et al. (2007) indicates several sites that failed to define the TIW zone. The following is a list: Eielson Air Force Base, Missouri Electric, Schofield Barracks, Milltown Reservoir, and Whitewood Creek to name a few. This information provides further evidence of the EPA's inconsistency between regions and a failure to apply the criteria for TIWs to all approved sites using the EPA guidance.

Case Studies of Qualified Potential TIW Sites

The following case studies are sites that this author considers qualified for a TIW and are summarized in Appendix 2. Also several of these listed sites were in the works of Laskey et al. (2007). In the Laskey et al., study several sites were rated for the Air Force for obtaining a TIW. Some of the data from Laskey et al. (2007), as well as from other resources were investigated in depth and further research was conducted on the EPA database for the individual case studies used in this paper. The case studies described are purposely brief in content, and are for demonstrating the general characteristics of sites, using the EPA's TIW evaluation criteria as described in EPA (1999a) OSWER directive 9283.1-12. It is the opinion of this author, in general the EPA's criteria for determining applicability for granting a TIW of these sites basically met. These sites along with an unknown number of others could significantly impact the financial and environmental of the nation's hazardous waste sites for many years to come if they were properly screened using the EPA criteria and then submitted for approval using the TIW. This would in turn save hundreds of thousands of dollars or perhaps even millions of tax payer dollars being currently spent performing experimental alternatives that are forced on many PRPs by the current regulations.

1) Hanscom Air Force Base, Bedford, Massachusetts (EPA Region One)

This case study information was obtained from the Air Force (2012) fourth five year review, and indicates the typical Superfund VOCs contaminants such as TCE are found in the overburden and more importantly bedrock aquifers. The aquifers are classified as high use and value aquifers Air Force (2012). Three major operable units were defined and six sites remain some with DNAPL are known to be present. Dissolved arsenic is reported present at site six and the five year review indicates that a ROD amendment may be required Air Force (2012). The base history dates back to its use in the 1950s and 1960s. The third five year review, by the Air Force (2012) states that the ROD of 2007 remains protective using groundwater treatment systems and land use controls.

2) Naval Ships Parts Control Center, Mechanicsburg, Pennsylvania (EPA, Region Three)

This case study is located in Mechanicsburg, Pennsylvania. According to the Tetra Tech, report, (2013) it determined that no currently available remedial technology can reliably and safely achieve complete remediation of the deep bedrock groundwater at the site, and that complete flushing, back diffusion of the existing contamination VOCs, and follow-on attainment of cleanup levels will likely take over 100 years. The potential presence of some residual non-aqueous phase liquid (NAPL) at the site could further extend the restoration timeframe significantly. The report also determined that it is technically impracticable to attain compliance with the chemical-specific cleanup goals in the TIW zone in a reasonable timeframe. The presence of compounds of concern (COCs) deep within fractured bedrock matrix at depths of 350 feet is extremely difficult to remediate. Approximately 194,000 gallons of reagent were added in a two-phase four-round process during the 1990s.

The current data indicates that attainment of site groundwater remediation goals is technically impracticable. Trichloroethylene (TCE) and other VOCs were detected in the rock matrix indicating that some contamination has diffused from the groundwater in fractures into the rock mass GSI Environmental (2011). This residual rock mass contamination will act as a long term (over 100 years), low concentration, and residual source of contamination to groundwater through back-diffusion processes.

An alternate remedial strategy, which includes institutional controls was implemented for exposure prevention and deep bedrock plume containment through natural processes has been developed and implemented Tetra Tech (2013). This case study is considered a potential TIW site.

3) Anniston Army Depot, Alabama (EPA, Region Four)

This case study was chosen because it is a classic example of where a TIW should have been granted. The site is located in the EPA Region four, at the Anniston Army Depot in Alabama. The author notes this Region of EPA has granted no TIWs over the last 30 years. Based on the NRC (2013) study this site was used as a case study. This scenario involves one of the more ubiquitous contaminants TCE, which is commonly found at Superfund sites as well as heavy metals. According to the NRC (2013) report, the existing treatment of “pump & treat” is failing to reduce the groundwater contamination to drinking water standards. The system is also failing to control the extent of groundwater contamination; therefore, it is “not protective” (p. 29). Published studies show that pump & treat systems have a history of not living up to expectations, yet it is selected as an alternative strategy for cleanup of aquifers.

The Army was required to pursue additional options for meeting drinking water standards and protectiveness. The NRC (2013) report indicates a vast amount of time greater than 1,000 to 10,000 years may be required to reach drinking water standards (p. 29). The article further indicates that the Army has not been successful in obtaining a TIW for the site. According to the report, land use controls (LUCs) were put in place restricting site use. According to the EPA’s information webpage on the base, it indicates that the Army has taken other measure to protect the human health and safety by continuing to conduct monitoring of groundwater conditions including private water supplies EPA (2013b). The EPA indicates that the Army is continuing to operate groundwater treatment and evaluate alternative remediation strategies EPA (2013b). Based on the information from the NRC and EPA, this brief case study demonstrates a classic case of the restrictive EPA policy on granting the TIW. The case study demonstrates that the time line for cleanup to drinking water standards is well beyond any reasonable time frame and will likely cost millions more to complete and site closure. This is a potential site for a TIW.

4) Air Force Plant 6, Marietta, Georgia (EPA Region Four)

This case study is the former Air Force facility used as an aircraft assembly plant during World War II. The site is over 5,000 acres in size. Groundwater in both overburden and bedrock aquifers are contaminated with VOCs specifically TCE and DNAPL have been reported. Complex geological conditions of fractures, and folds are present in the bedrock Bentkowski (2010). According to the United States Geological Survey (USGS, 2014), this site is extremely difficult to remediate because of the complex geological conditions. The USGS explains further the site history indicates a long term use of solvents and has DNAPLs present. Several various technologies have been implemented including microbiological, chemical oxidation and permeable reactive barriers. EPA Region four according to Bentkowski (2010), recognizes that the presence of DNAPL in the bedrock presents a remedial challenge with no estimated cleanup time frame or method.

5) Tinker Air Force Base, Oklahoma (EPA Region Six)

This is an active Air Force base for the aircraft maintenance and repair and is over 5,000 acres and houses over 500 buildings B & V Waste Science and Technology Corp (1993). The groundwater contamination includes VOCs specifically chlorinated solvents and hexavalent chromium. The site known as building 3001 is operating under the ROD of 1990 and has an existing groundwater treatment system designed to remediate the aquifer. Two water supply wells at building 3001 have been abandoned as a result of contamination. Groundwater is estimated to range from 20 to 270 feet. The site, Solders Creek is considered to be protective of human health and the environment and the selected method of treatment is monitoring. According to the ROD prepared by B & V Waste Science and Technology Corp, (1993), this decision was made, because the contaminate levels did not exceed the risk assessment “carcinogenic” values.

6) Former Williams Air Force Base, Mesa, Arizona (EPA Region Nine)

This former Air Force base encompasses some 4,000 acres and like many DOD sites, was built in the 1940s to support the war effort. This was the location for flight training schools for pilots. VOCs such as TCE and PCE have been found in different sites at the base and are one the primary groundwater contaminants. It is estimated that jet fuel ranging from 640,000 to 12 million gallons have been released EPA (2013c). LNAPL remains in the aquifer considered to be a valuable drinking water source. The upper aquifer has groundwater depth from 140 to 240 feet below grade and is comprised of sand and gravel. For operable unit (OU2) the Air Force is currently using a pump and treat system and thermally enhanced extraction EPA (2013c). It should be noted, that pump treat testing suggests it may not be the best remedial alternative, and furthermore, the Air Force attempted based on prior studies to use other technology-strategy but had resistance from the regulatory community and was forced into the current alternative methods.

7) McClellan Air Force Base, Sacramento, California (EPA Region Nine)

This former Air Force base was established in 1936 and was used for maintenance, and repair of aircraft and various equipment repair EPA (2014c). This base like many others is contaminated with VOCs, PCBs, and heavy metals. Drinking water supply wells were impacted and replaced with an alternative water supply. The facility has a base wide ROD for groundwater and a groundwater treatment system and extracts over 1,500 gallons of groundwater per minute. Based on computer modeling, it is estimated that groundwater cleanup will last 55 years in order to reach MCLs for TCE EPA (2014c).

Significance of this Study

This research demonstrates why the EPA's current policy on TIWs is too restrictive, ineffective, inconsistent among Regions, costly, and outdated. The policy should be changed to become less restrictive using the EPA criteria for TIW evaluations. A more middle-of-the-road approach should be used in the decision model of the TIWs. Given the increasing cost and complexity of many site cleanups, the need is there for selective managing of these sites. It is understood that the policy is to provide for the reuse of contaminated groundwater back to beneficial use within a reasonable time frame. While the enforcement of the drinking water standards is a noble cause, 30 years of evidence suggest it is not practicable to meet such strict standards everywhere. It is well known that many of these Superfund sites along with other hazardous waste sites throughout the country have been a technological and financial challenge to remediate. The current political attitude is for reduced environmental funding to most government agencies, this will only exacerbate the problem, duration and therefore increase cost to complete cleanup.

Given the extreme cost of remediation in situations that are not practicable to cleanup, it would be prudent to change the current model. Today, perhaps more than ever, with reduced funding for government agencies, and shrinking budgets, it is a moral and ethical requirement that funds be appropriately allocated in the cleanup of the most hazardous of the CERCLA sites. An amended TIW process that is less restrictive could continue to provide for the protection outline by CERCLA. Many of the DOD (2013) agencies consider themselves as “Stewards of the taxpayer”, an EPA policy change might very well give credence to this statement, while saving the taxpayers potentially billions of dollars. This in turn would realign the use of such funds to cleanup more perilous sites. This is an area of needed research that should be completed to fill in the data gaps and improve the EPA’s TIW program.

Financial Analysis

A brief financial analysis was conducted using the existing information available from various public (EPA, and DOD) sectors. When discussing financial aspects of environmental remediation, one must consider the cost of cleanup methods used to meet the regulatory standards. The cost of meeting the regulatory compliance over the years has only increased, even though technology has improved and methods have become more efficient at removing contaminants. The, groundwater sites that are contaminated with chlorinated compounds, NAPL, and DNAPL in complex geological setting continue to pose a great challenge. An article by Hardisty and Ozdemiroglu (2005) points out that these complex issues have been ongoing for a very long time and are a well-documented area of research.

Hardisty and Ozdemiroglu (2005), provide an economic approach that is recommended for selection of the best method of remediation for complex cases. This helps to provide a path forward for consideration when weighing the benefits of attempting to restore an aquifer to achieve regulatory standards. In their paper the authors point out that one should consider using this economic approach when faced with the possibility of using a TIW.

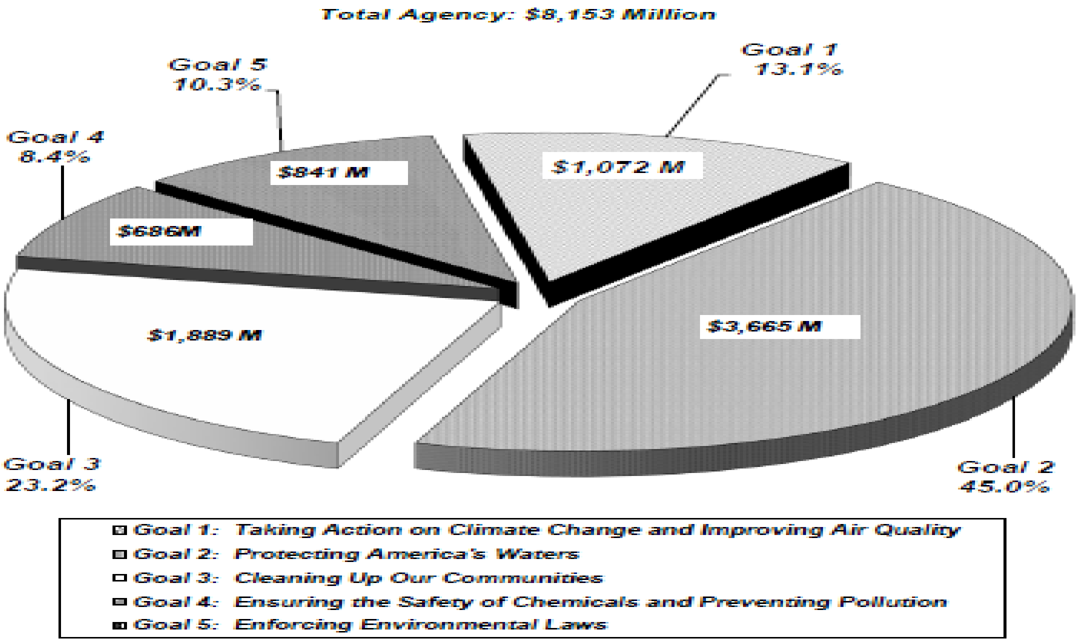
The Hardisty and Ozdemiroglu (2005) article shows a case example that, when faced with the remediation of NAPL in a complex geological setting, and the technology at the time, the benefits would not outweigh the cost associated with the restoration process. Perhaps one of the most important points the authors make is when one is dealing with contaminants that are not fully delineated because of complex geological settings, simple restoration methods can fail.

The authors Hardisty and Ozdemiroglu (2005) indicate because of the numerous scientific unknowns associated with investigation and remediation at complex sites, the cost of cleanup tends to be high. The article is instrumental in demonstrating that one is better to take preventive measures sooner than later, and that it avoids additional damages, thereby saving even more cost Hardisty and Ozdemiroglu (2005). From the author's study, when selecting a remedial method and the proposed technology for cleaning up the contamination, the time required to accomplish the cleanup objective must be considered. The total economic costs compared to the benefits should be analyzed. The article shows that in situations where an aquifer is an important resource such as a drinking water supply, it may make economic sense to justify the expenditure of the necessary funds. The article from Hardisty and Ozdemiroglu (2005) also drives home the fact that the less expensive option may not be the most economic if the total cost over time are not correctly calculated. This means in many cases the PRP is focused only on the original estimate for cleanup and not the wider benefits of remediation and the larger picture.

The message from the authors is that one must consider all economics of the big picture when planning a remedial effort for a complex situation and examine the aspects of the value of the aquifer and its potential use for the greater benefit of society. Based on the above study, the cost in many situations does not warrant the level of effort required to meet the regulatory objectives, and in these cases it makes better economic sense to apply for TIW. With this economic approach in mind, the author of this research paper looks at the current funding at the federal level for various agencies within the U.S. government and analyzes the funding set aside for cleanup of the Superfund sites.

The following diagram from the EPA (2013d) "Budget in Brief," describes the current year (FY 2014) financial appropriations set by EPA (p. 11). The pie chart shows the various areas of fund distribution by goal, the largest Goal 2 of (45%) being for the "Protection of America's Waters", followed by "Cleanup of Our Communities",

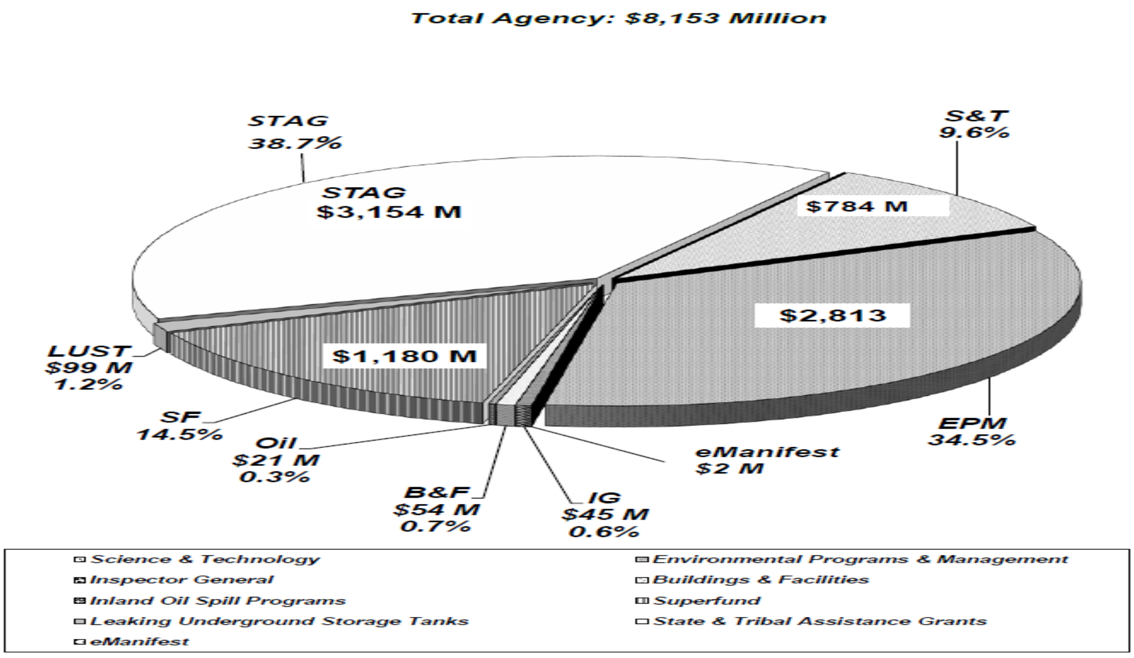
Figure 5: EPA's FY 2014 Budget By Goal (Source: EPA, 2013d)



Note: Totals may not add due to rounding.

23.2%, and then the other categories. The various goals have subcategories and for the Goal 2 the protection of waters, this includes funding for drinking water programs and drinking water standards etc. For 2014, this is an increase in the appropriation of approximately five million dollars EPA (2013d). Yet, one must keep in mind the general category incorporates a very wide range of drinking water issues and projects.

Figure 6: EPA's FY 2014 Budget By Appropriation (Source: EPA, 2013c)



Note: Totals may not add due to rounding.

It should be noted, this diagram does not depict the land control which the EPA categorizes Superfund as a part of this analyses. The EPA (2013d) report does indicate that within the program the budget was cut $1.8 million down to $187.8 million and the

EPA has to manage approximately 170 remediation sites where no PRP has been identified. The report goes on to indicate the EPA remains protective of human health and the environment despite the reduction in funding.

The above diagram shows the current FY year 2014 funding for Superfund managed projects is only 14.5 % or approximately 187.8 million dollars. This represents a reduction of approximately $33 million dollars for the Superfund program. One must realize that these funds are distributed over many sites and prioritized. Therefore, only limited advancement toward closure can be achieved at various sites controlled by EPA. The EPA (2013d) claims that a rebalancing of funds to complete sites in various stages instead of starting new projects will occur (p. 22). The EPA report does not explain which sites and the amounts of funds will be appropriated to each location. The EPA (2013d) does note that as many as 40 to 50 construction projects will be unfunded as a result of budget reductions.

Based on a review of the DOD Fiscal Year 2012 Defense Environmental Programs Annual Report to Congress, DOD (2013), the budgets for various DOD departments are summarized for the years 2008 through 2013 for the Installation Restoration Program (IRP). The table also includes the Base Alignment and Closure (BRAC) and Formally Used Defense Sites (FUDs) data. While the data do not specifically list the estimates for appropriations of funds for NPL sites from each agency, it does indicate the overall trend in the reduction of general funding for the years 2008 to 2013 and the proposed year 2014 estimate. The total requested is $886 million dollars for the active IRP for

Table 1: DOD's Installation Restoration Program Funding

(Source: Department of Defense, 2013)

	FY 2008 Actual	FY 2009 Actual	FY 2010 Actual	FY 2011 Actual	FY 2012 Actual	FY 2013 Estimated	FY 2014 Requested
Active Installations							
Army	$396.	$337.3	$327.8	$236.6	$263.4	$253.3	$220.0
Navy*	$261.	$245.5	$247.7	$246.9	$251.3	$246.7	$252.0
Air Force	$414.	$387.8	$393.7	$448.8	$480.6	$454.6	$405.3
Defense-wide	$14.	$11.5	$15.2	$10.1	$11.7	$11.1	$8.8
Active Total	**$1,087.**	**$982.1**	**$984.4**	**$942.4**	**$1,007.0**	**$965.7**	**$886.1**
FUDS Properties							
FUDS Total	**$153.9**	**$167.6**	**$164.5**	**$243.0**	**$214.3**	**$169.4**	**$168.1**
Legacy BRAC Locations							
Army	$53.8	$34.0	$77.7	$50.5	$38.6	$46.5	$96.3
Navy*	$268.2	$219.2	$201.5	$130.3	$180.5	$116.0	$115.3
Air Force	$118.3	$112.3	$108.3	$110.6	$90.6	$112.6	$118.0
Defense-wide	$3.6	$2.6	$4.0	$0.0	$0.0	$0.0	$0.0
Legacy BRAC Total	**$443.9**	**$368.1**	**$391.5**	**$291.4**	**$309.7**	**$275.1**	**$329.6**
BRAC 2005 Locations**							
Army	$4.3	$17.5	$8.9	$7.9	$46.4	$19.2	$0.0
Navy*	$16.2	$2.6	$13.7	$12.9	$32.9	$8.1	$0.0
Air Force	$0.0	$0.0	$14.8	$3.0	$1.6	$1.6	$0.0
Defense-wide	N/A	N/A	N/A	N/A	N/A	N/A	N/A
BRAC 2005 Total	**$20.5**	**$20.1**	**$37.4**	**$23.8**	**$80.9**	**$28.9**	**$0.0**
DOD Total++	**$1,705.4**	**$1,537.9**	**$1,577.8**	**$1,500.6**	**$1,611.9**	**$1,439.1**	**$1,383.8**

* DON includes Navy and Marine Corps, as these DOD Components manage Environmental Restoration as a combined program.

+Defense-wide accounts include other defense agencies and DLA. DLA does not have BRAC 2005 locations.

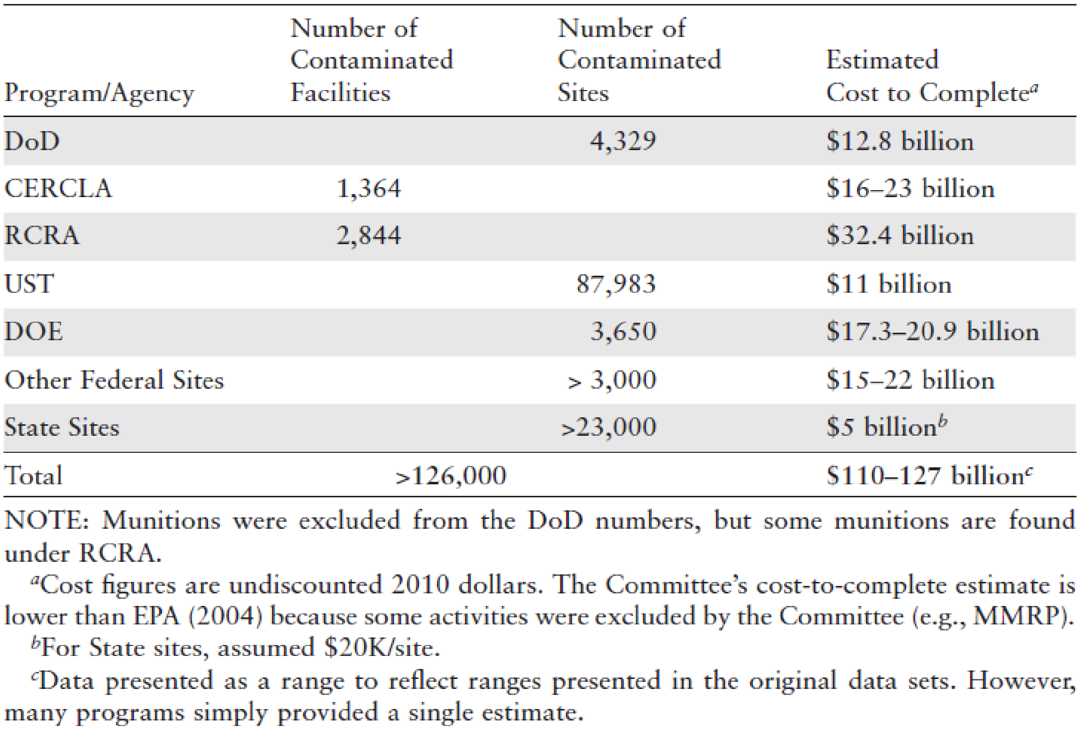
** The Legacy BRAC and BRAC 2005 accounts are merging in FY 2014.

++Due to rounding, subtotals may not equal FY totals.

all the agencies. The legacy BRAC sites total is estimated at $329 million. This also indicates a decreasing trend in funding. The DOD confirms that some of the legacy sites that remain are due to complex groundwater contaminated sites and because of the limitations in technology for cleanup, these sites have slowed the DOD from reaching their goals. The DOD points out of some IRP 38,000 sites, over 29,000 are now in monitoring or complete DOD (2013).

The following Table 2 from the NAS (2013) depicts the various program agencies and the estimated number of contaminated facilities and the estimated cost to complete. Specifically the information of interest from NAS (2013) the estimated number of CERCLA facilities (1,364) and the estimated number of contaminated sites (4,329) and the estimated total cost to complete $12.8 billion dollars for the DOD sites (p. 69), based on 2010 dollar value. The table puts the problem into perspective as evidence of the significant financial commitment that will be required to achieve closure at these sites. The CERCLA estimate is even greater than the DOD at $16-$23 billion dollars. Based on these estimates combined with the current EPA estimated budgets one can understand the enormity of the management issues facing the various PRPs. The other programs-agencies listed such as RCRA, UST, DOE, state, and other sites and are not part of this research and therefore are omitted from the discussion.

Table 2: DOD's IRP Estimated Number Of Active & Cost To Complete Sites (Source: Reprinted with permission from the National Academy of Sciences, Courtesy of the National Academies Press, 2013)



Program/Agency	Number of Contaminated Facilities	Number of Contaminated Sites	Estimated Cost to Complete[a]
DoD		4,329	$12.8 billion
CERCLA	1,364		$16–23 billion
RCRA	2,844		$32.4 billion
UST		87,983	$11 billion
DOE		3,650	$17.3–20.9 billion
Other Federal Sites		> 3,000	$15–22 billion
State Sites		>23,000	$5 billion[b]
Total	>126,000		$110–127 billion[c]

NOTE: Munitions were excluded from the DoD numbers, but some munitions are found under RCRA.

[a] Cost figures are undiscounted 2010 dollars. The Committee's cost-to-complete estimate is lower than EPA (2004) because some activities were excluded by the Committee (e.g., MMRP).

[b] For State sites, assumed $20K/site.

[c] Data presented as a range to reflect ranges presented in the original data sets. However, many programs simply provided a single estimate.

Research Data Collection

The methodology for this research is based on the identification and review of existing information from publicly available documents from various agencies and sources. In addition keyword searches of various databases were performed. Information and data searches were conducted from online sources to identify and use material pertaining to the TIW approval process from the EPA's National Center for Environmental Publications and as well as other databases. A review of the various applicable regulations were obtained and completed. The research methods used are a combination of quantitative and qualitative methods. Case studies where data is analyzed using EPA's criteria are represented. Table 1 from the EPA (1993) depicts examples of factors affecting groundwater restoration. It is this decision tool that the EPA uses in determining the TIW justification for approval. This research investigates and challenges the overall paradigm that sites must meet the most complex criteria as outlined in the diagram in order to be granted a TIW. It is worth noting despite changes within EPA's policy on TIW over time, EPA still looks at Superfund sites with DNAPL as major criteria for granting TIWs. As previously mention, based on EPA (2012a) data, only a total of 91 TIWs have been approved. The case studies of the approved sites meet the general specifications outlined in the attached Table. It should be noted some of the approved TIW case studies used do not meet all the criteria used in the analysis of granting a TIW. The table depicts various criteria and the degrees of difficulty for restoration. This includes the five major categories:

Site Use: Large volume releases, long duration, and continual release compared to small volumes, short duration and intermittent releases.

Chemical Properties: Biotic-abotic decay, volatility, and contaminant retardation potential based on high rates compared to low rates of decay and volatility etc.

Contaminant Distribution: Contaminant phase, volume of contaminated media, and contaminant depth where dissolved aqueous concentrations compared to DNAPL presence, shallow compared to deep (200+ft).

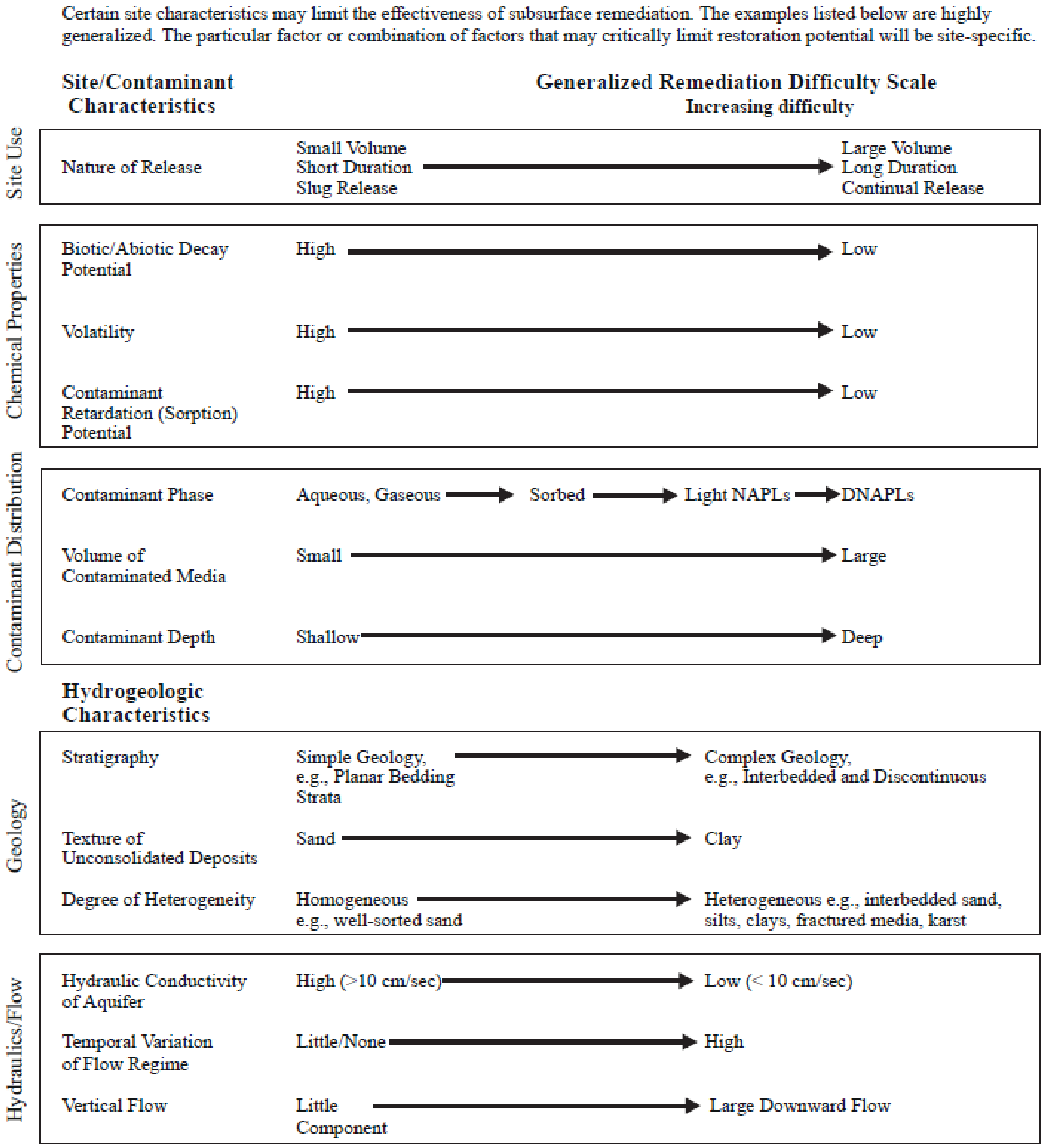
Geology: Stratigraphy, texture of unconsolidated deposits (clays compared to coarse sands), and degree of heterogeneity where geology is simple compared to complex fractured bedrock or karst geology.

Hydraulic Flow: Hydraulic conductivity of aquifer, temporal variation of flow regime, and vertical flow for aquifer characteristics compares low conductivity and flow rates to high rates.

As noted by as far back as 1998, the DOE (1998) EPA views the sites that fall into the more difficult side of the spectrum tend to be potential selection for a TIW. At the time of the DOE (1998) report, DNAPLs accounted for the majority of TIW approvals. DOE report noted in 1998, the TIW evaluation process consisted of the EPA evaluating sites specifics such as: ARARs, the proposed TI zone, the conceptual model, restoration potential, and the cost estimate. The research shows this approach has changed little, but remains inconsistent between the various regions.

Table 3: EPA's General TIW Evaluation Criteria

(Source: EPA, 1993)



Certain site characteristics may limit the effectiveness of subsurface remediation. The examples listed below are highly generalized. The particular factor or combination of factors that may critically limit restoration potential will be site-specific.

	Site/Contaminant Characteristics	Generalized Remediation Difficulty Scale Increasing difficulty	
Site Use	Nature of Release	Small Volume Short Duration Slug Release →	Large Volume Long Duration Continual Release
Chemical Properties	Biotic/Abiotic Decay Potential	High →	Low
	Volatility	High →	Low
	Contaminant Retardation (Sorption) Potential	High →	Low
Contaminant Distribution	Contaminant Phase	Aqueous, Gaseous → Sorbed → Light NAPLs →	DNAPLs
	Volume of Contaminated Media	Small →	Large
	Contaminant Depth	Shallow →	Deep
	Hydrogeologic Characteristics		
Geology	Stratigraphy	Simple Geology, e.g., Planar Bedding Strata →	Complex Geology, e.g., Interbedded and Discontinuous
	Texture of Unconsolidated Deposits	Sand →	Clay
	Degree of Heterogeneity	Homogeneous e.g., well-sorted sand →	Heterogeneous e.g., interbedded sand, silts, clays, fractured media, karst
Hydraulics/Flow	Hydraulic Conductivity of Aquifer	High (>10 cm/sec) →	Low (< 10 cm/sec)
	Temporal Variation of Flow Regime	Little/None →	High
	Vertical Flow	Little Component →	Large Downward Flow

V. SUMMARY OF DATA ANALYSIS

The data analysis is summarized in Appendix 1 the Evaluation of NPL Sites with Approved Waivers and depicts the various site characteristics plotted against sites located in the various eight of the nine EPA Regions for locations with TIW approved sites. Region four was omitted because they not have any approved TIW sites and therefore, no example was included in this section of discussion. The analysis of the data demonstrates that four sites had NAPL or DNAPL present of the nine sites used in the case study. Although required in the TIW approval process, some of these sites did not have the TIW zone delineated. The majority id impacted drinking water supplies. The cost for site cleanup is either still to be determined or was estimated to be very high. The time for estimated cleanup of these sites are either unknown or greater than 100 years.

The second case study section is for the list of potential sites that are deemed qualified for a TIW. Appendix 2 summarizes the list of sites. Using the EPA's methodology, for evaluating TIWs, the case studies that were reviewed appear to be qualified for TIWs. The analysis depicts seven sites located in various EPA Regions including EPA Region four. Based on the EPA criteria, all of the sites appear to be potentially good for obtaining TIWs if submitted to the EPA for approval. The majority of the sites meet the various criteria as plotted in Appendix 2. Some of the sites have either DNAPL of complex geological conditions associated with them. Many of the Appendix 2 sites are very similar to the approved sites found in Appendix 1.

The estimated cleanup times are either unknown or over 100 years. Four sites have impacted drinking water supplies. The cost of cleanup is yet to be determined for most of these sites. However, the data suggest cost to be in the millions of dollars.

Limitations of Research

This research is limited to data for each case study; therefore, the conclusions are equally limited. This research is based on the availability of information contained in the sources used in the study. The research was limited to a select number of NPL sites used in the study. The greater number of sites that can be used would increase the significance of the data. An attempt was made to research all pertinent databases available, from federal sources as well as others sources. No research can guarantee the extent of the comprehensiveness of the study. This document does not provide assurance that every document pertaining to the TIW process has been found and reviewed. The TIW data analysis included the review of several CERCLA sites using keyword identification search within various databases. A discussion of common characteristics and other commonalties of various TIW sites were made. These data sources were obtained from publically available documents. In addition, the EPA's National Service Center for Environmental Publications was reviewed for data sources.

The number of TIWs not approved by EPA is unknown and could be object of future research.

VI. CONCLUSIONS

Results

Since 1980 the EPA has granted only 91 TIWs as of 2011 and appears to use the authority to grant TIWs sparingly. The data indicate that most of these approved TIW sites have groundwater contamination with the presence of DNAPL and complex conditions that prevent technology from achieving regulatory requirements such as MCLs. Furthermore, the data suggest that the EPA is inconsistent in the application of TIWs between the various Regions; Region four is excluded in the case studies because no TIWs have been approved. In any event, a great disparity in the number of TIWs granted between the various EPA Regions exists. This research shows that several sites that have been granted a waiver, some are well defined, however, some are not as well defined. In fact some sites fail to have the TIW zone defined at all as required by the EPA's own criteria for TIWs.

The Appendix 2 summary of case studies are sites that have not been submitted for a TIW. These sites have complex hydrogeological situations and meet most of the EPA's criteria for a TIW. The reasons may either because the PRPs have not wanted to spend the funds and time since the TIW process is very time consuming and expensive, or perhaps of regulatory resistance toward the TIW. The data also supports the theory that the EPA's practice-policy is to not grant many TIWs. The research suggest the policy and not so much the science is restrictive and is responsible for preventing more TIWs from being granted. After reviewing several sites in EPA Region four, it is apparent, that given the similar scientific criteria for granting TIWs in other Regions, this particular EPA Region chooses to not to approve TIWs. One other reason could be PRPs know that the Region's policy is against the approval of the TIW and they choose not to pursue such time consuming process. In any case, the limited EPA policy toward TIWs is well known through the environmental world. It is estimated that billions of dollars have and will continue to be expended in an attempt to address these sites in order to meet the EPA's requirement for attaining drinking water standards. The data confirms that the more complex sites remain and are the greatest challenge for the PRPs and regulatory agencies to remediate. The data also suggest that funds should be better appropriated and the correct alternatives should be selected, and in cases where it appears that the groundwater will not meet the remedial objective, a TIW should be implemented. The EPA, DOD and other agencies have seen a significant reduction in the FY 2014 allocated to the cleanup of Superfund sites. Based on the research it is apparent that many legacy CERCLA sites of both private and public PRPs remain a financial burden-challenge for clean-up. The data analysis of the second series of case studies indicates that using the EPA's criteria, several sites used in the analysis merit a TIW.

Discussion

This research demonstrates that the economics of each individual site must be considered when selecting a potential remedial strategy. The least expensive initial remedy may not be the best economically over the many years required to reach closure. The federal agencies are considered “Stewards of the tax payer’s funds”, and therefore, have a duty to consider the best remedial alternative and use proper method of economic analysis to make the selection of the correct alternative. In cases where the selected alternative fails or does not meet the regulatory objective, the TIW should be considered. At the federally managed sites, because of less funding, less work will likely be completed and the progress toward construction complete and site closure will be reduced. The evidence suggests that a change in EPA’s policy toward granting more TIWs would be advantageous in the short term. This would beneficial at least until better technology can be developed to remediate these residually complex sites.

Recommendations for Future Research

The result of this study indicates that there is a need for additional research into the number of TIWs that have not been approved. This data could be reviewed to make sure it is consistent with the TIW process for approving TIWs on a national scale. This may improve the EPA’s current policy.

This could lead the EPA to focus on the more complex sites and ensure that funding is being appropriated for the most critical sites.

This author also recommends based on the available data, that the EPA consider updating its guidance for TIWs while expanding the use of the TIW. It is also recommended that the EPA's policy on TIWs be consistent between all regions. An increase of number of approved TIWs would have significant economic and environmental benefits for the taxpayer and PRPs.

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APPENDIX 1: EVALUATION OF NPL SITES WITH APPROVED TIWS

Appendix 1: Evaluation Of NPL Sites With Approved TIWs

Site / Contaminant Characteristics	*Site Name* *EPA -*	Pease Air Force Base NH Region 1	GE Moreau NY Region 2	Rodale Manufacturing PA Region 3	Continental Steel IN Region 5
Site Use:		🟢	🟢	🟡	🟢
Chemical Properties:	🟢 : Supports TIW	🟢	🟡	🟢	🟢
Contaminant Distribution:	🟡 : Marginally Supportive	🟢	🟢	🟡	🟢
Geology:	🔴 : Not Supportive	🟢	🟡	🟢	🟢
Hydraulics / Flow:	⚫ : No Data	🟢	🟡	🟡	🟢
Fiscal - Other Constraints -					
Drinking Water Supply Impact:	**No / Yes**	**Yes**	**Yes**	**Yes**	**Yes**
Total Estimated Cost To Clean-Up Suspect Site:	**Millions of Dollars**	**100+**	TBD	**4+**	**6**
Estimated Time Required To Clean-Up Suspect Site:	**Years**	TBD	**200+**	**100+**	**30**

Appendix 1: Evaluation Of NPL Sites With Approved TIWs

Site / Contaminant Characteristics	*Site Name* *EPA -*	Crystal Chemical Co TX Region 6	Missouri Electric MO Region 7	Silver Bow MT Region 8	Schofield Barracks HI Region 9
Site Use:		🟡	🟢	🟢	🟢
Chemical Properties:	🟢 : Supports TIW	🟢	🟢	🟢	🟢
Contaminant Distribution:	🟡 : Marginally Supportive	🟢	🟢	🟢	🟢
Geology:	🔴 : Not Supportive	🟡	🟢	🟡	🟢
Hydraulics / Flow:	● : No Data	🟡	🟢	🟡	🟢
Fiscal - Other Constraints -					
Drinking Water Supply Impact:	**No / Yes**	**No**	**No**	**Yes**	**Yes**
Total Estimated Cost To Clean-Up Suspect Site:	**Millions of Dollars**	TBD	TBD	**Billions**	**Very High**
Estimated Time Required To Clean-Up Suspect Site:	**Years**	TBD	TBD	**Unknown**	**100+**

Appendix 1: Evaluation Of NPL Sites With Approved TIWs

Site / Contaminant Characteristics	*Site Name* *EPA -*	**Eielson Air Force Base AK** **Region 10**
Site Use:		🟢
Chemical Properties:		🟢
Contaminant Distribution:		🟢
Geology:		🟡
Hydraulics / Flow:		🟡
Fiscal - Other Constraints -		
Drinking Water Supply Impact:	**No / Yes**	**Yes**
Total Estimated Cost To Clean-Up Suspect Site:	**Millions of Dollars**	**10**
Estimated Time Required To Clean-Up Suspect Site:	**Years**	**100+**

- 🟢 : Supports TIW
- 🟡 : Marginally Supportive
- 🔴 : Not Supportive
- ⚫ : No Data

APPENDIX 2: EVALUATION OF POTENTIAL TIW SITES

Appendix 2: Evaluation Of Potential TIW Sites

Site / Contaminant Characteristics	*Site Name* *EPA -*	Hanscom Air Force Base MA Region 1	NSPCC Mechancisburg PA Region 3	Anniston Army Depot AL Region 4	Air Force Plant 6 GA Region 4
Site Use:		🟢	🟢	🟢	🟢
Chemical Properties:	🟢 : Supports TIW	🟢	🟡	🟢	🟢
Contaminant Distribution:	🟡 : Marginally Supportive	🟢	🟢	🟢	🟢
Geology:	🔴 : Not Supportive	🟢	🟢	🟢	🟢
Hydraulics / Flow:	⚫ : No Data	🟢	🟢	🟢	🟢
Fiscal - Other Constraints -					
Drinking Water Supply Impact:	**No / Yes**	**Yes**	**No**	**No**	**Yes**
Total Estimated Cost To Clean-Up Suspect Site:	**Millions of Dollars**	**120+**	**20**	TBD	TBD
Estimated Time Required To Clean-Up Suspect Site:	**Years**	**100+**	**100**	**100+**	**100+**

Appendix 2: Evaluation Of Potential TIW Sites

Site / Contaminant Characteristics	*Site Name* *EPA -*	Tinker Air Force Base CA Region 6	Williams Air Force Base AZ Region 9	McClellan Air Force Base CA Region 9
Site Use:		🟢	🟢	🟢
Chemical Properties:		🟢	🟢	🟢
Contaminant Distribution:		🟢	🟢	🟢
Geology:		🟡	🟡	🟢
Hydraulics / Flow:		🟢	🟢	🟢
Fiscal - Other Constraints -				
Drinking Water Supply Impact:	**No / Yes**	**Yes**	**No**	**Yes**
Total Estimated Cost To Clean-Up Suspect Site:	**Millions of Dollars**	TBD	TBD	**17**
Estimated Time Required To Clean-Up Suspect Site:	**Years**	**100+**	TBD	**200+**

🟢 : Supports TIW
🟡 : Marginally Supportive
🔴 : Not Supportive
⚫ : No Data