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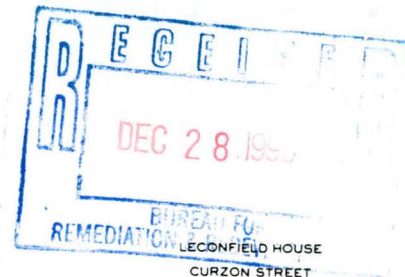
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December 21, 1998

By Federal Express

Mr. Binyoti Amungwafor  
Wisconsin Department of Natural Resources  
DNR SER HQ - RR  
2300 N. Martin Luther King Dr.  
Milwaukee, Wisconsin 53212

Dear Mr. Amungwafor:

Gary Edelstein has requested that I forward a copy of my letter and enclosure of December 18, 1998, to U.S. EPA.

Please feel free to contact me if you have any questions.

Very truly yours,

Richard A. Meserve

cc: Gary A. Edelstein, P.E

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December 18, 1998



By Federal Express

Mr. Russell D. Hart  
Remedial Project Manager (HSRW-6J)  
U.S. Environmental Protection Agency  
Region V  
77 West Jackson Boulevard  
Chicago, Illinois 60604

Re: Moss-American Site, Milwaukee, Wisconsin

Dear Mr. Hart:

I am writing to follow up on my letter of November 19, 1998, and on our telephone conversation on December 8, 1998, concerning the Amended ROD for the above-captioned Site. Although Kerr-McGee Chemical LLC ("Kerr-McGee") heartily endorses some aspects of the Amended ROD – including, in particular, EPA's recognition that the use of a bioslurry reactor is infeasible and its application of revised cleanup standards for PAHs – other aspects of the Amended ROD are very troublesome. In Part I of this letter, I discuss some of these concerns. Then, in Part II, I discuss how these matters might be resolved.

I.

I enclose an analysis of the Amended ROD that has been prepared by Roy F. Weston, Inc. ("Weston"). Perhaps the most significant problem with the Amended ROD is that EPA has established a significant new cleanup requirement – namely, EPA now directs that soils with concentrations of naphthalene at or in excess of 0.4 ppm must be excavated and treated in the thermal desorption unit. Weston estimates that this single change will increase the volume of soils that must be treated to approximately 125,000 cubic yards. This is of great significance because EPA premises its analysis in the Amended ROD on the incorrect assumption that only 20-30,000 cubic yards of material would require treatment at the Site.

Mr. Russell D. Hart  
December 18, 1998  
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Amended ROD, at 8. In short, the new naphthalene standard is by far the most important cleanup criterion that EPA has established.

As discussed by Weston, a review of the Wisconsin regulations (and associated guidance materials) shows that EPA should not have imposed a rigid naphthalene limit of 0.4 ppm. The limit is purportedly derived from Wisconsin regulations that establish certain residual contaminant levels ("RCLs") for the protection of groundwater. Although the Wisconsin Department of Natural Resources ("WDNR") has established a generic RCL for naphthalene of 0.4 ppm, WDNR specifically advises that "[t]he use of these suggested generic values for decisions regarding a given site . . . without full consideration of their context and qualifications on their use is not appropriate." WDNR, Soil Cleanup Levels for Polycyclic Aromatic Hydrocarbons (PAHs) Interim Guidance (Apr. 1997) (emphasis in original). The Weston analysis shows that the WDNR regulations provide significant flexibility with respect to such RCLs and that EPA should have allowed Kerr-McGee the full benefit of the regulatory scheme. A sensible application of the WDNR regulations would not have required the extensive excavation and treatment that EPA now demands to address the presence of naphthalene.

Suffice it to say, EPA did not provide Kerr-McGee with an opportunity to comment on this issue in the review that led up to the Amended ROD. The Proposed Plan makes no mention of the fact that EPA was proposing to alter the cleanup criteria in a fashion that would radically expand Kerr-McGee's obligations. As a result, EPA has failed to comply with 40 C.F.R. § 300.430(f)(3) in connection with the Amended ROD because Kerr-McGee and others were deprived of the opportunity to comment on perhaps the single most important change in the remedy. Moreover, because EPA has misstated the volumes associated with its new cleanup levels, EPA cannot have undertaken the required balancing of cost, environmental, and other factors that are associated with the selection of the remedy. 40 C.F.R. § 300.430(f)(1). In short, EPA's actions in connection with its promulgation of the Amended ROD were arbitrary and capricious and not in accordance with law.

Moreover, as discussed in the Weston memorandum, there are a variety of other aspects of the Amended ROD that raise the same problems. The areas of controversy include the following:

- The Amended ROD would require remediation of the entire length of the Little Menomonee River (the "River") to the confluence with the Menomonee River on the incorrect premise that background is 15 mg/kg. This would effectively require cleanup to levels below background in Mile 5 of the River.

Mr. Russell D. Hart  
December 18, 1998  
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- The Amended ROD needlessly requires a 54-inch cover over treated materials so as to provide groundwater protection. Since the treated materials must satisfy RCLs for groundwater, it is pointless to require a cover design that limits infiltration.
- The Amended ROD limits cover options on the railroad property in a fashion that may needlessly restrict the efficient usage of that property.
- The Amended ROD, by requiring that all deed restrictions must be in place within 180 days, is needlessly restrictive. EPA, through its inclusion of the generic naphthalene groundwater RCL, has significantly altered the remedy, which may well require extensive discussion with affected landowners.

Although all of these changes are troublesome, Kerr-McGee is particularly aggrieved by EPA's announcement that sediment cleanup would include cleanup of Mile 5 of the River. This need not - and should not - have been an element of the Amended ROD because EPA purports to have postponed resolution of River-related issues. Proposed Plan, 5 (March 1998). Moreover, we find EPA's justification for this change to be nothing short of astonishing. In a context in which the parties were focusing on remediation of only miles 1-3 and approximately one half of mile 4, Kerr-McGee, in an effort to reach a compromise, proposed that the parties apply a background limit of 15 mg/kg in the areas to be remediated. Now, EPA seizes on Kerr-McGee's proposal and demands that Kerr-McGee conduct remediation to 15 mg/kg throughout the River - **even though everyone agrees that the background is far higher than 15 mg/kg in Mile 5.** See Responsiveness Summary, 30. This is patently unfair.

## II.

The various defects in the Amended ROD are very serious and require correction. We suspect that these errors were inadvertent - namely, EPA did not appreciate the consequences of the Amended ROD - and arose because EPA failed to disclose many of the aspects of the Amended ROD to Kerr-McGee and the public before execution. As a result, Kerr-McGee had no way to make its views known until the Amended ROD was issued. (And, as indicated in my letter of November 19, Kerr-McGee did not even receive a copy of the Amended ROD until long after it had been executed.)

We understand that EPA intends to modify the Statement of Work ("SOW") to reflect the Amended ROD and then will seek to amend the Consent Decree. Responsiveness Summary, 2-3. We suggest that it would be appropriate for EPA to defer any such modification of the SOW and amendment of the Consent Decree until the issues that are raised in this letter are resolved and the Amended ROD is corrected. We are hopeful that the problems can be resolved quickly and gracefully so as not to delay progress at the Site.

Mr. Russell D. Hart  
December 18, 1998  
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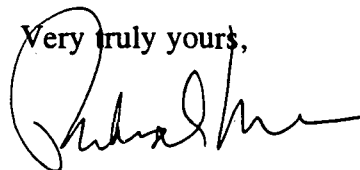
As you know, the Consent Decree refers to the SOW to define Kerr-McGee's obligations. Consent Decree, ¶¶ 11, 12. Because the SOW has not yet been modified to reflect the Amended ROD, the provisions of the Consent Decree that relate to dispute resolution, *id.* ¶¶ 16, 37-43, are not yet ripe for application. We are nonetheless hopeful that this letter will start a process that will allow the amicable resolution of these issues without the invocation of these procedures. We would then be in a position to join with EPA in the modification of the Consent Decree.

\* \* \*

We would be happy to meet with you to discuss the issues raised in this letter and in the enclosed Weston memorandum. Moreover, we would be happy to provide further information about these issues.

Please place this letter and the enclosure in the administrative record that you maintain in this matter.

Very truly yours,



Richard A. Meserve  
Counsel for Kerr-McGee  
Chemical LLC

Enclosure

cc: Maria E. Gonzalez, Esq.  
Gary A. Edelstein, P.E.  
Linda Meyer, Esq.  
Gregory L. Sukys, Esq.

**COMMENTS ON THE AMENDED ROD  
(30 SEPTEMBER 1998)  
MOSS-AMERICAN SITE  
MILWAUKEE, WISCONSIN**

Prepared for

**KERR-McGEE CHEMICAL LLC**  
Oklahoma City, Oklahoma

Prepared by

**ROY F. WESTON, INC.**  
Three Hawthorn Parkway  
Vernon Hills, Illinois 60061

December 1998

This report comments on aspects of the Amended ROD executed by U.S. EPA on September 30, 1998, for the Moss-American Site (Site) in Milwaukee, Wisconsin. In Part I, we discuss perhaps the most serious defect of the Amended ROD—namely, the requirement that soils with naphthalene levels of 0.4 ppm or higher must be treated. In Part II, we discuss a variety of other defects in the Amended ROD.

## PART I

In the Amended ROD U.S. EPA expanded the category for soils requiring treatment to include soils exceeding Wisconsin generic residual contaminant levels (RCLs) for the groundwater pathway for two new constituents of concern (COCs): naphthalene and fluorene. U.S. EPA selected generic groundwater pathway RCLs for naphthalene (0.4 mg/kg) and fluorene (100 mg/kg) and directed that soils with contamination in excess of these levels must be treated. U.S. EPA established these new requirements without giving KMC (or any member of the public) an opportunity to comment on them. Selection of these values (especially for naphthalene) is extremely conservative, is inconsistent with WDNR guidance, and will very significantly increase the volume of soil requiring treatment. This is particularly troublesome since U.S. EPA notes that groundwater usage is not a particularly meaningful exposure pathway at the Site (Responsiveness Summary, p. 8).

The Wisconsin regulation from which U.S. EPA purports to draw the new requirements is NR 720. That regulation addresses soil cleanup standards, referred to as RCLs, that are based upon both the toxicological and physicochemical properties of a contaminant. A single contaminant may have several different RCLs, with each addressing a separate “pathway” of exposure or migration pathway of concern at a site. Pathways identified in NR 720 include:

- Groundwater pathway.
- Direct contact pathway.
- Surface water pathway.
- Pathway to sensitive environments.
- Plant uptake and food chain pathway.

It is the RCLs for the groundwater pathway that are of concern here.

Groundwater pathway RCLs are soil cleanup levels that address the potential for soil contaminants in the vadose zone (i.e., above the water table) to migrate to and adversely impact groundwater. WDNR established generic groundwater pathway RCLs for PAHs in Soil Cleanup Levels for Polycyclic Aromatic Hydrocarbons (PAHs), Interim Guidance, April 1997, by incorporating the concepts of soil: water partitioning and a simple groundwater mixing zone into an algorithm that can be used to calculate generic RCLs. As discussed below, these desktop generic calculations are but one option available for the determination of groundwater pathway RCLs; other site-specific approaches are more appropriate.

**1. Selection of generic groundwater pathway RCLs is inconsistent with WDNR guidance.**

WDNR provides specific guidance concerning the generic RCLs on which U.S. EPA has relied. WDNR states in its Soil Cleanup Levels for Polycyclic Aromatic Hydrocarbons (PAHs), Interim Guidance, April 1997:

*“The use of these suggested generic values for decisions regarding a given site, either by Department staff or other parties, without full consideration of their context and qualifications on their use is not appropriate. The availability of the suggested generic residual contaminant levels (RCLs) for PAHs provided in this guidance is not in any way intended to preclude or discourage site-specific analysis and decisionmaking under s. NR 720.19 Wis. Adm. Code.”*

U.S. EPA simply ignored this explicit guidance.

The WDNR regulations provide that several options are available to establish site-specific soil cleanup standards. NR 720.19(2) and (4); see WDNR Understanding Wisconsin Standards for Cleanup of Contaminated Soil, An Overview of Wisconsin Administrative Code Chapter NR 720, March 1997. These options include:





- a. Groundwater mixing zone. Site-specific information describing the hydrogeology at a site can be used to estimate the groundwater concentration that would result from the dilution and attenuation processes that accompany the mixing of soil moisture with groundwater.
- b. Contaminant transport and fate modeling. Additional or alternative modeling can be used to predict the behavior of soil constituents and their interaction with site groundwater.
- c. Soil leaching tests. Direct leaching of site soil samples under laboratory conditions can be used to determine the groundwater pathway RCL for a given site constituent.
- d. Other methods. Additional unspecified methods that receive WDNR review and approval are appropriate.
- e. Performance standards. Soil performance standards can be developed to address the groundwater pathway. Examples include placement of a barrier cap, and natural attenuation processes.

Because KMC was not given an opportunity to examine these alternatives, practical and viable approaches to addressing groundwater were ignored by U.S. EPA.

Moreover, U.S. EPA also ignored the specific WDNR guidance that the use of generic groundwater pathway RCLs is inappropriate for a site where the contamination is in or immediately adjacent to a shallow water table. The guidance states (Soil Cleanup Levels for Polycyclic Aromatic Hydrocarbons (PAHs), Interim Guidance, April 1997):

*“In cases where PAH-contaminated “soil” lies near or below the water table where it is directly in contact with groundwater during all or part of the year, the use of the suggested generic RCLs based on protection of groundwater quality is inappropriate.”*

Because the Moss-American site has a shallow water table, U.S. EPA’s selection of generic groundwater RCLs runs counter to WDNR guidance for this reason as well.



**2. Soil volume requiring treatment will increase significantly if generic groundwater pathway RCLs are used.**

The areas to be excavated and treated via thermal desorption are identified in Figure 1 of the Proposed Plan and in Figures 5 and 6 of the Amended ROD. Combined soil and sediment volumes requiring treatment are estimated by U.S. EPA to be 20,000 to 30,000 cubic yards in the Amended ROD (page 8, first full paragraph).

A review of the data collected during the Remedial Investigation (RI) and Pre-Design soil sampling indicates that the Proposed Plan and Amended ROD grossly underestimate the soil areas and volumes that will require treatment if the generic groundwater pathway RCLs are imposed. Figure 1 of the Proposed Plan and Figure 5 of the Amended ROD are both based upon pre-Amended ROD KMC/Agency discussions regarding soils that would require treatment by way of low-temperature thermal desorption (LTTD). The estimates were based on the assumption that only soils exceeding any of the following criteria would require treatment:

- Free-product areas.
- Soils containing greater than 78 mg/kg total CPAHs.
- Soils exceeding generic groundwater pathway RCLs for BTEX or benzo(a)pyrene.

In the Amended ROD, U.S. EPA adds the following criterion to the triggers for treatment in the thermal desorption unit:

- Soils exceeding generic groundwater pathway RCLs for naphthalene or fluorene.

In Figure 6 of the Amended ROD U.S. EPA suggests that a relatively small number of soil samples exhibit exceedences of the generic groundwater pathway RCLs for naphthalene and fluorene. The text of the Amended ROD (p. 9) indicates that only 7 RI soil samples indicate an exceedence of the naphthalene groundwater pathway RCL, and 5 soil samples indicate an exceedence of the fluorene groundwater pathway RCL. U.S. EPA also states that there may be “overlap” of the areas requiring treatment based on naphthalene and fluorene groundwater

pathway RCL exceedences, with the areas requiring treatment based on pre-Amended ROD KMC/Agency discussions. U.S. EPA evidently concluded that the impact of requiring treatment of soils containing exceedences of groundwater pathway RCLs for naphthalene and fluorene would be minor, based upon the relatively small number of soil samples showing exceedences of these groundwater pathway RCLs and also based upon their co-location with soils that were otherwise destined for treatment ("overlap").

Unfortunately, U.S. EPA's understanding of the soil data is completely incorrect. Site soil data collected during the RI and Pre-Design investigation indicate that exceedences of naphthalene and fluorene groundwater pathway RCLs in vadose zone soils are far more widespread than U.S. EPA has acknowledged. In fact, Table 1 indicates that there are 33 RI soil samples and 47 Pre-Design soil samples with an exceedence of either the naphthalene or fluorene generic groundwater pathway RCLs.

The areal extent of soils requiring treatment is illustrated in Figure A and is shown to be far more extensive than U.S. EPA has assumed. Areas are identified based upon pre-ROD Amendment KMC/Agency discussions of soils requiring treatment, as well as the expansion of soils requiring treatment based on the new RCLs. Assuming an average depth to groundwater of 4 ft, the soil volume identified in Figure A is approximately 18,000 cubic yards, without addressing naphthalene and fluorene. This volume is consistent with KMC's previous statements and consistent with the estimates in the Amended ROD. However, the estimated soil volume increases to approximately 125,000 cubic yards when the generic groundwater pathway RCLs for naphthalene and fluorene are included.

The Proposed Plan stated that unit costs for thermal desorption are approximately \$75-100 per cubic yard. Requiring thermal desorption treatment of soils exceeding naphthalene and fluorene generic groundwater pathway RCLs is thus estimated to increase remedial costs by approximately \$8.0 million to \$10.7 million for treatment alone. Moreover, the substantial increase in the volume of treated soils resulting from the new RCLs will have a very substantial effect on the schedule and the other costs of remediation. For example, the substantial increase



in volume will create additional challenges and costs associated with soil management (temporary storage, areas for final placement) and the final cover.

**4. Existing pattern of naphthalene groundwater impacts is limited and does not correlate well with more widespread naphthalene detections in soils.**

If the model that was used to justify the generic groundwater pathway RCLs were in fact appropriate for the Moss-American site, then one would expect to find widespread naphthalene groundwater contamination across the Site. That is, because naphthalene contamination of soils has existed at the Site for decades at levels far above the generic RCL, the model on which the RCL is based would predict extensive naphthalene contamination of groundwater. Yet the groundwater data collected during Pre-Design sampling (1995) and the 1998 quarterly groundwater monitoring program indicate only five wells where the naphthalene preventive action limit (PAL) is exceeded (MW-4S, MW-7S, MW-20S, TW-05, and TW-09). [The groundwater exceedences of the naphthalene (8 ug/L) and fluorene (80 ug/L) PALs are illustrated on Figure B.] Thus, while the soil data for the Site suggests a widespread occurrence of detectable naphthalene, there is no evidence for widespread exceedences of the naphthalene PAL in groundwater. Taken together, these data show that the model used to justify the generic groundwater RCL for naphthalene is inappropriate for the Site.

Equally significant, four of the wells with naphthalene PAL exceedences are in the vicinity of free product areas – areas that already have been identified to contain soils requiring treatment for reasons other than the RCLs (Figure B). KMC expects that LTDD treatment of the free product areas will address any meaningful naphthalene PAL exceedences in groundwater. There is no evidence that additional soils require treatment to address naphthalene groundwater concerns.

It bears noting in this connection that the groundwater remedy for the site has been reviewed and approved by U.S. EPA and WDNR. The remedy was based on groundwater impacts identified during the RI and confirmed during Pre-Design investigations. These investigations and this design process clearly established that groundwater impacts were only associated with the few free product areas and adjacent downgradient areas. After exhaustive investigation of the site

over many years, there is no evidence that the generic naphthalene groundwater RCL is a useful indicator of soil naphthalene impacts to groundwater.

**5. Areas of soil requiring treatment will have a potentially severe short-term adverse impact on the ability of the Union Pacific Railroad to conduct its business.**

A substantial area of soil with detectable levels of naphthalene is located beneath existing asphalt or beneath rail sidings on the railroad property (Figure A). The Amended ROD would require excavation and treatment of this soil. But such action can not be accomplished without severely curtailing the business activities on the railroad property for several months. Moreover, the excavation of these materials is unwarranted because: 1) the existing asphalt could be incorporated into a performance standard consistent with WDNR guidance, and 2) groundwater samples from the well installed in this area do not indicate an exceedence of the naphthalene groundwater pathway RCL. There is no justification for the proposed remedial action in this area of the site.

**6. Naphthalene is a prime candidate for soils to be addressed in situ by natural attenuation.**

The Pre-Design bioslurry treatment pilot study confirmed what has been learned at a wide variety of petroleum-release sites – namely, that the small 2- and 3-ring PAHs are more readily biodegraded than the larger 4- and 5-ring members of this group. As discussed previously, the Amended ROD would require treatment of as much as an additional 100,000 cubic yards of soil solely on the basis of exceedence of the generic naphthalene groundwater pathway RCL, in the absence of evidence that indicates a corresponding groundwater problem. Certainly no active remediation of these soils is warranted. Monitoring of natural attenuation processes in the soil is appropriate for this site.

**7. The groundwater pathway RCL for naphthalene is extremely conservative.**

All risk-based cleanup levels are based in part upon a chemical-specific toxicity value. WDNR selected a toxicity value for naphthalene ingestion of 0.004 mg/kg-day (oral reference dose) to address potential noncarcinogenic effects. U.S. EPA, by contrast, established and uses a





naphthalene oral reference dose of 0.020 mg/kg-day [U.S. EPA's Integrated Risk Information System (IRIS), November 1998]. (IRIS is widely acknowledged as a repository for the most recent and carefully evaluated toxicity information.) If all other factors are held constant, use of U.S. EPA's toxicity value for naphthalene would increase the naphthalene groundwater pathway RCL by a factor of five.

The naphthalene groundwater pathway RCL proposed for the Site is also based on the assumption that soils containing naphthalene at levels above the RCL will result in naphthalene leaching to groundwater at levels that will exceed the PAL established for naphthalene in NR 140. Since naphthalene is noncarcinogenic, the PAL is set to a level of 20 percent of the level at which noncarcinogenic effects could be expected in the most sensitive human receptor who hypothetically consumes the water on a daily basis. By contrast, the Enforcement Standard (ES) is set at 100 percent of that conservative, protective level. Selecting the ES for naphthalene as the acceptable groundwater level would result in an additional factor of five increase in the groundwater pathway RCL. Because it is highly unlikely that anyone would rely on the shallow groundwater at this Site for drinking water purposes, the many layers of conservatism in the WDNR's approach reinforce the need to apply the WDNR regulations in the flexible manner which WDNR itself advises. U.S. EPA has failed to follow this approach.

## PART II

In addition to our primary concern regarding the inappropriate groundwater pathway RCL for naphthalene, KMC also identifies the following issues.

### **1. Remediation of Little Menomonee River segment 5 is unjustified.**

Consistent with the Proposed Plan, U.S. EPA commented at the 18 March 1998 public meeting in Milwaukee regarding the Proposed Plan that the Amended ROD would not address sediments in the Little Menomonee River (River), and that modifications of the remedy for the River might be the subject of another ROD amendment in the future. U.S. EPA further stated at the meeting, however, that it was considering a remedy involving sediment cleanup throughout all five miles



of the Little Menomonee River, from the Site to the confluence with the Menomonee River. KMC discussed this issue in its comments on the Proposed Plan and U.S. EPA responded in its Responsiveness Summary attached to the Amended ROD.

As stated in our comments on the Proposed Plan, KMC participated in sediment cleanup discussions with the U.S. EPA and the WDNR that focussed on the first three miles plus approximately ½ of mile 4. The discussions focused on just these reaches of the River based on a comparison of site data to background values proposed by WDNR that varied for each river mile. This comparison indicated that sediment cleanup in mile 5 was unwarranted. In an effort to facilitate agreement among the parties in the context of the limited remediation that is justified by the WDNR's background analysis, KMC further acceded as a simplifying compromise to a single sediment cleanup value (15 mg/kg) for the first three miles plus approximately ½ of mile 4 (15 mg/kg). Now, U.S. EPA twists KMC's compromise into an admission and agreement that the entire five miles of the River must be remediated at a 15 mg/kg level. Responsiveness Summary, p. 30.

U.S. EPA's response states that KMC did not understand the implications of its proposed single sediment cleanup value of 15 mg/kg, but that KMC now must live with the consequences. But this approach is both misleading and unfair. KMC did not propose to apply a cleanup standard of 15 mg/kg to all five miles. U.S. EPA unfairly distorts KMC's proposal by interpreting it to apply to the entirety of the River, particularly in view of the fact that U.S. EPA apparently recognizes that even WDNR's estimate of background in mile 5 would not justify any cleanup in this stretch of the River.

In any event, KMC views it as completely inappropriate for U.S. EPA to have addressed any of the sediment issues in the Amended ROD. U.S. EPA has acknowledged that discussions with respect to this aspect of the remedy are ongoing and that, as a result, further amendment of the ROD may be necessary in the future. Responsiveness Summary, pp. 10, 24; Proposed Plan, p. 5. In light of this fact, U.S. EPA should not have made any determinations relating to sediment cleanup at this time.



**3. The 54-inch soil cover option is inappropriate.**

The amended ROD identifies certain soils that will require a 54-inch cover after treatment. This cover, which is identified as cover alternative A or the NR 504.07 cover, consists of the following components (top to bottom): 6 in. topsoil, 18 in. frost protection layer, 24 in. compacted clay, and 6 in. grading layer. The Amended ROD indicates that post-treatment soil residuals will require this cover if they do not meet direct contact RCLs. All treated soils are required to meet groundwater RCLs. Thus, treated soils in this category are a potential concern only with respect to a direct contact.

A moment's reflection reveals that U.S. EPA's cover requirement is completely inappropriate. The NR 504.07 cover is designed to protect groundwater by minimizing infiltration through the covered materials: the low permeability 24-inch compacted clay layer and the 18-inch frost protection layer have the sole function of protecting the compacted clay layer from frost-induced damage (i.e., increases in permeability). But there is no need to minimize infiltration through these materials because the treated soils are required to satisfy the groundwater RCLs. Since direct contact with these covered materials is the only potential environmental concern, there is no need for placing and maintaining an expensive low-permeability cover.

The Amended ROD also states that there may be soils that do not require treatment, but which exceed direct contact RCLs. In this situation the Amended ROD calls for two possible cover options (identified as cover alternative B): existing asphalt, or 24 in. of soil plus 6 in. of topsoil. The soils beneath cover alternative B would be identical to those beneath cover alternative A with respect to all site-specific soil standards. Both would meet groundwater RCLs, but exceed applicable direct contact RCLs. Yet the amended ROD would treat these soils in very different ways by requiring a bulky, expensive cover over soils that had been treated. Cover alternative B is appropriate for both types of soils; cover alternative A is inappropriate.



**4. The Amended ROD limits cover options on the railroad property.**

The Amended ROD identifies “existing (as of the date of this amendment) asphalt pavement” as an acceptable cover under alternative B for soils that do not require treatment, but which exceed direct contact RCLs. The industrial activities on the railroad property suggest the possibility that an expansion of the asphalt surface might be desirable and in accordance with the opportunities for future development. While KMC is not now suggesting that additional portions of the railroad property should be covered with asphalt to address soils exceeding direct contact RCLs, we do believe that such an approach is an appropriate option that is consistent with the Amended ROD and that should be available as remediation is undertaken. The language of the Amended ROD precludes this option and should be revised to allow it.

**5. The 180 day time limitation for deed restrictions is unreasonably short.**

KMC has been forced to expend substantial time and effort to assess the implications of the Amended ROD, in particular the significant change in remedial scope that results from the inclusion of the generic naphthalene groundwater RCL. KMC must now enter into discussions with multiple landowners in which the landowners are likely to want to assess the technical and legal consequences of this change. Given this situation, the allowance of 180 days for these negotiations is needlessly restrictive.





**Table 1**

**Soil Samples Exceeding Generic Groundwater Pathway  
RCLs for Naphthalene and Fluorene<sup>a</sup>  
Moss-American Site  
Milwaukee, Wisconsin**

Sample ID	Sample Source	Depth Interval, ft	Coordinates (N,E)	Naphthalene (mg/kg)	Fluorene (mg/kg)
SS012-1	RI	0-4	110, 1175	3	
SS012-2	RI	0-4	110, 1175	19	
SS012-2FR	RI	0-4	110, 1175	57	
SS015-1	RI	0-4	330, 880	100	230
SS015-2	RI	0-4	330, 880	3.5	
SS015-2FR	RI	0-4	330, 880	3.9	
SS017-2	RI	0-4	105, 855	3	
SS018-1	RI	0-4	125, 760	25	200
SS018-2	RI	0-4	125, 760	38	
SS019-1	RI	0-4	15, 890	79	150
SS024-1	RI	0-4	110, 1015	9	
SS024-2	RI	0-4	110, 1015	0.89	
SS025-1	RI	0-4	5, 1105	4	
SS030-1	RI	0-4	35, 925	3800	3200
SS030-2	RI	0-4	35, 925	1800	1700
SS032-1	RI	0-4	-30, 1350	7	
SS037-1	RI	0-4	590, 1640	34	280
SS038-1	RI	0-4	430, 1800	71	600
SS038-2	RI	0-4	430, 1800	530	150
SS049-1	RI	0-4	145, 1905	96	320
SS064-1	RI	0-4	65, 2575	8	
SS064-2	RI	0-4	65, 2575		480
SS089-1	RI	0-4	840, 2800	1700	1200
SS089-2	RI	0-4	840, 2800	1500	1100
SS098-1	RI	0-4	265, 1010	10	
SS103-1	RI	0-4	235, 1235	6	
SS106-1	RI	0-4	360, 1160	2	
SS113-1	RI	0-4	590, 1480	1800	660
SS113-2	RI	0-4	590, 1480	660	950
SS129-2	RI	0-4	-85, 1465	0.66	
SS142-1	RI	0-4	40, 670	0.46	
SSI023-1R	RI	0-4	500, 2185	2	
SB-19-1	RI	6-8	840, 2800	2600	2100



**Table 1**

**Soil Samples Exceeding Generic Groundwater Pathway  
RCLs for Naphthalene and Fluorene<sup>a</sup>  
Moss-American Site  
Milwaukee, Wisconsin  
(Continued)**

Sample ID	Sample Source	Depth Interval, ft	Coordinates (N,E)	Naphthalene (mg/kg)	Fluorene (mg/kg)
SSG04-0401-01	Pre-Design	4 - 8	0, 900	610	500
0N-1050E-01	Pre-Design	2 - 10	0, 1050	20	
0N-1050EM-01	Pre-Design	2 - 10	0, 1050	100	
0N-2500E	Pre-Design	0.5 - 3.5	0, 2500	1500	1200
0N-2500ED	Pre-Design	0.5 - 3.5	0, 2500	580	680
0N-2550E-01	Pre-Design	0 - 4	0, 2550	410	1700
0N-2650E	Pre-Design	4 - 8	0, 2650	2.5	
0N-2700E-01	Pre-Design	0 - 4	0, 2700	3.5	
0N-3000E-01	Pre-Design	0 - 4	0, 3000	1.5	
0N-3300E-01	Pre-Design	0 - 4	0, 3300	1.5	
75N-900E-01	Pre-Design	3 - 13	75, 900	21	
150N-563E-01	Pre-Design	0.5 - 4.5	150, 563	10	
150N-1050E-01	Pre-Design	4 - 8	150, 1050	1100	390
150N-1350E-01Dup	Pre-Design	2 - 6	150, 1350	0.54	
150N-2550E-01	Pre-Design	0 - 4	150, 2550	1.5	
154N-481E	Pre-Design	0.5 - 8.5	154, 481	10	
SSG16-0302-01	Pre-Design	0 - 4	300, 600	10	
SSG17-0402-01	Pre-Design	0 - 4	300, 900	10	
300N-1050E	Pre-Design	4 - 8	300, 1050	36	
SSG18-0502-01	Pre-Design	5 - 9	300, 1200	200	110
300N-1350E-01	Pre-Design	0 - 4	300, 1350	0.56	
SSG19-0602-01	Pre-Design	0 - 4	300, 1500	1.5	
300N-1800E	Pre-Design	0 - 4	300, 1800	1.5	
300N-2700E	Pre-Design	0 - 4	300, 2700	1.5	
300N-3000E-01	Pre-Design	0 - 4	300, 3000	2	
380N-1270E-01	Pre-Design	2 - 6	380, 1270	1.5	
425N-2425E	Pre-Design	0 - 4	425, 2425	1.5	
445N-1480E-01	Pre-Design	0 - 4	445, 1480	1.5	
485N-552ED-01	Pre-Design	2 - 4	485, 552	3.5	
500N-1500E-01	Pre-Design	4 - 10	500, 1500	610	340
500N-1500ED-01	Pre-Design	4 - 10	500, 1500	640	340
500N-1500E-02	Pre-Design	10 - 12	500, 1500	1.8	
500N-2100E-01	Pre-Design	0 - 4	500, 2100	1.5	
550N-550E-01	Pre-Design	0 - 4	550, 550	70	
575N-1665E	Pre-Design	0 - 4	575, 1665	1.5	
SSG26-0503-01	Pre-Design	0 - 4	600, 1200	1.5	



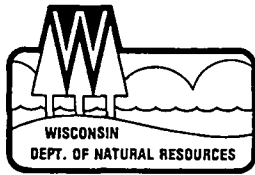
**Table 1**

**Soil Samples Exceeding Generic Groundwater Pathway  
RCLs for Naphthalene and Fluorene<sup>a</sup>  
Moss-American Site  
Milwaukee, Wisconsin  
(Continued)**

Sample ID	Sample Source	Depth Interval, ft	Coordinates (N,E)	Naphthalene (mg/kg)	Fluorene (mg/kg)
SSG25-0403-02	Pre-Design	4-8	615, 900	1.6	
640N-1545E-01	Pre-Design	5 - 8	640, 1545	300	160
640N-1545E-02	Pre-Design	9 - 10	640, 1545	0.5	
665N-1490E-01	Pre-Design	4 - 10	665, 1490	1000	400
SSG34-0804-01	Pre-Design	0 - 4	800, 2100	1.5	
840N-2990E	Pre-Design	8 - 10	840, 2990	5	
840N-2990E	Pre-Design	11 - 12	840, 2990	7	
900N-2850E	Pre-Design	7 - 8	900, 2850	400	300
SSG37-1004-01	Pre-Design	4 - 10	900, 3000	4	
SSG37-1004D-01	Pre-Design	4 - 10	900, 3000	6	
75S-600E-01	Pre-Design	2.5 - 6.5	-75, 600	10	
75S-900E	Pre-Design	0 - 6	-75, 900	72	

<sup>a</sup> Non-detect samples with a naphthalene detection limit of 2 mg/kg or lower were excluded from this table. All other non-detect samples are reported at ½ detection limit.





Wisconsin  
Department of  
Natural Resources

Bureau for  
Remediation and  
Redevelopment

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## Understanding Wisconsin Standards for Cleanup of Contaminated Soil, An Overview of Wisconsin Administrative Code Chapter NR 720

### PURPOSE

This overview has been written to help responsible parties and environmental consultants understand the options they may select to meet the standards contained in chapter NR 720, Wis. Adm. Code. The cleanup standards in Chapter NR 720 apply to hazardous substance soil contamination (including discharges from leaking underground storage tanks, landfills, hazardous waste disposal sites, and wastewater lagoons).

Standards for contaminated soil cleanup are applied *after* a site investigation has been completed in accordance with the requirements of chapter NR 716. The site investigation determines the nature and extent of the contamination. Chapters NR 716, NR 722 (selecting remedial actions) and NR 726 (case closure) are all important to the decisions made under chapter NR 720. The Department may also allow "no further action" under the provisions of NR 708.09 when an immediate action has been taken to contain, treat or remove a hazardous substance discharge, the environment has been restored to the extent practicable and there is no evidence to indicate that residual contamination on the site will pose a threat to public health, safety or welfare or the environment.





## **DISCLAIMER**

This document is intended solely as guidance, and does not contain any mandatory requirements except where requirements found in statute or administrative rule are referenced. This guidance does not establish or affect legal rights or obligations, and is not finally determinative of any of the issues addressed. This guidance cannot be relied upon and does not create any rights enforceable by any party in litigation with the State of Wisconsin or the Department of Natural Resources. Any regulatory decisions made by the Department of Natural Resources in any matter addressed by this guidance will be made by applying the governing statutes and administrative rules to the relevant facts.

This guidance is based on requirements found in chs. NR 140, 720, 722, 724, and 726, Wis. Adm. Code; the Hazardous Substance Spill Law, s. 292.11, Wis. Stats., the Environmental Repair Statute, s. 292.31, Wis. Stats., and the Groundwater Law, s. 160.23 and 160.25, Wis. Stats.

## **OTHER RELEVANT GUIDANCES**

This guidance may be more complete when used in conjunction with:

- Interim Guidance on Soil Cleanup Levels for Polycyclic Aromatic Hydrocarbons (PAHs), RR-519-97
- Interim Guidance for Selection of Natural Attenuation for Groundwater Restoration and Case Closure Under Section NR 726.05(2)(b), RR-530-97
- Interim Guidance on Use of Leaching Tests for Unsaturated Contaminated Soils to Determine Groundwater Contamination Potential, RR-523-97
- Interim Guidance on Soil Performance Standards, RR-528-97

This list will be expanded as additional guidances are developed.

These guidances may be obtained by:

- A. Sending a request to: Public Information Requests, Bureau for Remediation and Redevelopment, Department of Natural Resources, P.O. Box 7921, Madison, WI 53707.
- B. Calling the publication request line at (608)264-6009.
- C. Calling the Bureau for Remediation & Redevelopment Bulletin Board via computer modem at (608)261-6455.

This guidance will be updated as needed. Comments and concerns may be sent to "Guidance Revisions", Dale Ziege - RR/3, WDNR, P.O. Box 7921, Madison, WI 53707.



## ***UNDERSTANDING THE RULE REQUIREMENTS***

### **A. What are the "pathways" a soil contaminant can take?**

Pathways are routes through which contaminants can move and affect human health and the environment. Soil standards, called Residual Contaminant Levels (RCLs) in chapter NR 720, have been established to control the spread of contamination along several "pathways". The RCLs are based on the toxicological characteristics of the contaminants and the ability of the contaminants to persist in and move through the environment. All potential pathways along which contamination can spread must be evaluated. The pathway with the lowest RCL value will govern the site cleanup.

#### **1. The groundwater pathway:**

The groundwater pathway means the migration of a soil contaminant to the water table, potentially contaminating groundwater above state groundwater standards, which are established in chapter NR 140. People are exposed to contaminated groundwater by drinking, showering and washing. Soil contaminant table values ("look up numbers") have been calculated for some compounds. Site specific values can be calculated based on the criteria in section NR 720.19.

#### **2. The direct contact pathway:**

The direct contact pathway means the human inhalation and ingestion of contaminated soil particles. Standards for the direct contact pathway can be developed for industrial land use values (based on an adult's normal working hours), or non-industrial land use values (based on a juvenile resident). Soil contaminant table values ("look up numbers") have been calculated for some compounds. Site specific values can be calculated based on the criteria in section NR 720.19.

#### **3. The pathway to surface waters:**

The surface water pathway [section NR 720.07(1)(c)] means the washing of contaminated soil into wetlands, streams, rivers and lakes, potentially causing a detrimental impact on water quality and aquatic life. There are no table values for the surface water pathway in chapter NR 720, but surface water quality standards are established in chapters NR 102 and 105. The need to control this pathway is dependant upon the location of the site. Controlling other pathways, such as direct contact, may also control the surface water pathway.

4. The pathway to sensitive environments:

The sensitive environment pathway [section NR 720.07(1)(c)] means an adverse impact from contaminated soil on an ecosystem that supports threatened or endangered species, or other sensitive environments. There are no table values for the sensitive environment pathway. Consultants are expected to use reasonable judgement in evaluating the risk to sensitive environments.

5. The plant uptake and food chain pathway:

The plant uptake and food chain pathway [section NR 720.07(1)(c)] means that humans, domestic livestock, and wildlife species may be adversely impacted due to consumption of plants grown in contaminated soil. There are no table values for the plant uptake pathway. Consultants are expected to use reasonable judgement and published information in evaluating the risk of plant uptake of the contaminant.

B. What are the options for determining acceptable Residual Contaminant Levels (RCLs) for soil contaminants?

It may seem contradictory to have "options" for determining "standards", but a key to understanding this rule is knowing that different methods can be used to evaluate the potential impact of soil contamination and to arrive at a RCL that fits the site. NR 720 is more than a list of cleanup numbers. It provides options to adapt the cleanup process to site specific circumstances.

1. Table Values

For the groundwater and direct contact pathways, the simplest approach to determining RCLs for listed contaminants is to use the pre-established values ("look up numbers") in the tables. Table 1 in s. NR 720.09 includes groundwater pathway values for some contaminants. They are based on PALs found in Chapter NR 140, Groundwater Quality. The table values can be used when the soil contamination is more than a meter above bedrock and is less than 6 meters in thickness. There are also generic standards specified for total petroleum contamination, gasoline range organics (GRO) and diesel range organics (DRO), in section NR 720.09(4). Both the Table 1 values **and** the generic GRO or DRO standards must be complied with at sites with petroleum contamination, unless site-specific standards are established pursuant to section NR 720.19.

Table 2 in section NR 720.11 includes direct contact values for some compounds. There are two sets of table values. One is for industrial property and one is for non-industrial property. Use of the industrial values requires that a deed restriction be recorded so that future owners will be aware of the contaminant levels and will use the land for industrial purposes only.

For small volumes of contaminated soil, use of the table values ("look up numbers") for contaminants listed in Table 1 and Table 2 may be more cost effective than establishing site specific RCLs for these pathways.

## 2. Site Specific Soil Cleanup Standards

Site specific RCLs may be calculated for both the groundwater pathway and the direct contact pathway, as well as for other pathways of exposure that may be of concern at a specific site or facility (e.g. runoff to surface water). Calculation of site-specific groundwater pathway and direct contact pathway RCLs uses the same principles used to calculate the Table 1 and Table 2 values, unsaturated zone contaminant transport and inhalation and ingestion of toxic and carcinogenic particles. Development of site specific RCLs allows consideration of the land use and the specific soil and groundwater conditions at a property, rather than generalized Wisconsin conditions. There are several different options that can be used to calculate site-specific soil cleanup standards:

### a. Performance standards [section NR 720.19(2)]:

Performance standards can be used to address both the groundwater and the direct contact pathways. A performance standard requires a specified level of performance for a remedial action that is implemented and maintained so that the contamination is contained and does not pose a threat to human health or the environment. Examples of performance standards include placing a barrier cap over contaminated soil which will limit infiltration and will be maintained and repaired for an appropriate time period, or demonstrating that natural attenuation of groundwater contains and remediates the contamination that is leaching from the soils. Once a performance standard has been established, contaminated soil can be left in place with no further action as long as the conditions established for the performance standard are maintained. Further guidance on performance standards is contained in the Department's document "*Interim Guidance on Soil Performance Standards, RR-528-97*".

### b. Site-Specific RCLs for the Groundwater Pathway:

(1) Groundwater mixing zone [section NR 720.09(3)]

This method uses the predicted rate of groundwater movement to calculate the level of contamination in groundwater that will result from the soil contaminants. It requires knowledge of the site's physical groundwater conditions, including the hydraulic conductivity and gradient.

(2) Contaminant transport and fate modeling [section NR 720.19(4)]

This method uses a model to predict the movement and end points of soil contaminants. A model may involve relatively straightforward mathematics or may include sophisticated computer calculations. In either case, it's critical that an appropriate model be chosen based on the complexity of the site and the contaminants. The consultant must understand the limits of the model and properly interpret and explain its results. A model is only as good as the site sampling data that go into it.

(3) Soil leaching tests [section NR 720.19(4)]

This method uses undisturbed soil samples from the contaminated area. The samples are flushed with water in a laboratory to determine what portion of the contamination will remain in the soil and what portion will be washed into the groundwater under normal rainfall conditions. Further guidance on soil leaching tests is contained in the Department's document "*Interim Guidance on Use of Leaching Tests for Determination of Site Specific Soil Cleanup Levels, RR-523-97*".

(4) Other methods [section NR 720.19(4)]

The rule allows use of other methods to calculate site specific RCLs for the groundwater pathway if these methods have been reviewed and approved by the Department.

c. Site Specific RCLs for the Direct Contact Pathway: [section NR 720.19(5)]

(1) Industrial and non-industrial land use values can be calculated for site specific conditions, and for compounds which do not have Table 2 values. For carcinogenic contaminants, a one-in-one-million excess cancer risk level must be used (or a one-in-one-hundred-thousand risk level for multiple contaminants). For non-carcinogenic compounds, a hazard quotient, the ratio of exposure to a specified level of a substance over a standard time, is used.

(2) The rule provides assumptions for the amount of contaminated soil that a child would ingest and inhale in a non-industrial area, and that an adult would ingest and inhale during normal working hours in an industrial area.

**CLEANUP ALTERNATIVES FOR CONTAMINATED SOIL  
AND  
RISK-BASED CORRECTIVE ACTION**

Numerous cleanup methods for contaminated soil are available. Responsible parties should evaluate the alternatives in terms of technical feasibility, cost, potential future liability, the length of time involved, and disruption to their property. The most important decision made during an environmental cleanup is the choice of a remedy, or combination of remedies, to address the contamination. The remedy *must* be appropriate to the type of contaminant and to the soil type in order to be effective. Responsible parties need to understand *why* a consultant's recommended remedy is the right one for property and for the property owner.

Contaminated soil may be excavated or treated in place. Excavated soil may be incorporated into asphalt, "incinerated" in a thermal treatment unit, landspread, or placed in an on-site or commercial "bio-pile" for degradation of the contaminants. Soil may also be disposed of in a landfill in accordance with the criteria in chapter NR 722, Standards For Selecting Remedial Actions. That chapter requires evaluation of the alternatives to disposing of contaminated soil, and requires written approval from DNR for disposal of more than 2,000 cubic yards of soil in a landfill.

In-situ, or "unexcavated" soil treatment methods may also be used. These methods include "venting" the soil with perforated underground piping, or simply monitoring the natural breakdown of the contamination.

Risk-based corrective action (RBCA) means choosing a remedy based on the pathways for contaminant movement, the toxicology of the contaminants and the site-specific risks of exposure. These factors (other than site specific risks) have been considered in the calculation of Table 1 and Table 2 values in chapter NR 720, based on the general soil and groundwater conditions in Wisconsin, and will be appropriate for many contaminated properties.

Chapter NR 720 follows the RBCA approach by allowing calculation of site specific RCLs based on very localized conditions. The development of site specific RCLs for



contaminated soil should be always be considered, especially in areas of extensive soil contamination, and where soil contaminants are difficult to treat. **However, consultants need to remember that, in Wisconsin, groundwater must be protected regardless of whether or not water supply wells are located nearby.**

Please note that the volume of submittals that calculate site specific RCLs for contaminated soils may not allow the Department to approve each methodology prior to its use. Environmental professionals are expected to utilize chapter NR 720 as written, and may apply the associated technical guidance documents, to the cleanup of contaminated properties without Department oversight. The Department will generally review reports on completed cleanup actions in the order in which they are received.





Wisconsin  
Department of  
Natural Resources

Bureau for  
Remediation and  
Redevelopment

Publication RR-519-97  
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## **Soil Cleanup Levels for Polycyclic Aromatic Hydrocarbons (PAHs) Interim Guidance**

Technical Resources Section

This document is intended to provide interim guidance on suggested generic soil cleanup levels for polycyclic aromatic hydrocarbons (PAHs) based on protection of groundwater quality and protection of human health from direct contact with contaminated soil via direct ingestion and through inhalation of volatiles and particulate matter. It includes a discussion of the technical background, toxicological basis, and qualifications and considerations for the appropriate use of these suggested values, and considerations for sampling. **The use of these suggested generic values for decisions regarding a given site, either by Department staff or other parties, without full consideration of their context and qualifications on their use is not appropriate.** The availability of the suggested generic residual contaminant levels (RCLs) for PAHs provided in this guidance is not in any way intended to preclude or discourage site-specific analysis and decisionmaking under s. NR 720.19, Wis. Adm. Code. This guidance also includes discussion of some site-specific issues related to PAH contamination. The suggested generic residual contaminant levels included in this document do not address other pathways, such as potential surface water impacts, which may be of concern at some sites.

### ***Disclaimer***

This document is intended solely as guidance and does not contain any mandatory requirements except where requirements found in statute or administrative rule are referenced. This guidance does not establish or affect legal rights or obligations and is not a final determination for any of the issues addressed. This guidance cannot be relied upon to and does not create any rights enforceable by any party in litigation with the State of Wisconsin or the Department of Natural Resources. Any regulatory decisions made by the Department of Natural Resources in any matter addressed by this guidance will be made by applying the governing statutes and administrative rules to the relevant facts. This guidance is based on requirements found in chs. NR 140, 720, 722, and 726, Wis. Adm. Code; the Hazardous Substance Spill law, s. 292.11, Wis. Stats.; the Environmental Repair law, s. 292.31, Wis. Stats.; and the Groundwater law, ch. 160, Wis. Stats.

### **Background**

Polycyclic aromatic hydrocarbons (PAHs) - also referred to as polynuclear aromatic hydrocarbons (PNAs) or polyaromatic hydrocarbons - are commonly contaminants of concern at petroleum contamination sites involving diesel fuel, fuel oils, waste oil, and crude oils. They are also typically found as contaminants at wood preserving sites (as major components of creosote) and at coal gas sites. Additionally, the PAHs are relatively recalcitrant compounds and are likely still to remain in petroleum-contaminated soils even after treatment. Thus, they present an issue for soil cleanup levels at many sites, and for the ultimate disposition of many petroleum-contaminated soils treated *ex situ*.

A recognized difficulty with implementation of ch. NR 720, Wis. Adm. Code, is the lack of specific

cleanup levels for the polycyclic aromatic hydrocarbons (PAHs). The generic GRO/DRO soil cleanup levels included in s. NR 720.09(4), Wis. Adm. Code, were developed as “catch-alls” for other petroleum compounds with consideration of the PAHs in mind. However, GRO and DRO are indicator parameters for petroleum contamination and situations are likely where these are not adequate or appropriate.

The PAHs include more than a hundred compounds with fused benzene rings. They comprise a large family of compounds with a rather large range of toxic potency (IARC, 1983; Santodonato et al., 1981). PAHs are products of incomplete combustion and are components of petroleum. They are ubiquitous in the environment from both natural and anthropogenic sources. PAHs are seldom found separately in the environment; rather, they occur as complex mixtures of numerous compounds. The specific PAH compounds addressed in this guidance are shown in Table 1. While these compounds are likely to be the most common PAHs encountered at most sites (ATSDR, 1995a; 1995b), their inclusion does not imply that these are the only PAH compounds of concern. Additional PAH compounds may be of concern at some sites and these should be evaluated on a site-specific basis.

Previous approaches to developing soil cleanup levels for PAHs have typically assumed that all carcinogenic PAHs are equipotent to benzo[*a*]pyrene (BaP). It has become apparent in recent years that the equipotency approach results in an overestimation of the carcinogenic risks associated with PAHs (U.S. EPA, 1993; LaGoy and Quirk, 1994). The basis for establishing risk-based soil cleanup levels for "total PAHs" relies on assumptions regarding the composition of a PAH mixture combined with assumed equipotency with benzo[*a*]pyrene or toxic equivalency factors. Thus, cleanup levels for “total PAHs” are inherently site-specific and generic values tend to be overly conservative.

### Development of Suggested Generic Soil Cleanup Levels for PAHs

The suggested generic soil cleanup levels for PAHs provided in this guidance were developed consistent with the methodology used in developing the generic RCLs in ch. NR 720, Wis. Adm. Code, and with the procedures outlined in s. NR 720.19(4)-(5), Wis. Adm. Code. The suggested generic residual contaminant levels (RCLs) for individual PAH compounds are shown in Table 1.

**Table 1. – Suggested generic residual contaminant levels (RCLs) for PAH compounds in soil (mg/kg)**

Compound	CAS #	Groundwater Pathway	Direct Contact Pathway	
			Non-industrial	Industrial
acenaphthene	83-32-9	38	900	60000
acenaphthylene	208-96-8	0.7	18	360
anthracene	120-12-7	3000	5000	300000
benz[ <i>a</i> ]anthracene	56-55-3	17	0.088	3.9
benzo[ <i>a</i> ]pyrene	50-32-8	48	0.0088	0.39
benzo[ <i>b</i> ]fluoranthene	205-99-2	360	0.088	3.9
benzo[ <i>ghi</i> ]perylene	191-24-2	6800	1.8	39
benzo[ <i>k</i> ]fluoranthene	207-08-9	870	0.88	39
chrysene	218-01-9	37	8.8	390
dibenz[ <i>ah</i> ]anthracene	53-70-3	38	0.0088	0.39
fluoranthene	206-44-0	500	600	40000
fluorene	86-73-7	100	600	40000
indeno[123- <i>cd</i> ]pyrene	193-39-5	680	0.088	3.9
1-methyl naphthalene	90-12-0	23	1100	70000
2-methyl naphthalene	91-57-6	20	600	40000
naphthalene	91-20-3	0.4	20	110
phenanthrene	85-01-8	1.8	18	390
pyrene	129-00-00	8700	500	30000

## Toxicological Basis

The commonly occurring PAHs are routinely subdivided into the "carcinogenic" and "noncarcinogenic" PAHs. Seven of the PAHs -- benzo[*a*]anthracene, benzo[*a*]pyrene, benzo[*b*]fluoranthene, benzo[*k*]fluoranthene, chrysene, dibenz[*ah*]anthracene, and indeno[123*cd*]pyrene -- are classified as B2, probable human carcinogens, under U.S. EPA's weight of evidence classification system (U.S. EPA, 1997). The remaining PAHs addressed in this guidance are classified as D, not classifiable as to human carcinogenicity (U.S. EPA, 1997).

A cancer slope factor has only been established for benzo[*a*]pyrene (U.S. EPA, 1997; Smith, 1996). Several authors have evaluated the available data on the carcinogenic potency of different PAHs and developed toxicity equivalency factors (TEFs) for the individual PAHs (Clement Assoc., 1988; Nisbet and LaGoy, 1992; U.S. EPA, 1993). These TEFs are more properly termed estimated relative potency factors (RPFs) and indicate the carcinogenic potency of each compound relative to benzo[*a*]pyrene. Multiplying the RPF of each PAH by the cancer slope factor for benzo[*a*]pyrene can provide an estimated cancer slope factor for each compound.

Table 2 shows the RfDs and cancer slope factors used in development of the suggested generic RCLs for PAHs. The suggested generic soil cleanup levels for PAHs were developed using accepted reference doses (RfDs) or minimal risk levels (MRLs) for "noncarcinogenic" PAHs where such values are available (U.S. EPA, 1997; Anderson et al, 1992; ATSDR, 1995a; 1995b). Suggested soil cleanup levels for "carcinogenic" PAHs were developed based on the estimated relative potency factors (RPFs) of U.S. EPA (1993) relative to the cancer slope factors for benzo[*a*]pyrene (U.S. EPA, 1997; Smith, 1996). Cancer slope factors for the "carcinogenic" PAHs were calculated by multiplying the slope factors for benzo[*a*]pyrene by the estimated relative potency factor (RPF) for the compound. For the "noncarcinogenic" PAHs that lack an established reference dose (RfD) or minimal risk level (MRL), cancer slope factors were determined using the RPFs of Nisbet and LaGoy (1992). This use of the RPF approach is thought to be appropriate, in the absence of another toxicity index upon which to base a soil

**Table 2. – Relative potency factors, estimated cancer slope factors, oral reference doses, and inhalation reference concentrations for individual PAH compounds**

Compound	CAS #	RPF <sup>a</sup>	CSF <sub>o</sub> <sup>b</sup> (mg/kg-d) <sup>-1</sup>	CSF <sub>i</sub> <sup>c</sup> (mg/kg-d) <sup>-1</sup>	RfD <sup>d</sup> (mg/kg-d)	RfC <sup>e</sup> (mg/m <sup>3</sup> )	Class <sup>f</sup>
acenaphthene	83-32-9	0.001			6x10 <sup>-2</sup>	na	D
acenaphthylene	208-96-8	0.001	7.3x10 <sup>-3</sup>	6.1x10 <sup>-3</sup>	na	na	D
anthracene	120-12-7	0.01			3x10 <sup>-1</sup>	na	D
benz[ <i>a</i> ]anthracene	56-55-3	0.1	7.3x10 <sup>-1</sup>	6.1x10 <sup>-1</sup>			B2
benzo[ <i>a</i> ]pyrene	50-32-8	1	7.3	6.1			B2
benzo[ <i>b</i> ]fluoranthene	205-99-2	0.1	7.3x10 <sup>-1</sup>	6.1x10 <sup>-1</sup>			B2
benzo[ <i>ghi</i> ]perylene	191-24-2	0.01	7.3x10 <sup>-2</sup>	6.1x10 <sup>-2</sup>	na	na	D
benzo[ <i>k</i> ]fluoranthene	207-08-9	0.01	7.3x10 <sup>-2</sup>	6.1x10 <sup>-2</sup>			B2
chrysene	218-01-9	0.001	7.3x10 <sup>-3</sup>	6.1x10 <sup>-3</sup>			B2
dibenz[ <i>ah</i> ]anthracene	53-70-3	1	7.3	6.1			B2
fluoranthene	206-44-0	0.001			4x10 <sup>-2</sup>	na	D
fluorene	86-73-7	0.001			4x10 <sup>-2</sup>	na	D
indeno[123- <i>cd</i> ]pyrene	193-39-5	0.1	7.3x10 <sup>-1</sup>	6.1x10 <sup>-1</sup>			B2
1-methyl naphthalene	90-12-0	0.001			7x10 <sup>-2</sup>	na	D
2-methyl naphthalene	91-57-6	0.001			4x10 <sup>-2</sup>	na	D
naphthalene	91-20-3	0.001			4x10 <sup>-3</sup>	2x10 <sup>-3</sup>	D
phenanthrene	85-01-8	0.001	7.3x10 <sup>-3</sup>	6.1x10 <sup>-3</sup>	na	na	D
pyrene	129-00-00	0.001			3x10 <sup>-2</sup>	na	D

<sup>a</sup> Estimated relative potency factor

<sup>b</sup> Oral cancer slope factor

<sup>c</sup> Inhalation cancer slope factor

<sup>d</sup> Oral reference dose (EPA/WDHS) or minimal risk level for oral exposure (ATSDR)

<sup>e</sup> Reference concentration (EPA) or minimal risk level for inhalation exposure (ATSDR)

<sup>f</sup> U.S. EPA weight-of-evidence classification for carcinogenicity

na = not available

cleanup level, because evidence exists that these compounds may exhibit co-carcinogenic effects in mixtures and are mutagenic (ATSDR, 1995b; Nisbet and LaGoy, 1992; EPA, 1997; Anderson et al, 1996). Also, the soil cleanup levels generated by using these values are unlikely to underestimate the potential human health risk associated with these compounds.

### ***Generic RCLs based on Direct Contact***

The suggested generic RCLs based on direct contact with contaminated soil through ingestion and through inhalation in Table 1 were developed using the risk-based algorithms and default exposure assumptions used in ch. NR 720, Wis. Adm. Code, with the additional consideration of inhalation of volatiles. Toxicity indices used are shown in Table 2 and summary calculations are provided in Attachment A. The risk-based algorithms and exposure factors used are provided in Attachment B. The suggested generic RCLs for non-industrial (residential) scenario are based on a target risk of  $1 \times 10^{-6}$  or a hazard quotient of 0.2, consistent with those in s. NR 720.11, Wis. Adm. Code. As provided in s. NR 720.19(5)(a), Wis. Adm. Code, these values can be adjusted on a site-specific basis to a target risk of  $1 \times 10^{-6}$  or a hazard quotient of 1.

### ***Generic RCLs based on Protection of Groundwater Quality***

The suggested generic RCLs based on protection of groundwater quality in Table 1 were developed by using equilibrium soil:water partitioning to estimate soil moisture concentrations in the unsaturated zone, combined with a modification of the generic dilution-attenuation factor calculation used for the generic RCLs in Table 1 of ch. NR 720, Wis. Adm. Code. Parameter values used and summary calculations are provided in Attachment A. The methodology used is explained in Attachment C.

Target groundwater concentrations for development of the suggested generic RCLs are based on: 1) NR 140 preventive action limits (PALs), 2) proposed PALs developed by the Department of Health and Social Services (DHSS), or 3) PAL-equivalent risk-based concentrations. Groundwater standards are presently available in ch. NR 140, Wis. Adm. Code, for three of the PAHs - benzo[a]pyrene, naphthalene, and fluorene. In addition, DHSS has proposed draft groundwater standards for six additional PAHs - acenaphthylene, anthracene, benzo[b]fluoranthene, chrysene, fluoranthene, and pyrene (Anderson et al, 1996). For the remaining PAH compounds, risk-based concentrations equivalent to a preventive action limit were calculated (see Attachment C).

## **Alternative Approaches for Determining PAH Soil Cleanup Levels**

Alternatives to the direct use of the suggested generic RCLs for individual PAHs may be appropriate and acceptable in some cases. These alternative approaches include the development of soil cleanup levels based on benzo[a]pyrene-equivalent concentrations and the application of soil cleanup levels for "total PAHs."

Both of these approaches may be suitable in cases where the pathway of concern is restricted to protection of human health from direct contact. Such "lumped parameter" approaches are not appropriate for protection of groundwater quality because the leaching potential for each PAH compound is specific to that compound and they cannot be considered as a group. Typically, the "carcinogenic" PAHs do not readily leach and, except for acenaphthylene, the methyl naphthalenes, and naphthalene, the PAH compounds are likely to be only of concern for direct contact with contaminated soil in many cases. However, the migration to groundwater pathway should be evaluated separately.

### ***Benzo[a]pyrene-Equivalent Concentrations***

This approach may be used to advantage in some situations where the PAH mixture is dominated by the "carcinogenic" PAHs. Where only one or two of the PAHs are present in significant concentrations, the use of the suggested generic RCLs based on direct contact in Table 1 can result in a cleanup action being undertaken where the cumulative risk for the PAH mixture may not really warrant it. An example of this approach is provided in Attachment D.

The application of the benzo[a]pyrene-equivalent concentration approach involves conversion of the measured concentrations of PAH compounds to an equivalent concentration (with regard to toxic potency) of benzo[a]pyrene. The RPFs in Table 2 indicate the carcinogenic potency of each compound compared with benzo[a]pyrene. Multiplying the concentration of each PAH by its RPF and summing the resultant concentrations yields a concentration for the total PAH mixture expressed as an equivalent concentration of benzo[a]pyrene, called a benzo[a]pyrene-equivalent concentration ( $BaP_{equiv}$ ).

Soil cleanup levels based on benzo[a]pyrene-equivalent concentrations are then developed using the risk-based algorithms for carcinogenic compounds in Attachment B and the cancer slope factor for benzo[a]pyrene ( $7.3 \text{ (mg/kg-d)}^{-1}$ ). However, in calculating soil cleanup levels for benzo[a]pyrene-equivalent concentrations, distributing the target risk equally among the PAH compounds and using a combined target excess cancer risk level is appropriate. This is conceptually consistent with the intent of the target risk requirements of ss. NR 720.11(3) and 720.19(5), Wis. Adm. Code, where risks are presumed to be additive and is appropriate here due to the underlying assumption of toxic potency for the other PAHs relative to benzo[a]pyrene. A combined target cancer risk level can be determined for the carcinogenic PAHs alone or for all the detected PAHs, up to the cumulative excess cancer risk limit of  $1 \times 10^{-5}$  specified in s. NR 720.11(3), Wis. Adm. Code.

The combined target excess cancer risk level is determined by multiplying the target risk for individual compounds by the number of compounds in the assessment. The generic RCLs in Table 2 of ch. NR 720, Wis. Adm. Code, are based on a target excess cancer risk for individual compounds of  $1 \times 10^{-6}$  for the nonindustrial (residential) scenario and  $1 \times 10^{-6}$  for the industrial scenario. The target risk for the nonindustrial scenario can be modified for *in situ* contaminated soil to  $1 \times 10^{-6}$  on a site-specific basis under s. NR 720.19(5)(a), Wis. Adm. Code. This distinction is important because soil cleanup levels equivalent to the generic RCLs are applicable to unrestricted off-site disposal under s. NR 718.14, Wis. Adm. Code.

### **Total PAHs**

A similar approach can also be used to determine soil cleanup levels for "total PAHs" if the assumption is made that measured total PAH concentration represents a benzo[a]pyrene-equivalent concentration and that all the PAHs are present. This assessment would involve all 18 compounds and use a combined target excess cancer risk level of  $1.8 \times 10^{-6}$  for the non-industrial (residential) scenario and  $1 \times 10^{-6}$  for the industrial scenario. The resultant soil cleanup levels for "total PAHs" equivalent to the generic RCLs would be 3.9 mg/kg for the industrial exposure scenario and 0.16 mg/kg for the non-industrial (residential) exposure scenario. Again, the value for the non-industrial scenario can be modified for *in situ* contaminated soil using a combined target risk of  $1 \times 10^{-5}$  to 0.9 mg/kg on a site-specific basis.

This approach can be useful for dealing with treatment residuals. It is inherently conservative since the resulting generic RCLs are compared directly to measured total PAH concentrations.

## **Qualifications and Considerations for Applying Suggested PAH Soil Cleanup Levels**

A variety of qualifications and considerations are involved in use of the suggested PAH soil cleanup levels included in this guidance. The suggested generic soil cleanup levels presented in this guidance are expected to be adequate and appropriate at most sites. If used properly, they should not result in overly conservative cleanups. However, **the availability of suggested generic soil cleanup levels for PAHs should not be construed to preclude site-specific decisionmaking**. Substantially higher levels could be allowable and appropriate if supported by a site-specific evaluation under s. NR 720.19, Wis. Adm. Code. A consideration of these issues is critical to defining the risk posed by PAHs at hazardous substance discharge sites.

### ***Background Concentrations of PAHs***

PAHs are widespread in the environment from both natural and anthropogenic sources (Menzie et al, 1992; IARC, 1983). Background concentrations of PAH compounds resulting from atmospheric deposition may be significantly elevated in some surface soils, particularly in urban areas and along roadways. The generic RCLs are not intended to require cleanup to below existing background concentrations at a site. Background concentrations should be considered, as provided in s. NR 720.11(5), Wis. Adm. Code. PAH compounds do not readily leach and background concentrations in subsoil can be expected to be *significantly* lower than those in surface soils. Elevated PAH concentrations at depth are typically associated with a release or waste material and are not "background." For comparison to background, the samples should be taken from a similar depth.

Background concentrations should be determined in the immediate vicinity of the site, but away from areas likely to be affected by a hazardous substance discharge involving PAHs. Sample locations likely to bias estimates of background concentrations should be avoided, such as around creosote-treated posts or telephone poles or immediately adjacent to asphalt surfaces. Direct comparison of elevated background concentrations of PAHs in surface soils to PAH concentrations occurring at depth in subsoils is not appropriate, since PAH concentrations in surface soil bear no direct relation to those in subsoils. The presence of PAH-contaminated soil at depth that is above background concentrations does not necessarily require that a cleanup action be done since the potential for exposure may not currently exist. Such situations could constitute a performance standard under s. NR 720.19(2), Wis. Adm. Code, where the "standard of performance" is that a soil cap of appropriate thickness is present and maintained so that no exposure is occurring. However, an institutional control, such as a deed restriction or deed affidavit, may be necessary to prevent excavation, or to minimize future exposure if the contaminated soil is brought to the surface and to ensure that it is managed properly. Also, the presence of a soil "cap" does not necessarily address inhalation of volatiles since volatilization to the atmosphere can occur from soils at depth and must be considered.

Comparisons between background concentrations and contaminant concentrations should be based on comparison of the sampled populations for the site. Sampling for comparisons to background is discussed below. Comparison of contaminant concentrations to maximum point values for background PAH concentrations can produce biased estimates and are not relevant to exposure concentrations. Similarly, the use of arbitrary statistical measures for background concentrations (e.g., mean plus three standard deviations) is not appropriate.

### ***Pathways Not Considered***

The suggested generic RCLs contained in this guidance apply to soil contamination in the unsaturated zone. They address protection of human health from direct contact through ingestion, inhalation of



volatiles and soil particulates, and protection of groundwater quality from leaching. The suggested RCLs based on direct contact can also be used for soil contamination in the saturated zone, as discussed below. They do *not* address potential surface water and sediment impacts from surface runoff and washload transport. These additional pathways should be evaluated on a site-specific basis where they are of concern, such as at many coal gas sites.

In addition, the suggested generic RCLs for protection of human health from direct contact with contaminated soil do not include consideration of dermal contact. Evidence exists to indicate that dermal contact may be a significant exposure pathway (ATSDR, 1995b) and a preliminary evaluation of site-of-contact risks associated with dermal exposure suggests that this could drive cleanups at some sites (LaGoy and Quirk, 1994). Therefore, dermal contact should be considered at sites where there is likelihood of significant exposure via this route. Approaches for evaluating dermal contact can be found in U.S. EPA (1992a).

The suggested soil cleanup levels for PAHs included in this guidance are *not* intended as cleanup criteria for contaminated sediment and should not be used as such.

### ***Contaminated Soil at or Near the Water Table***

In cases where PAH-contaminated "soil" lies near or below the water table where it is directly in contact with groundwater during all or part of the year, the use of the suggested generic RCLs based on protection of groundwater quality is inappropriate. In such cases the potential groundwater impacts should be evaluated directly through groundwater sampling. Groundwater samples should be taken at a time when the contaminated soil is below the water table.

At sites where depth to groundwater is only a few feet, the direct contact pathway is still of concern even where leaching to groundwater may not be an issue. While contaminated soil below the water table is not "soil" as defined in ch. NR720, Wis. Adm. Code, it is a contaminated media that must be addressed. The RCLs for direct contact are as appropriate for saturated soil as for soil in the unsaturated zone. As noted previously, the presence of PAH contaminated soil at depth does not necessarily require that a cleanup action be done since the potential for exposure may not currently exist. However, an institutional control, such as a deed restriction or deed affidavit, may be necessary to prevent excavation, or to minimize future exposure if the contaminated soil is brought to the surface and to ensure that it is managed properly.

### ***Relationship to Generic RCLs for GRO/DRO***

The generic soil cleanup levels for gasoline range organics (GRO) and diesel range organics (DRO) contained in s. NR 720.09(4), Wis. Adm. Code, were specifically included as "catch-alls" for other petroleum compounds, including PAHs. They are intended to be used for sites with contamination from *petroleum* where RCLs for other specific compounds are not available or not developed. However, GRO and DRO are merely indicator parameters for petroleum contamination and are measures of the total hydrocarbon concentration in a given range ( $C_5$ - $C_{10}$  for GRO and  $C_{10}$ - $C_{28}$  for DRO). For soil contamination other than from petroleum, the generic GRO/DRO soil cleanup levels are likely not adequate or appropriate since they do not provide information on the identity of the hydrocarbon constituents.

If needed, site-specific soil cleanup levels for GRO and DRO can be developed using surrogate compound approaches such as those presented in Heath et al (1993) and Magee et al (1993). The constituents of concern in petroleum products useful as surrogates include the BTEX compounds, MTBE, *n*-hexane, the trimethylbenzenes, and the PAHs. However, this approach requires development of RCLs for the

individual surrogate compounds which can be used directly.

The PAH compounds addressed in this guidance are in the range  $C_{10}$  -  $C_{22}$  and, with the trimethylbenzenes, constitute the major constituents of concern in the DRO range for petroleum. If compound-specific RCLs are used for all these constituents of concern, the additional application of an RCL for DRO is redundant and it can be disregarded. A more practical concern is that samples containing more than 100 mg/kg GRO/DRO require dilution prior to analysis which can increase detection limits for individual compounds above acceptable levels.

### ***Hazardous Waste Issues***

The suggested generic soil cleanup levels for PAHs contained in this guidance are *not* intended to address whether soil contaminated with PAHs could be a characteristic hazardous waste as determined by the toxicity characteristic leaching procedure (TCLP). It is important to remember that the TCLP test (EPA Method 1311) is intended to represent leaching of a waste disposed of in a municipal solid waste landfill. While this is not particularly relevant to soil cleanup levels, it is possible that PAH-contaminated soils that meet applicable soil cleanup levels could still fail TCLP. This could be an issue at some sites, particularly for disposal of excavated soils.

### ***Treatment Residuals***

Treated soils that meet the suggested generic RCLs provided in Table 1 should be considered to meet the criteria that are required for unrestricted off-site disposal under s. NR 718.14, Wis. Adm. Code.

The presence and nature of PAHs as contaminants at a site should be determined during the site investigation. Since PAHs are products of incomplete combustion and pyrolysis, thermal treatment of contaminated soils can result in production of PAHs that were not originally present as contaminants at the site.

### ***Toxicological Uncertainty***

Recent reviews of the toxicological information on the PAH compounds addressed in this guidance can be found in ATSDR toxicological profiles (ATSDR, 1995a; 1995b).

In calculating site risks, the PAHs historically have been separated into two categories: carcinogens and noncarcinogens, and all the carcinogenic PAHs treated as equipotent with benzo[a]pyrene, one of the more potent PAHs. This approach oversimplifies the situation, as some of the "carcinogenic" compounds are clearly more potent than others, and some of the "noncarcinogenic" compounds appear to have some weak carcinogenic activity or to act as cancer promoters or cocarcinogens (ATSDR, 1995b; Santodonato et al., 1981; Nisbet and LaGoy, 1992).

Issues related to regulatory toxicology that affect uncertainty in risk estimates for PAHs include the lack of a dose-response estimate for site-of-contact tumors caused by dermal exposure, questions regarding the accuracy of the available cancer slope factor for oral exposure, and the lack of an adequate approach for addressing the potency of mixtures of PAHs (LaGoy and Quirk, 1994). Toxic interactions among the PAHs are complex and no broadly applicable, consistent approach has been developed. The toxicological data base on PAHs is insufficient to support the development of cancer slope factors for individual PAH compounds other than benzo[a]pyrene (ATSDR, 1995b; U.S. EPA, 1993). The estimated relative potency approach used in this guidance does not meet all of the requirements necessary for the development of toxic equivalency factors (TEFs) similar to those used for assessment of risks from dioxin-like compounds

(Nisbet and LaGoy, 1992; U.S. EPA, 1993).

Nisbet and LaGoy (1992) and U.S. EPA (1993) evaluated several relative potency approaches for PAHs and presented modified versions that differ minimally. Nisbet and LaGoy (1992) suggest a relative potency of 0.01 for chrysene as compared with the EPA's value of 0.001. Additionally, this study considers a relative potency of five (5) more likely for dibenz[ah]anthracene at the low doses expected to be encountered in the natural environment; EPA recommends a relative potency of one (1) for dibenz[ah]anthracene. Nisbet and LaGoy (1992) also suggest that many PAHs now thought to be noncarcinogenic may in fact show some potency in mixtures and provide relative potency factors for these compounds. This possibility has been explored by other researchers, however, quantitative estimates are equivocal (ATSDR, 1995b) and insufficient evidence is available to classify these compounds as B2 carcinogens.

Other factors that affect uncertainty in exposure estimates include questions regarding the effect of the environmental matrix on the availability of the chemicals to a biological receptor and the lack of information on levels of those PAHs that are not detected using standard analytical procedures (LaGoy and Quirk, 1994). Where relevant data is available for a site, consideration of bioavailability is appropriate. The standard analytical methods used for PAHs (EPA methods 8310 and 8270) test for the presence of only 18 of the many PAHs likely to occur in environmental samples. While the PAHs that are analyzed in the standard EPA procedures may pose a substantial portion of the risk in most materials (ATSDR, 1995b), the other PAHs may contribute to risk at PAH-contaminated sites. It is likely that a significant percentage of the PAHs would be routinely overlooked and consequently not considered in risk estimates (LaGoy and Quirk, 1994). Furthermore, certain methylated PAHs and PAHs containing nitrogen or oxygen may be quite potent carcinogens and if present could pose substantial risks (Santodonato et al., 1981; IARC, 1983; ATSDR, 1995b).

### **Sampling for Comparison to Soil Cleanup Levels**

The following discussion is intended to highlight considerations for sampling for comparison to soil cleanup levels rather than to provide detailed guidance since these issues have broad application beyond the PAHs. Sources of additional information are provided and more detailed guidance on this subject will be available in the future.

Samples to determine the nature, degree, and extent of PAH contamination in soils should be collected during the site investigation phase at all sites where PAHs may be contaminants of concern due to the nature of the release. Site investigation soil samples must be discrete samples taken and handled in accordance with s. NR 716.13, Wis. Adm. Code. Subsequent soil sampling at the site may be modified for specific considerations.

When measured concentrations in soil are compared to RCLs, it is important to consider the basis for the RCL and what it is intended to protect. In all cases, measured concentrations from individual soil samples can be compared directly to the RCLs. However, in some cases this can result in soil cleanup actions being undertaken that may not be warranted by the pathway of concern.

### ***Sampling for the Direct Contact Pathway***

The generic RCLs for protection of human health from direct contact with contaminated soil are based on chronic (long term) exposure. Chronic exposure to site contaminants is best represented by an arithmetic

average concentration for an exposure area (U.S. EPA, 1992b). While point contaminant concentrations from individual discrete samples can be used for comparison to the RCLs, they are not necessarily relevant to exposure concentrations. Average measured soil concentrations are best represented by the upper 95% confidence limit on the arithmetic mean of the concentrations in individual samples. To be considered below the RCL, the upper 95% confidence limit on the arithmetic mean of the sampled contaminant concentrations should be less than the RCL. The method for calculating the upper 95% confidence limit on the mean can be found in U.S. EPA (1989; 1992b) or in statistics texts (e.g., Gilbert, 1987).

### ***Sampling for the Migration to Groundwater Pathway***

The generic RCLs for protection of groundwater quality are based on soil concentrations that will not result in leaching that will cause a preventive action limit to be exceeded in groundwater. For the migration to groundwater pathway, soils that have constituents that may leach to produce a groundwater impact that exceeds NR 140 preventive action limits are of primary concern. Therefore, it is the *source areas* that are of interest; not necessarily an exposure area as discussed above for the direct contact pathway. Areal averaging of concentrations is inappropriate. To determine whether soil contaminants exceed the RCLs for the migration to groundwater pathway, measured concentrations from discrete samples at specific locations should be used.

### ***Sampling for Comparison to Background Concentrations***

The purpose of comparison to background concentrations is to determine whether or not the exposure concentration for contaminated soil at the site is higher than the exposure concentration due to background. Background concentrations are best represented by the upper 95% confidence limit on the arithmetic mean. To be considered below background concentrations, the upper 95% confidence limit on the arithmetic mean of the sampled contaminant concentrations should be less than or equal to that of the sampled background concentration. Some statistical approaches for evaluating comparisons to background concentrations are presented in Gilbert (1987), Liggett (1984), and Gilbert and Simpson (1990).

The number of samples needed for determination of background concentrations is a site-specific consideration. However, the results of population comparisons are strongly affected by the sample size. The use of composite samples for PAHs may be appropriate, both for determining background and contaminant concentrations, and can reduce the associated analytical costs. However, if composite samples are used the sample statistics must be adjusted appropriately (Gilbert, 1987). The use of composite samples is described further below.

### ***Use of Composite Sampling for PAHs***

Compositing of samples can be appropriate where the measurement of interest is the mean. Therefore, composite sampling has potential application for comparison of contaminant concentrations to RCLs based on direct contact or for comparison to background concentrations, since the physical "averaging" that occurs is consistent with the use of the data. While compositing of soil samples is not appropriate for volatile organic compounds (U.S. EPA, 1989; 1992b), most of the PAH compounds are not subject to volatile loss to any significant extent. Therefore, the use of composite samples can be acceptable for PAHs and can reduce analytical costs. However, the presence of low molecular weight PAHs, such as naphthalene, the methyl naphthalenes, acenaphthene, etc., that may be affected by volatile losses should be considered. Compositing of samples can be done either in the field or at the analytical laboratory and due care should be exercised in sample handling to prevent sample degradation. The use of a single composite sample should be avoided and if composite samples are used the sample statistics used for determining the

upper 95% confidence limit on the mean must be adjusted appropriately (Gilbert, 1987). Other considerations for the appropriate use of composite samples are discussed in U.S EPA (1989; 1996).

### **Where to Go for Further Information**

Additional information and discussion of specific topics can be found in the references cited in this guidance. Additional copies of this guidance can be obtained from the Department at: Public Information Requests, Wisconsin Department of Natural Resources, P.O. Box 7921, RR/3, Madison, WI 53707, or by calling (608) 264-6009. It can also be obtained in electronic format from the Bureau for Remediation & Redevelopment BBS via modem at (608) 261-6455 (8-N-1). A Microsoft Excel 5.0 spreadsheet containing values and calculations for the suggested generic RCLs presented in this guidance is also available on the BBS. Questions regarding this guidance should be directed to Michael J. Barden at (608) 264-6007.

Additional discussion and elaboration on some issues addressed in this guidance can be found in the following guidance documents which are also available from the address above:

- *Interim Guidance on Soil Performance Standards-- PUBL RR-528-97*
- *Interim guidance on the Use of Leaching Tests for Unsaturated Soils to Determine Groundwater Contamination Potential -- PUBL RR-523-97*

This guidance will be updated as needed. Comments and suggestions can be sent to Guidance Updates, attn. Dale Zeige, at the address above.

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direct contact

Compound	CAS #	RfDo	RIC	CSFo	CSFi	Class	non-industrial				industrial				RCL (mg/kg)	
							non-cancer		cancer		non-cancer		cancer		non-industrial	industrial
							ingest	inhal	ingest	inhal	ingest	inhal	ingest	inhal		
acenaphthene	83-32-9	6e-02	na			D	900	nd			60000	nd			900	60000
acenaphthylene	208-96-8	na	na	7.3e-03	6.1e-03	D			18	51			390	360	18	360
anthracene	120-12-7	3e-01	na			D	5000	nd			300000	nd			5000	300000
benz(a)anthracene	56-55-3			7.3e-01	6.1e-01	B2			0.088	11			3.9	150	0.088	3.9
benzo(a)pyrene	50-32-8			7.3e+00	6.1e+00	B2			0.0088	1.6			0.39	22	0.0088	0.39
benzo(b)fluoranthene	205-99-2			7.3e-01	6.1e-01	B2			0.088	4.6			3.9	65	0.088	3.9
benzo(ghi)perylene	191-24-2	na	na	7.3e-02	6.1e-02	D			1.8	1100			39	7700	1.8	39
benzo(k)fluoranthene	207-08-9			7.3e-02	6.1e-02	B2			0.88	380			39	5300	0.88	39
chrysene	218-01-9			7.3e-03	6.1e-03	B2			8.8	270			390	3800	8.8	390
dibenz(ah)anthracene	53-70-3	high low		7.3e+00	6.1e+00	B2			0.0088	7.8			0.39	110	0.0088	0.39
				3.7e+01	3.1e+01	B2			0.0018	1.6			0.078	22	0.0018	0.078
fluoranthene	206-44-0	4e-02	na			D	600	nd			40000	nd			600	40000
fluorene	86-73-7	4e-02	na			D	600	nd			40000	nd			600	40000
indeno(123-cd)pyrene	193-39-5			7.3e-01	6.1e-01	B2			0.088	54			3.9	750	0.088	3.9
1-methyl naphthalene		7e-02	na			D	1100	nd			70000	nd			1100	70000
2-methyl naphthalene	91-57-6	4e-02	na			D	600	nd			40000	nd			600	40000
naphthalene	91-20-3	4e-03	2e-03			D	60	20			4000	110			20	110
phenanthrene	85-01-8	na	na	7.3e-03	6.1e-03	D			18	160			390	1100	18	390
pyrene	129-00-00	3e-02	na			D	500	nd			30000	nd			500	30000

na = not available

nd = not determined

groundwater

Compound	CAS #	RfD	CSF	Class	Risk (ug/L)	ES (ug/L)	PAL (ug/L)	NR 140?	Koc	DAF	RCL (mg/kg)
acenaphthene	83-32-9	6e-02		D	600	600	120		2.46e+03	1.23e+02	38
acenaphthylene	208-96-8	na	7.3e-03	D	4.8	5	1	p	3.68e+03	1.79e+02	0.7
anthracene	120-12-7	3e-01		D	3000	3000	600	p	1.10e+04	5.06e+02	3000
benz(a)anthracene	56-55-3		7.3e-01	B2	0.048	0.048	0.0048		2.77e+05	1.25e+04	17
benzo(a)pyrene	50-32-8		7.3e+00	B2	0.0048	0.2	0.02	y	2.31e+05	1.04e+04	48
benzo(b)fluoranthene	205-99-2		7.3e-01	B2	0.048	0.2	0.02	p	6.33e+05	2.85e+04	360
benzo(ghi)perylene	191-24-2	na	7.3e-02	D	0.48	0.48	0.096		1.26e+06	5.65e+04	6800
benzo(k)fluoranthene	207-08-9		7.3e-02	B2	0.48	0.48	0.048		6.33e+05	2.85e+04	870
chrysene	218-01-9		7.3e-03	B2	4.8	0.2	0.02	p	2.01e+05	9.08e+03	37
dibenz(ah)anthracene	53-70-3		7.3e+00	B2	0.0048	0.0048	0.00048		1.33e+06	5.98e+04	38
fluoranthene	206-44-0	4e-02		D	400	400	80	p	1.10e+04	5.09e+02	500
fluorene	86-73-7	4e-02		D	400	400	80	y	5.03e+03	2.39e+02	100
indeno(123-cd)pyrene	193-39-5		7.3e-01	B2	0.048	0.048	0.0048		1.77e+06	7.96e+04	680
1-methyl naphthalene		7e-02		D	700	700	140		1.71e+03	8.97e+01	23
2-methyl naphthalene	91-57-6	4e-02		D	400	400	80		1.87e+03	9.69e+01	20
naphthalene	91-20-3	4e-03		D	40	40	8	y	8.28e+02	5.02e+01	0.4
phenanthrene	85-01-8	na	7.3e-03	D	4.8	4.8	0.96		6.32e+03	2.97e+02	1.8
pyrene	129-00-00	3e-02		D	300	250	50	p	6.21e+04	2.81e+03	8700

y = included in NR 140

p = proposed for inclusion in NR 140



## Attachment B

### Risk-Based Algorithms for RCLs Based on Direct Contact

The risk-based algorithms used in developing the suggested generic residual contaminant levels (RCLs) for the PAHs are provided below. They are the same algorithms used in the development of generic RCLs in Table 2 of ch. NR 720, Wis. Adm. Code, with the addition of consideration of inhalation of volatiles for the inhalation pathway. These algorithms back-calculate a soil concentration (RCL) from a target risk level (for carcinogens) or hazard quotient (for noncarcinogens). They are based on the methodology presented in RAGS HHEM, Part B (U.S. EPA, 1991) and updates to those methods presented in U.S. EPA (1996).

The default target hazard quotients for noncarcinogens and target excess cancer risk levels for carcinogens provided are those used for individual compounds in the development of generic RCLs in Table 2 of ch. NR 720, Wis. Adm. Code. The basis of these values for the non-industrial (residential) exposure scenarios is analogous to the derivation of preventive action limits (PALs) for groundwater. They are determined as a percentage of the target hazard quotient or target excess cancer risk used for the industrial exposure scenario; 20% for the noncarcinogens and class D carcinogens, and 10% for carcinogens. This effectively results in a target hazard quotient of 0.2 for noncarcinogens and a target excess cancer risk of  $1 \times 10^{-7}$  for carcinogens. For the PAHs that are class D carcinogens where a cancer endpoint was used in developing the suggested generic RCLs, an excess target cancer risk of  $2 \times 10^{-7}$  was used. These target levels can be modified on a site-specific basis for *in situ* soil contamination to a hazard quotient of one (1) and an excess cancer risk of  $1 \times 10^{-6}$  as provided in s. NR 720.19(5)(a), Wis. Adm. Code.

#### ***Risk-Based Algorithms for Soil Ingestion***

The default exposure factors used for direct ingestion of contaminated soil are those specified in s. NR 720.19(5)(c), Wis. Adm. Code. The values for non-industrial (residential) exposure are the same as the default values used by U.S. EPA in the soil screening level methodology (U.S. EPA, 1996).

#### **Algorithm for Ingestion of Noncarcinogenic Contaminants in Non-Industrial (Residential) Soil Based on Childhood Exposure**

$$\text{Soil Contaminant Level (mg/kg)} = \frac{\text{THQ} \times \text{BWc} \times \text{AT} \times 365 \text{ d/yr}}{1/\text{RfDo} \times 10^{-6} \text{ kg/mg} \times \text{EF} \times \text{ED}} \quad (1)$$

Parameter/Definition (units)	Default
THQ/target hazard quotient (unitless)	0.2
BWc/average body weight for child (kg)	15
AT/averaging time (yr) <sup>a</sup>	6
RfDo/oral reference dose (mg/kg-d)	chemical-specific
EF/exposure frequency (d/yr)	350
ED/exposure duration (yr)	6

Parameter/Definition (units)	Default
IRc/soil ingestion rate for child (mg/d)	200

<sup>a</sup> For noncarcinogens, averaging time is equal to exposure duration.

### Algorithm for Ingestion of Noncarcinogenic Contaminants in Industrial Soil

$$\text{Residual Contaminant Level (mg/kg)} = \frac{\text{THQ} \times \text{BW}_a \times \text{AT} \times 365 \text{ d/yr}}{1/\text{RfDo} \times 10^{-6} \text{ kg/mg} \times \text{EF} \times \text{ED}} \quad (2)$$

Parameter/Definition (units)	Default
THQ/target hazard quotient (unitless)	1
BW <sub>a</sub> /average body weight for adult (kg)	70
AT/averaging time (yr) <sup>a</sup>	25
RfDo/oral reference dose (mg/kg-d)	chemical-specific
EF/exposure frequency (d/yr)	250
ED/exposure duration (yr)	25
IR <sub>a</sub> /soil ingestion rate for adult (mg/d)	100

<sup>a</sup> For noncarcinogens, averaging time is equal to exposure duration.

### Algorithm for Ingestion of Carcinogenic Contaminants in Non-Industrial (Residential) Soil

$$\text{Residual Contaminant Level (mg/kg)} = \frac{\text{TR} \times \text{AT} \times 365 \text{ d/yr}}{\text{SFo} \times 10^{-6} \text{ kg/mg} \times \text{EF} \times \text{IF}_s} \quad (3)$$

where

$$\text{IF}_s = \frac{\text{IR}_c \times \text{ED}_c}{\text{BW}_c} + \frac{\text{IR}_a \times \text{ED}_a}{\text{BW}_a} \quad (4)$$

Parameter/Definition (units)	Default
TR/target cancer risk level (unitless)	1×10 <sup>-7</sup>
AT/averaging time (yr)	70
SFo/oral cancer slope factor (mg/kg-d) <sup>-1</sup>	chemical-specific
EF/exposure frequency (d/yr)	350
IF <sub>s</sub> /age-adjusted soil ingestion factor (mg-yr/kg-d)	114
IR <sub>c</sub> /ingestion rate of soil age 1-6 (mg/d)	200

Parameter/Definition (units)	Default
EDc/exposure duration during ages 1-6 (yr)	6
BWc/average body weight from ages 1-6 (kg)	15
IRa/ingestion rate of soil age 7-31 (mg/d)	100
EDa/exposure duration during ages 7-31 (yr)	24
BWa/average body weight from ages 7-31 (kg)	70

### Algorithm for Ingestion of Carcinogenic Contaminants in Industrial Soil

$$\text{Annual Contaminant Level (mg/kg)} = \frac{\text{TR} \times \text{BWA} \times \text{AT} \times 365 \text{ d/yr}}{\text{SFO} \times 10^{-6} \text{ kg/mg} \times \text{EF} \times \text{ED} \times \text{IRa}} \quad (5)$$

Parameter/Definition (units)	Default
TR/target cancer risk level (unitless)	1×10 <sup>-6</sup>
BWa/average body weight for adult (kg)	70
AT/averaging time (yr)	70
SFO/oral cancer slope factor (mg/kg-d) <sup>-1</sup>	chemical-specific
EF/exposure frequency (d/yr)	250
ED/exposure duration (yr)	25
IRa/soil ingestion rate for adult (mg/d)	100

### Risk-Based Algorithms for Inhalation Exposure

The algorithms for the inhalation pathway include consideration of inhalation of volatiles and inhalation of particulate matter. The default exposure factors used for the inhalation pathway are those specified in s. NR 720.19(5)(c), Wis. Adm. Code. The values for non-industrial exposure are the same as the default values used by U.S. EPA in the soil screening level methodology (U.S. EPA, 1996), with the exception of the particulate emission factor (PEF). The soil-to-air volatilization factor is described below.

The algorithms for industrial exposure include a correction factor to adjust the inhalation rate to 24 m<sup>3</sup>/d as specified in s. NR 720.19(5)(c), Wis. Adm. Code. Also, the algorithms for inhalation of carcinogenic contaminants are written in terms of the inhalation cancer slope factor (CFS<sub>s</sub>) rather than the inhalation unit risk factor (URF) since only CFS<sub>s</sub> were available for the PAHs. The algorithms should be appropriately modified if used with URFs (see U.S. EPA, 1996).

### Algorithm for Inhalation of Noncarcinogenic Contaminants from Non-Industrial (Residential) Soil

$$\text{Contaminant Level (mg/kg)} = \frac{\text{THQ} \times \text{AT} \times 365 \text{ d/yr}}{\frac{1}{\text{RfC}} \times \text{EF} \times \text{ED} \times \left[ \left( \frac{1}{\text{VF}} \right) + (\text{Cp} \times 10^{(6)}) \right]}$$

Parameter/Definition (units)	Default
THQ/target hazard quotient (unitless)	0.2
AT/averaging time (yr) <sup>a</sup>	30
RfC/reference concentration (mg/m <sup>3</sup> )	chemical specific
EF/exposure frequency (d/yr)	350
ED/exposure duration (yr)	30
VF/volatilization factor (kg/m <sup>3</sup> )	chemical specific
Cp/concentration of particulates less than 10 μm in air (μg/m <sup>3</sup> ) <sup>b</sup>	1.4

<sup>a</sup> For noncarcinogens, averaging time is equal to exposure duration.

<sup>b</sup> The quantity Cp × 10<sup>-9</sup> kg/μg is equivalent to the term 1/PEF in U.S. EPA (1996)

#### Algorithm for Inhalation of Noncarcinogenic Contaminants from Industrial Soil

$$\text{Contaminant Level (mg/kg)} = \frac{\text{THQ} \times \text{AT} \times 365 \text{ d/yr}}{\frac{1}{\text{RfC}} \times \text{EF} \times \text{ED} \times \text{IRc} \times \left[ \left( \frac{1}{\text{VF}} \right) + (\text{Cp} \times 10^{(7)}) \right]}$$

Parameter/Definition (units)	Default
THQ/target hazard quotient (unitless)	1
AT/averaging time (yr) <sup>a</sup>	25
RfC/reference concentration (mg/m <sup>3</sup> )	chemical specific
EF/exposure frequency (d/yr)	250
ED/exposure duration (yr)	25
IRc/inhalation rate correction for adult laborer (unitless)	1.2
VF/volatilization factor (kg/m <sup>3</sup> )	chemical specific
Cp/concentration of particulates less than 10 μm in air (μg/m <sup>3</sup> ) <sup>b</sup>	1.4

<sup>a</sup> For noncarcinogens, averaging time is equal to exposure duration.

<sup>b</sup> The quantity Cp × 10<sup>-9</sup> kg/μg is equivalent to the term 1/PEF in U.S. EPA (1996)

**Algorithm for Inhalation of Carcinogenic Contaminants from Non-Industrial (Residential) Soil**

$$\text{Contaminant Level (mg/kg)} = \frac{\text{TR} \times \text{BWa} \times \text{AT} \times 365 \text{ d/yr}}{\text{SFi} \times \text{EF} \times \text{ED} \times \text{IR} \times \left[ \left( \frac{1}{\text{VF}} \right) + (\text{Cp} \times 10^{-9}) \right]} \quad (8)$$

Parameter/Definition (units)	Default
TR/target cancer risk level (unitless)	1×10 <sup>-7</sup>
BWa/average body weight for adult (kg)	70
AT/averaging time (yr)	70
SFi/inhalation cancer slope factor (mg/kg-d) <sup>-1</sup>	chemical specific
EF/exposure frequency (d/yr)	350
ED/exposure duration (yr)	30
IR/inhalation rate (m <sup>3</sup> /d)	20
VF/volatilization factor (kg/m <sup>3</sup> )	chemical specific
Cp/concentration of particulates less than 10 μm in air (μg/m <sup>3</sup> ) <sup>a</sup>	1.4

<sup>a</sup> The quantity Cp × 10<sup>-9</sup> kg/μg is equivalent to the term 1/PEF in U.S. EPA (1996)

**Algorithm for Inhalation of Carcinogenic Contaminants from Industrial Soil**

$$\text{Contaminant Level (mg/kg)} = \frac{\text{TR} \times \text{BWa} \times \text{AT} \times 365 \text{ d/yr}}{\text{SFi} \times \text{EF} \times \text{ED} \times \text{IRw} \times \left[ \left( \frac{1}{\text{VF}} \right) + (\text{Cp} \times 10^{-9}) \right]} \quad (9)$$

Parameter/Definition (units)	Default
TR/target cancer risk level (unitless)	1×10 <sup>-6</sup>
BWa/average body weight for adult (kg)	70
AT/averaging time (yr)	70
SFi/inhalation cancer slope factor (mg/kg-d) <sup>-1</sup>	chemical specific
EF/exposure frequency (d/yr)	250
ED/exposure duration (yr)	25
IRw/inhalation rate for adult laborer (m <sup>3</sup> /d)	24
VF/volatilization factor (kg/m <sup>3</sup> )	chemical specific

Parameter/Definition (units)	Default
Cp/concentration of particulates less than 10 µm in air (µg/m <sup>3</sup> ) <sup>a</sup>	1.4

<sup>a</sup> The quantity Cp × 10<sup>-9</sup> kg/µg is equivalent to the term 1/PEF in U.S. EPA (1996)

### Volatilization Factor

The soil-to-air volatilization factor (VF) is used to relate the concentration of the contaminant in soil to the flux of the contaminant in the vapor phase to the atmosphere. The volatilization factor (VF) equation presented here is based on the infinite source volatilization model of Jury et al. (1983; 1984). This equation and the default parameter values are taken from U.S. EPA (1996).

$$VF (m^3/kg) = Q/C \times \frac{(3.14 \times D_A \times T)^{\frac{1}{2}}}{2 \times \rho_b \times D_A} \times 10^{-4} (m^2/cm^2) \quad (10)$$

where

$$D_A = \frac{\left( \theta_a^{\frac{10}{3}} D_a H' + \theta_w^{\frac{10}{3}} D_w \right) \times \frac{1}{n^2}}{\rho_b K_d + \theta_w + \theta_a H'} \quad (11)$$

Parameter/Definition (units)	Default
VF/volatilization factor (kg/m <sup>3</sup> )	--
Q/C/inverse of the mean concentration at center of square source ((g/m <sup>2</sup> -s)/(kg/m <sup>3</sup> ))	68.81
D <sub>A</sub> /apparent diffusivity (cm <sup>2</sup> /s)	--
T/exposure interval (s)	9.5×10 <sup>8</sup>
ρ <sub>b</sub> /soil dry bulk density (g/cm <sup>3</sup> )	1.5
θ <sub>a</sub> /air-filled porosity (cm <sup>3</sup> /cm <sup>3</sup> )	0.28
D <sub>a</sub> /air diffusion coefficient (cm <sup>2</sup> /s)	chemical-specific
H'/dimensionless Henry's law constant (unitless)	chemical-specific
θ <sub>w</sub> /volumetric soil moisture content (cm <sup>3</sup> /cm <sup>3</sup> )	0.15
D <sub>w</sub> /water diffusion coefficient (cm <sup>2</sup> /s)	chemical-specific
n/total soil porosity (cm <sup>3</sup> /cm <sup>3</sup> )	0.43
K <sub>d</sub> /soil:water distribution coefficient (L/kg)	= K <sub>oc</sub> × f <sub>oc</sub>
K <sub>oc</sub> /organic carbon:water partitioning coefficient (L/kg)	chemical-specific
f <sub>oc</sub> /soil organic carbon content (g/g)	0.006

The infinite source volatilization model is used for determination of generic RCLs because the mass limitations associated with a finite source model are inherently site-specific and cannot be handled in a generic fashion. The infinite source model (Jury et al., 1983; 1984) is consistent with the finite source volatilization model of Jury et al. (1990), which can be used for development of site-specific RCLs that include consideration of mass limitations.

The chemical parameter values used for calculating the volatilization factor for the PAHs and the resulting values are summarized in Table B-1. Determination of values for the organic carbon:water partitioning coefficient ( $K_{oc}$ ) is discussed in Attachment C. Values for the Henry's law constant (H) are taken from U.S. EPA (1996) or ATSDR (1995a; 1995b). Values for the air diffusion coefficient ( $D_a$ ) and water diffusion coefficient ( $D_w$ ) are taken from U.S. EPA (1996), except the values for acenaphthylene, benzo[ghi]perylene, the methyl naphthalenes, and phenanthrene were estimated from the values for acenaphthene, benzo[a]pyrene, naphthalene, and anthracene, respectively, using the following relationship (Lyman et al., 1990):

$$\frac{D_1}{D_2} = \sqrt{\frac{MWT_2}{MWT_1}} \quad (12)$$

where  $D_1$  and  $D_2$  are the diffusion coefficients and  $MWT_1$  and  $MWT_2$  are the molecular weights of compound 1 and compound 2.

### References

ATSDR, 1995a, *Toxicological Profile for Naphthalene, 1-Methylnaphthalene, and 2-Methylnaphthalene (Update)*. U.S Department of Health & Human Services, Agency for Toxic Substances and Disease Registry, Atlanta, GA; August, 1995. 200 p.

ATSDR, 1995b, *Toxicological Profile for Polycyclic Aromatic Hydrocarbons (PAHs) (Update)*. U.S Department of

**Table B-1.** – Chemical parameter values for PAH compounds used for volatilization factor

Compound	CAS #	$K_{oc}^a$ (L/kg)	$H'^b$ (unitless)	$D_a^c$ ( $cm^2/s$ )	$D_w^d$ ( $cm^2/s$ )	$D_a^c$ ( $cm^2/s$ )	$VF^d$ ( $m^3/kg$ )
acenaphthene	83-32-9	$2.46 \times 10^3$	$6.36 \times 10^{-3}$	$4.21 \times 10^{-2}$	$7.69 \times 10^{-6}$	$9.37 \times 10^{-7}$	$1.29 \times 10^5$
acenaphthylene	208-96-8	$3.68 \times 10^3$	$4.67 \times 10^{-3}$	$4.24 \times 10^{-2}$	$7.74 \times 10^{-6}$	$4.64 \times 10^{-7}$	$1.84 \times 10^5$
anthracene	120-12-7	$1.10 \times 10^4$	$2.67 \times 10^{-3}$	$3.24 \times 10^{-2}$	$7.74 \times 10^{-6}$	$6.88 \times 10^{-8}$	$4.78 \times 10^5$
benz[a]anthracene	56-55-3	$2.77 \times 10^5$	$1.37 \times 10^{-4}$	$5.10 \times 10^{-2}$	$9.00 \times 10^{-6}$	$2.53 \times 10^{-10}$	$7.88 \times 10^6$
benzo[a]pyrene	50-32-8	$2.31 \times 10^5$	$4.63 \times 10^{-5}$	$4.30 \times 10^{-2}$	$9.00 \times 10^{-6}$	$1.17 \times 10^{-10}$	$1.16 \times 10^7$
benzo[b]fluoranthene	205-99-2	$6.33 \times 10^5$	$4.55 \times 10^{-3}$	$2.26 \times 10^{-2}$	$5.56 \times 10^{-6}$	$1.41 \times 10^{-9}$	$3.33 \times 10^6$
benzo[ghi]perylene	191-24-2	$1.26 \times 10^6$	$5.90 \times 10^{-5}$	$4.11 \times 10^{-2}$	$8.60 \times 10^{-6}$	$9.04 \times 10^{-12}$	$4.17 \times 10^7$
benzo[k]fluoranthene	207-08-9	$6.33 \times 10^5$	$3.40 \times 10^{-5}$	$2.26 \times 10^{-2}$	$5.56 \times 10^{-6}$	$1.99 \times 10^{-11}$	$2.81 \times 10^7$
chrysene	218-01-9	$2.01 \times 10^5$	$3.88 \times 10^{-3}$	$2.48 \times 10^{-2}$	$6.21 \times 10^{-6}$	$4.15 \times 10^{-9}$	$1.94 \times 10^6$
dibenz[a,h]anthracene	53-70-3	$1.33 \times 10^6$	$6.03 \times 10^{-7}$	$2.02 \times 10^{-2}$	$5.18 \times 10^{-6}$	$4.28 \times 10^{-12}$	$6.05 \times 10^7$
fluoranthene	206-44-0	$1.10 \times 10^4$	$6.60 \times 10^{-4}$	$3.02 \times 10^{-2}$	$6.35 \times 10^{-6}$	$1.62 \times 10^{-9}$	$9.84 \times 10^5$
fluorene	86-73-7	$5.03 \times 10^3$	$2.61 \times 10^{-3}$	$3.63 \times 10^{-2}$	$7.88 \times 10^{-6}$	$1.64 \times 10^{-7}$	$3.09 \times 10^5$
indeno[123-cd]pyrene	193-39-5	$1.77 \times 10^6$	$6.56 \times 10^{-5}$	$1.90 \times 10^{-2}$	$5.66 \times 10^{-6}$	$9.53 \times 10^{-12}$	$4.06 \times 10^7$
1-methyl naphthalene	90-12-0	$1.71 \times 10^3$	$1.47 \times 10^{-2}$	$5.60 \times 10^{-2}$	$7.12 \times 10^{-6}$	$4.12 \times 10^{-6}$	$6.17 \times 10^4$
2-methyl naphthalene	91-57-6	$1.87 \times 10^3$	$2.08 \times 10^{-2}$	$5.60 \times 10^{-2}$	$7.12 \times 10^{-6}$	$5.26 \times 10^{-6}$	$5.46 \times 10^4$
naphthalene	91-20-3	$8.28 \times 10^2$	$1.98 \times 10^{-2}$	$5.90 \times 10^{-2}$	$7.50 \times 10^{-6}$	$1.19 \times 10^{-5}$	$3.63 \times 10^4$
phenanthrene	85-01-8	$6.32 \times 10^3$	$1.08 \times 10^{-3}$	$3.24 \times 10^{-2}$	$7.74 \times 10^{-6}$	$4.76 \times 10^{-8}$	$5.74 \times 10^5$
pyrene	129-00-00	$6.21 \times 10^4$	$4.51 \times 10^{-4}$	$2.72 \times 10^{-2}$	$7.24 \times 10^{-6}$	$1.83 \times 10^{-9}$	$2.93 \times 10^6$

<sup>a</sup> see Attachment C

<sup>b</sup> dimensionless Henry's law constant =  $H$  (atm-m<sup>3</sup>/mol)  $\times$  41 (@ 20°C) (U.S. EPA, 1996)

<sup>c</sup> calculated from equation 11

<sup>d</sup> calculated from equation 10

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## Attachment C

### Methodology Used for Development of RCLs Based on Protection of Groundwater Quality

The suggested generic residual contaminant levels (RCLs) for the PAHs based on protection of groundwater quality are calculated using a soil:water partitioning equation, which relates the adsorbed and dissolved concentrations of a compound, to represent the unsaturated zone, combined with a generic groundwater mixing zone to represent the additional reduction in concentration due to dilution and attenuation in groundwater. The soil concentrations are adjusted to reflect the concentration that would be measured in a soil sample, which is the sum of the contaminant mass in the adsorbed and dissolved phases divided by the dry bulk density of the soil.

The combination of the static groundwater mixing zone based on simple volumetric relationships with a relatively high recharge rate and simple soil:water partitioning appears to provide a reasonable balance of conservative and non-conservative assumptions. Therefore, it is considered appropriate for use in developing *generic* soil cleanup levels. However, it is *not* appropriate for use in site-specific determinations. In such cases the balance of assumptions incorporated into the generic mixing zone equation can, and likely will, be seriously violated.

#### Development of Soil:Water Partitioning Equation for the Unsaturated Zone

The methodology used to estimate contaminant release from soil in leachate is based on linear equilibrium soil:water partitioning. If adsorption is linear with respect to concentration, soil:water partitioning is described by the ratio of the equilibrium concentrations in the sorbed and dissolved phases:

$$K_d = \frac{C_s}{C_w} \quad (13)$$

where  $K_d$  is the soil:water distribution coefficient (L/kg);  $C_s$  is the concentration sorbed on soil (mg/kg); and  $C_w$  is the concentration in soil moisture (mg/L). Rearranging in terms of calculating the sorbed concentration, the basic soil:water partitioning equation is:

$$C_s = K_d \times C_w \quad (14)$$

For hydrophobic organic compounds such as the PAHs, soil organic matter is the dominant sorbant in soil if the organic carbon content is above a critical level. Thus  $K_d$  can be normalized to the organic carbon content of the soil and can be approximated by a partitioning coefficient that is relatively independent of soil type by:

$$K_d = K_{oc} \times f_{oc} \quad (15)$$

where  $K_{oc}$  is the organic carbon:water partitioning coefficient (L/kg) and  $f_{oc}$  is the organic carbon fraction

of the soil (g/g).

To specify an RCL that can be compared to measured soil concentrations, adjusting the sorbed concentration derived above ( $C_s$ ) to the total concentration measured in a soil sample ( $C_m$ ) is appropriate. Contaminants in a soil sample can be associated with the soil solids, the soil water, and the soil air. The measured contaminant concentration in a soil sample is described by:

$$C_m = \frac{C_s \rho_b + C_w \theta + C_a \theta_a}{\rho_b} \quad (16)$$

where  $C_m$  is the measured concentration in soil (mg/kg);  $\rho_b$  is the dry bulk density of the soil (g/cm<sup>3</sup>);  $\theta$  is the volumetric soil moisture content (cm<sup>3</sup>/cm<sup>3</sup>);  $C_a$  is the concentration in the soil air (mg/cm<sup>3</sup>); and  $\theta_a$  is the air-filled porosity of the soil (cm<sup>3</sup>/cm<sup>3</sup>). This equation assumes that soil solids, water, and gas are conserved during sampling. Soil gas is typically not conserved during sampling and the PAHs are not volatile to any significant extent. Therefore, for practical purposes the mass in soil air ( $C_a \theta_a$ ) can be disregarded and Equation (4) can be reduced to:

$$C_m = \frac{C_s \rho_b + C_w \theta}{\rho_b} \quad (17)$$

Substituting Equation (2) into Equation (5) and simplifying yields:

$$C_m = C_w \left( K_d + \frac{\theta}{\rho_b} \right) \quad (18)$$

Substituting Equation (3) into Equation (6) yields:

$$C_m = C_\theta \left( K_{oc} f_{oc} + \frac{\theta}{\rho_b} \right) \quad (19)$$

For RCL calculation,  $C_\theta$  is the target soil moisture concentration for the leachate.

### Development of Groundwater Mixing Zone

The purpose of the groundwater mixing zone is to incorporate consideration of how groundwater concentrations are measured for compliance with groundwater standards. Basing the soil cleanup levels on groundwater concentrations that would actually be measured in the field is reasonable from a conceptual standpoint. In practice, groundwater samples are taken from monitoring wells and sample the entire saturated screened interval of the well. A typical water table monitoring well would have a 10-foot screen and, ideally, will be centered on the water table. This provides a saturated screened interval of about 5 feet (152.4 cm).

Contaminant concentrations in soil moisture at the water table do not necessarily reflect the concentrations that would be expected to be measured in groundwater. Contaminant concentrations are reduced through a variety of dilution and attenuation processes in mixing with groundwater. Therefore, the contaminant concentration in groundwater is generally lower than the original concentration in soil leachate. This reduction in contaminant concentration can be expressed succinctly by the groundwater dilution-attenuation factor (DAF) which is the ratio of the original concentration in soil moisture to the concentration in groundwater.

The dilution and attenuation of contaminants in groundwater are dependent upon many factors, including: hydraulic conductivity, hydraulic gradient, dispersivity and diffusion, sorption, and biodegradation. None of these factors are consistent from site to site, making generic assumptions regarding appropriate values tenuous at best. The incorporation of mixing in groundwater into the development of generic soil cleanup levels is hampered by the inherently site-specific nature of the parameters governing water balance fluxes and groundwater flow.

### ***Simple "Volumetric" Mixing Approach***

The approach taken for development of the generic RCLs uses a simple "volumetric" mass balance calculation with no consideration of groundwater flow. The volume of water recharging groundwater can be considered to displace an equivalent volume of water in the mixing zone and be uniformly mixed. A groundwater dilution-attenuation factor (DAF) can be determined using a simple mass balance approach that mixes the mass of a contaminant in groundwater recharge into the volume of a groundwater mixing zone and allowing equilibrium partitioning of the contaminant between the dissolved and adsorbed phases within the mixing compartment. This is a "static" model based on simple volume and mass relationships. Thus, it is not "real" in any physical sense. The simple groundwater mixing zone presented here was specifically developed for determination of **generic RCLs**. It is *not* appropriate and should *not* be used for any other purpose.

The mass of a compound in groundwater recharge can be defined as:

$$C_{\theta} x y R \theta \tag{20}$$

where  $C_{\theta}$  is the concentration of the compound in the soil moisture ( $\mu\text{g/L}$ );  $x$  and  $y$  are the length and width of the compartment (cm), respectively;  $R$  is the average amount of groundwater recharge (cm); and  $\theta$  is the volumetric soil moisture content ( $\text{cm}^3/\text{cm}^3$ ). Assuming equilibrium partitioning, the total mass of a compound in the groundwater mixing zone is equal to the sum of the mass in the dissolved phase and the mass adsorbed to aquifer solids. Thus, the total mass of the compound in the groundwater mixing zone is:

$$C_w x y d n + C_s x y d \rho_b \tag{21}$$

where  $C_w$  and  $C_s$  are the concentrations of the compound dissolved in groundwater ( $\mu\text{g/L}$ ) and adsorbed to aquifer solids ( $\mu\text{g/kg}$ ), respectively;  $d$  is the depth (thickness) of the groundwater mixing zone below the water table (cm);  $n$  is the porosity of the aquifer material; and  $\rho_b$  is the dry bulk density of the aquifer material ( $\text{g/cm}^3$ ). The equilibrium concentrations of a compound in the dissolved and adsorbed phases can be related by the linear soil:water partitioning equation:

$$C_s = K_d \times C_w \quad (22)$$

where  $K_d$  is the soil:water distribution coefficient (L/kg), which is commonly approximated from the organic carbon:water partitioning coefficient, which represents the soil:water distribution coefficient normalized to the organic carbon content of the aquifer solids, by:

$$K_d = K_{oc} \times f_{oc} \quad (23)$$

where  $K_{oc}$  is the organic carbon:water partitioning coefficient (L/kg) and  $f_{oc}$  is the organic carbon fraction of the aquifer solids (g/g). Substituting Equations (10) and (11), Equation (9) can be rewritten in terms of the concentration in the dissolved phase:

$$C_w \times y \times d \times n + C_w \times K_{oc} \times f_{oc} \times y \times d \times \rho_b \quad (24)$$

Combining like terms, Equation (12) can be simplified to:

$$C_w \times y \times d \times (K_{oc} \times f_{oc} \times \rho_b + n) \quad (25)$$

Thus, a mass balance for transferring the mass of a compound in groundwater recharge from the unsaturated zone into the groundwater mixing zone can be described by:

$$C_\theta \times y \times R \times \theta = C_w \times y \times d \times (K_{oc} \times f_{oc} \times \rho_b + n) \quad (26)$$

Rearranging Equation (14) and canceling like terms give:

$$C_\theta = C_w \frac{d}{R \theta} (K_{oc} \times f_{oc} \times \rho_b + n) \quad (27)$$

where the dilution-attenuation factor (DAF) for the groundwater mixing zone is:

$$DAF = \frac{d}{R \theta} (K_{oc} \times f_{oc} \times \rho_b + n) \quad (28)$$

By substituting the target groundwater concentration of the compound for  $C_w$  in equation (15), the term in (16) becomes the dilution attenuation factor relating the target concentration of a compound in soil moisture to the dissolved concentration in the groundwater mixing zone.

## Algorithm for Generic RCL for Migration to Groundwater Pathway

$$d \text{ Contaminant Level (mg/kg)} = \text{PAL} \times 10^{-3} \text{ mg/}\mu\text{g} \times \left( K_{oc} f_{oc} + \frac{\theta}{\rho_b} \right) \quad (29)$$

where

$$\text{DAF} = \frac{d}{R \theta} (K_{oc} f_{oc} \rho_b + n)$$

Parameter/Definition (units)	Default
PAL/preventive action limit ( $\mu\text{g/L}$ )	chemical-specific
$K_{oc}$ /organic carbon:water partitioning coefficient ( $\text{L/kg}$ )	chemical-specific
$f_{oc}$ /fractional organic carbon content ( $\text{g/g}$ )	0.001
$\theta$ /average volumetric soil moisture content of unsaturated zone ( $\text{cm}^3/\text{cm}^3$ )	0.2
$n$ /porosity ( $\text{cm}^3/\text{cm}^3$ )	0.43
$d$ /depth of groundwater mixing zone ( $\text{cm}$ )	152.4
$R$ /annualized groundwater recharge ( $\text{cm}$ )	25.4
$\rho_b$ /soil dry bulk density ( $\text{g/cm}^3$ )	1.5

## Target Groundwater Concentrations

Target groundwater concentrations for the suggested generic RCLs for the PAHs are based on preventive action limits (PALs) for the compounds for which PALs are available. For the other PAH compounds, a target groundwater concentration equivalent to the PAL was determined as provided in s. NR 720.19(4)(a) and s. NR 722.07(2)(b)2, Wis. Adm. Code.

For noncarcinogenic compounds, s. 160.13, Wis. Stats., requires that an enforcement standard be developed assuming exposure for a 10-kg child ingesting one (1) liter of water per day. The resulting calculation for the enforcement standard is (Anderson et al, 1992):

$$\text{Enforcement Standard } (\mu\text{g/L}) = \frac{\text{RfD} \times 10 \text{ kg}}{1 \text{ L/d}} \times 1000 \mu\text{g/mg} \quad (31)$$

where RfD is the oral reference dose for the compound ( $\text{mg/kg-d}$ ).

For carcinogenic compounds, s. 160.13, Wis. Stats., provides that enforcement standards are developed based on a lifetime excess cancer risk of  $1 \times 10^{-6}$ . The Department of Health and Social Services uses assumed exposure for a 70-kg adult ingesting two (2) liter of water per day for a 70-year lifetime. The resulting calculation for the enforcement standard is (Anderson et al, 1992):

$$\text{Enforcement Standard } (\mu\text{g/L}) = \frac{1 \times 10^{-6} \times 70 \text{ kg}}{\text{SFo} \times 2 \text{ L/d}} \times 1000 \mu\text{g/mg} \quad (32)$$

where SFo is the oral cancer slope factor for the compound ((mg/kg-d)<sup>-1</sup>).

The preventive action limit is determined as a percentage of the enforcement standard. The specific percentages provided by s. 160.15, Wis. Stats., for substances of human health concern are 10% for carcinogens and 20% for noncarcinogens. The enforcement standards are developed assuming 100% of the exposure to the chemical is from drinking water. Thus, the percentage reductions used for determining the preventive action limits are essentially equivalent to using a target excess cancer risk of  $1 \times 10^{-7}$  for carcinogens and a target hazard quotient of 0.2 for noncarcinogens. For class D carcinogens that are evaluated using a cancer endpoint, the PAL is equivalent to assuming a  $2 \times 10^7$  target excess cancer risk.

### K<sub>oc</sub> Values for PAHs

Soil:water partitioning coefficients (K<sub>d</sub>) were estimated using the organic carbon:water partitioning coefficient (K<sub>oc</sub>). K<sub>oc</sub> values for the PAHs were determined from an evaluation of available measured values or estimated if no measured values were available. A Microsoft Excel 5.0 spreadsheet containing the compiled data and analysis is available in electronic format and can be downloaded via modem from the Bureau for Remediation and Redevelopment BBS at (608) 261-6455 (8-N-1).

Values for K<sub>oc</sub> reported in the literature for the PAHs exhibit a wide range of variation. Reported measured values for a given compound sometimes vary over several orders of magnitude. An extensive literature search was conducted to identify available measured values for K<sub>oc</sub> and original references were consulted wherever possible. A summary of results are shown in Table C-1. The K<sub>oc</sub> values used for the suggested generic RCLs are based on the lower 95% confidence limit for the mean of measured log K<sub>oc</sub> values for each compound.

**Table C-1. – Summary of data on measured K<sub>oc</sub> values for PAH compounds**

Compound	CAS #	Mean log K <sub>oc</sub> <sup>a</sup>	95% C.I. <sup>b</sup>	log K <sub>oc</sub> <sup>c</sup> lower 95% C.L.	K <sub>oc</sub> <sup>d</sup> lower 95% C.L.	# meas. <sup>e</sup>
acenaphthene	83-32-9	3.60	± 0.21	3.39	2.46x10 <sup>3</sup>	3
acenaphthylene	208-96-8	3.72	± 0.15	3.57	3.68x10 <sup>3</sup>	3
anthracene	120-12-7	4.23	± 0.19	4.04	1.10x10 <sup>4</sup>	18
benz[a]anthracene	56-55-3	5.74	± 0.30	5.44	2.77x10 <sup>5</sup>	7
benzo[a]pyrene	50-32-8	5.85	± 0.49	5.36	2.31x10 <sup>6</sup>	12
benzo[b]fluoranthene	205-99-2			none found		
benzo[ghi]perylene	191-24-2			none found		
benzo[k]fluoranthene	207-08-9			none found		
chrysene	218-01-9			none found		
dibenz[ah]anthracene	53-70-3	6.25	± 0.13	6.12	1.33x10 <sup>6</sup>	14
fluoranthene	206-44-0	4.38	± 0.34	4.04	1.10x10 <sup>4</sup>	9
fluorene	86-73-7	3.88	± 0.18	3.70	5.03x10 <sup>3</sup>	7
indeno[123-cd]pyrene	193-39-5			none found		
1-methyl naphthalene	90-12-0	3.37	± 0.14	3.23	1.71x10 <sup>3</sup>	14
2-methyl naphthalene	91-57-6	3.46	± 0.19	3.27	1.87x10 <sup>3</sup>	8
naphthalene	91-20-3	3.01	± 0.09	2.92	8.28x10 <sup>2</sup>	59
phenanthrene	85-01-8	4.01	± 0.21	3.80	6.32x10 <sup>3</sup>	18
pyrene	129-00-00	4.84	± 0.05	4.79	6.21x10 <sup>4</sup>	46

<sup>a</sup> arithmetic mean of measured log K<sub>oc</sub> values

<sup>b</sup> 95% confidence interval for the mean of log K<sub>oc</sub> values

<sup>c</sup> log K<sub>oc</sub> value at the lower 95% confidence limit for the mean log K<sub>oc</sub> values

<sup>d</sup> K<sub>oc</sub> value at the lower 95% confidence limit for the mean log K<sub>oc</sub> value

<sup>e</sup> number of measured values

Measured  $K_{oc}$  values were not found in the literature for several of the PAH compounds. For these compounds, a regression equation was developed based on the available measured PAH  $\log K_{oc}$  values and the octanol:water partitioning coefficient ( $K_{ow}$ ). Linear regression of measured values for  $\log K_{oc}$  on  $\log K_{ow}$  yielded the following relationship:

$$\log K_{oc} = 1.02 \log K_{ow} + 0.467 \quad (33)$$

where  $K_{ow}$  is the octanol:water partitioning coefficient.

A summary of the estimated  $K_{oc}$  values is shown in Table C-2. The estimated  $K_{oc}$  values used for the suggested generic RCLs are based on the lower 95% confidence limit for the estimated mean from the regression equation.

**Table C-2.** – Summary of estimated  $K_{oc}$  values for PAH compounds without measured  $K_{oc}$  values based on octanol:water partition coefficient ( $K_{ow}$ )

Compound	CAS #	$\log K_{ow}$ <sup>a</sup>	Est. $\log K_{oc}$ <sup>a</sup>	Est. $\log K_{oc}$ <sup>c</sup> lower 95% C.L.	Est. $K_{oc}$ <sup>d</sup> lower 95% C.L.
benzo[b]fluoranthene	205-99-2	6.20	5.86 ± 0.06	5.80	6.33x10 <sup>6</sup>
benzo[ghi]perylene	191-24-2	6.50 <sup>e</sup>	6.17 ± 0.07	6.10	1.26x10 <sup>6</sup>
benzo[k]fluoranthene	207-08-9	6.20	5.86 ± 0.06	5.80	6.33x10 <sup>6</sup>
chrysene	218-01-9	5.70	5.35 ± 0.05	5.30	2.01x10 <sup>6</sup>
indeno[123-cd]pyrene	193-39-5	6.65	6.32 ± 0.07	6.25	1.77x10 <sup>6</sup>

<sup>a</sup> log octanol:water partitioning coefficient; values from U.S. EPA (1996) unless otherwise indicated

<sup>b</sup> estimated mean log organic carbon:water partitioning coefficient; ± indicates 95% confidence interval

<sup>c</sup> estimated  $\log K_{oc}$  value at the lower 95% confidence limit for the mean  $\log K_{oc}$  values

<sup>d</sup> estimated  $K_{oc}$  value at the lower 95% confidence limit for the mean  $\log K_{oc}$  value

<sup>e</sup> value from ATSDR (1995)

## References

ATSDR, 1995, *Toxicological Profile for Polycyclic Aromatic Hydrocarbons (PAHs) (Update)*. U.S. Department of Health & Human Services, Agency for Toxic Substances and Disease Registry, Atlanta, GA; August, 1995. 458 p.

U.S. EPA, 1996, *Soil Screening Guidance: Technical Background Document*. U.S. Environmental Protection Agency, Office of Emergency and Remedial Response, Washington, DC. EPA/540/R-96/128.

## Attachment D

### Example Determination of Soil Cleanup Levels for PAHs Using the Benzo[a]pyrene-Equivalent Concentration Approach

The application of the benzo[a]pyrene-equivalent concentration approach involves conversion of the measured concentrations of PAH compounds to an equivalent concentration (with regard to toxic potency) of benzo[a]pyrene. This concentration can be compared to an RCL developed for the PAH mixture in terms of a benzo[a]pyrene-equivalent concentration.

#### **Calculation of Benzo[a]pyrene-Equivalent Concentrations**

The equivalent concentration of benzo[a]pyrene is determined by multiplying the measured concentration of a PAH compound by its relative potency factor:

$$C_{B[a]P\text{-equiv}} = C_n \times RPF_n \quad (34)$$

where  $C_n$  is the measured concentration of the PAH compound in soil (mg/kg) and  $RPF_n$  is the relative potency factor for that compound. The sum of the B[a]P-equivalent concentrations for the individual compounds yields the B[a]P-equivalent concentration for the PAH mixture:

$$C_{B[a]P\text{-equiv}} = \sum (C_n \times RPF_n) \quad (35)$$

Table D-1 shows the benzo[a]pyrene-equivalent concentrations determined for some example PAH data; please note that calculated BaP-equivalent concentrations typically will be much less than the measured PAH concentrations.

**Table D-1.** – An example comparison of measured and benzo[a]pyrene-equivalent concentrations for a contaminated soil (mg/kg)

Detected compound	CAS #	RPF	Measured Conc.	BaP <sub>equiv</sub> Conc.	
				Carcinogenic PAHs	All detected PAHs
acenaphthene	83-32-9	0.001	0.22		0.00022
acenaphthylene	208-96-8	0.001	0.12		0.00012
anthracene	120-12-7	0.01	1.3		0.013
benz[a]anthracene	56-55-3	0.1	5.5	0.55	0.55
benzo[a]pyrene	50-32-8	1	4.2	4.2	4.2
benzo[b]fluoranthene	205-99-2	0.1	3.9	0.39	0.39
benzo[ghi]perylene	191-24-2	0.01	3.3		0.033
benzo[k]fluoranthene	207-08-9	0.01	3.3	0.033	0.033
chrysene	218-01-9	0.001	4.9	0.0049	0.0049
dibenz[ah]anthracene	53-70-3	1	1.6	1.6	1.6
fluoranthene	206-44-0	0.001	6.2		0.0062
fluorene	86-73-7	0.001	1.4		0.0014
indeno[123-cd]pyrene	193-39-5	0.1	3.9	0.39	0.39
1-methyl naphthalene	90-12-0	0.001	1.1		0.0011
2-methyl naphthalene	91-57-6	0.001	2.1		0.0021
naphthalene	91-20-3	0.001	0.65		0.00065
phenanthrene	85-01-8	0.001	2.1		0.0021
pyrene	129-00-00	0.001	8.8		0.0088
Subtotal PAHs			54.59		
Total BaP-equivalent				7.1679	7.23659

#### **Calculating RCLs for Benzo[a]pyrene-Equivalent Concentrations**



Soil cleanup levels based on benzo[a]pyrene-equivalent concentrations are then developed using the risk-based algorithms for carcinogenic compounds in Attachment B and the cancer slope factor for benzo[a]pyrene ( $7.3 \text{ (mg/kg-d)}^{-1}$ ). The RCLs can be developed based on either the “carcinogenic” PAHs or based on all the PAHs in the mixture. A combined target cancer risk level can be determined for the carcinogenic PAHs alone or for all the detected PAHs, up to the cumulative excess cancer risk limit of  $1 \times 10^{-5}$  specified in s. NR 720.11(3), Wis. Adm. Code.

The combined target excess cancer risk level is determined by multiplying the target risk for individual compounds by the number of compounds in the assessment. The generic RCLs in Table 2 of ch. NR 720, Wis. Adm. Code, are based on a target excess cancer risk for individual compounds of  $1 \times 10^{-7}$  for the non-industrial (residential) scenario and  $1 \times 10^{-6}$  for the industrial scenario. The target risk for individual compounds for the non-industrial scenario can be modified for *in situ* contaminated soil to  $1 \times 10^{-6}$  on a site-specific basis under s. NR 720.19(5)(a), Wis. Adm. Code.

For the example PAH data in Table D-1, since there are seven (7) carcinogenic PAHs present, this assessment would use a combined target excess cancer risk level of  $7 \times 10^{-7}$  for the non-industrial (residential) scenario and  $7 \times 10^{-6}$  for the industrial scenario. The resultant soil cleanup level equivalent to the generic RCLs (expressed as benzo[a]pyrene-equivalent concentration) for direct ingestion calculated using Equation 4 from Attachment B for the industrial exposure scenario and the combined target risk of  $7 \times 10^{-6}$  is:

$$\text{RCL} = \frac{(7 \times 10^{-6}) \times 70 \times 70 \times 365}{7.3 \times 10^{-6} \times 250 \times 25 \times 100} = 2.7 \text{ mg/kg}$$

The resultant soil cleanup level equivalent to the generic RCLs (expressed as benzo[a]pyrene-equivalent concentration) for direct ingestion calculated using Equation 3 from Attachment B for the non-industrial (residential) scenario and the combined target risk of  $7 \times 10^{-7}$  is:

$$\text{RCL} = \frac{(7 \times 10^{-7}) \times 70 \times 365}{7.3 \times 10^{-6} \times 350 \times 114} = 0.061 \text{ mg/kg}$$

This value for the non-industrial scenario can be modified for *in situ* contaminated soil using a combined target risk of  $7 \times 10^{-6}$  to 0.61 mg/kg on a site-specific basis.

Similarly, benzo[a]pyrene-equivalent RCLs can be developed for all the PAHs present in the mixture. For the example PAH data in Table D-1, since there are eighteen (18) PAHs present, this assessment would use a combined target excess cancer risk level of  $1.8 \times 10^{-6}$  ( $= 18 \times 1 \times 10^{-7}$ ) for the non-industrial (residential) scenario. However, for the industrial scenario a combined target excess cancer risk level of  $1 \times 10^{-5}$  would be used since  $18 \times 1 \times 10^{-6} = 1.8 \times 10^{-5}$  which exceed the cumulative risk limit specified in s. NR 720.19(5)(a), Wis. Adm. Code. The resultant soil cleanup level equivalent to the generic RCLs (expressed as benzo[a]pyrene-equivalent concentration) for direct ingestion calculated using Equation 4 from Attachment B for the industrial exposure scenario and the combined target risk of  $1 \times 10^{-5}$  is:

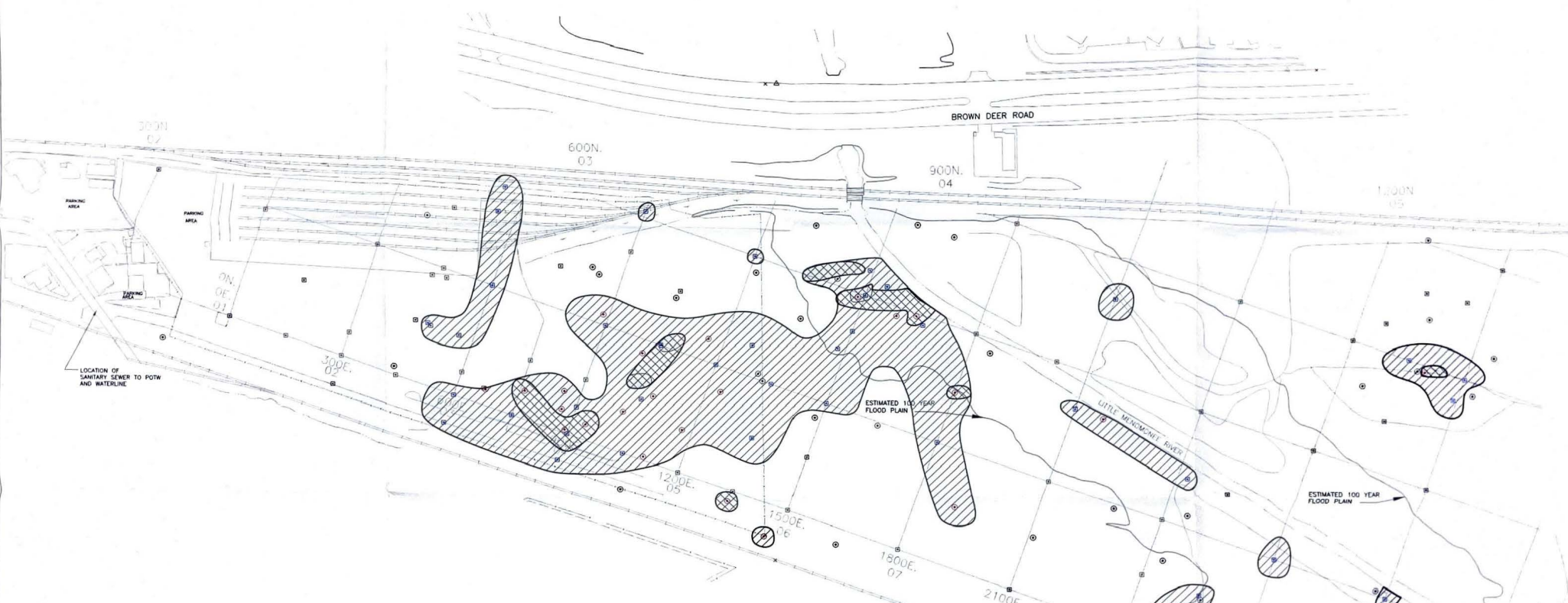
$$\text{RCL} = \frac{(1 \times 10^{-5}) \times 70 \times 70 \times 365}{7.3 \times 10^{-6} \times 250 \times 25 \times 100} = 3.9 \text{ mg/kg}$$

The resultant soil cleanup level equivalent to the generic RCLs (expressed as benzo[a]pyrene-equivalent concentration) for direct ingestion calculated using Equation 3 from Attachment B for the non-industrial (residential) scenario and the combined target risk of  $1.8 \times 10^{-6}$  is:



$$\text{RCL} = \frac{(7 \times 10^{-7}) \times 70 \times 365}{7.3 \times 10^{-6} \times 350 \times 114} = 0.061 \text{ mg/kg}$$

Again, the value for the non-industrial scenario can be modified for *in situ* contaminated soil. However, in this case a combined target excess cancer risk level of  $1 \times 10^{-5}$  would be used since  $18 \times 1 \times 10^{-6} = 1.8 \times 10^{-5}$  which exceeds the cumulative risk limit specified in s. NR 720.19(5)(a), Wis. Adm. Code. The resultant soil cleanup level equivalent to the generic RCLs (expressed as benzo[a]pyrene-equivalent concentration) for direct ingestion calculated using Equation 3 from Attachment B for the non-industrial (residential) scenario and the combined target risk of  $1 \times 10^{-5}$  is:








$$\text{RCL} = \frac{(1 \times 10^{-5}) \times 70 \times 365}{7.3 \times 10^{-6} \times 350 \times 114} = 0.9 \text{ mg/kg}$$



**AREAS REQUIRING SOIL EXCAVATION AND TREATMENT**

 <b>PRE-ROD AMENDMENT</b> <small>MMC/AGENCY DISCUSSIONS</small>	 <b>ROD AMENDMENT</b> <small>(30 SEPTEMBER 1998)</small>
TREATMENT REQUIRED FOR SOILS EXCEEDING ANY OF THE FOLLOWING CRITERIA: <ul style="list-style-type: none"> <li>• FREE PRODUCT AREAS</li> <li>• SOILS &gt; 78 mg/kg TOTAL CPAH</li> <li>• SOILS &gt; GENERIC GROUNDWATER PATHWAY RCLs FOR BTEX AND BENZO(a)PYRENE</li> </ul>	TREATMENT REQUIRED FOR SOILS EXCEEDING ANY OF THE FOLLOWING CRITERIA: <ul style="list-style-type: none"> <li>• FREE PRODUCT AREAS</li> <li>• SOILS &gt; 78 mg/kg TOTAL CPAH</li> <li>• SOILS &gt; GENERIC GROUNDWATER PATHWAY RCLs FOR BTEX AND BENZO(a)PYRENE</li> <li>• SOILS &gt; GENERIC GROUNDWATER PATHWAY RCLs FOR NAPHTHALENE AND FLUORENE</li> </ul>

**LEGEND**

-  SOIL SAMPLE DERIVED FROM PRE-DESIGN DATA EXCEEDING CLEANUP REQUIREMENTS UNDER 30 SEPT 1998 ROD AMENDMENT
-  SOIL SAMPLE DERIVED FROM RI DATA EXCEEDING CLEANUP REQUIREMENTS UNDER 30 SEPT 1998 ROD AMENDMENT
-  SOIL SAMPLE DERIVED FROM PRE-DESIGN DATA NOT EXCEEDING CLEANUP REQUIREMENTS UNDER 30 SEPT 1998 ROD AMENDMENT
-  SOIL SAMPLE DERIVED FROM RI DATA NOT EXCEEDING CLEANUP REQUIREMENTS UNDER 30 SEPT 1998 ROD AMENDMENT
-  AREAS REQUIRING EXCAVATION AND TREATMENT DUE TO POTENTIAL FREE-PRODUCT PRESENCE IN SUBSURFACE
-  AREAS REQUIRING EXCAVATION AND TREATMENT UNDER THE PRE-ROD AMENDMENT MMC/AGENCY DISCUSSIONS
-  AREAS REQUIRING EXCAVATION AND TREATMENT UNDER THE ROD AMENDMENT 30 SEPT. 1998



TOPOGRAPHIC MAP  
OF  
MOSS-AMERICAN SUPERFUND SITE  
MILWAUKEE COUNTY, WISCONSIN  
PREPARED FOR  
KAPUR AND ASSOCIATES, INC.  
MILWAUKEE, WISCONSIN  
SHEET 11

ACCURACIES NOT GUARANTEED IN UNSHADDED AREAS SHOWN BY SHADDED COVERSAGES AND UNDERLINES ELEVATIONS

**ABRAMS**  
ADVISORY SERVICES CORPORATION  
 1234 NORTH LARCH LAMON, WI 53012  
 PO BOX 10558 LAMON, WI 53012

**WESTON**  
MANAGERS DESIGNERS/CONSULTANTS

Three Hawthorn Parkway  
 Vernon Hills, Illinois  
 60061

FIGURE A

DIFFERENCE IN AREAS TO BE EXCAVATED AND TREATED UNDER 30 SEPTEMBER 1998 ROD AMENDMENT vs PRE-ROD AMENDMENT MMC/AGENCY DISCUSSIONS

MOSS - AMERICAN SITE  
 Milwaukee, Wisconsin

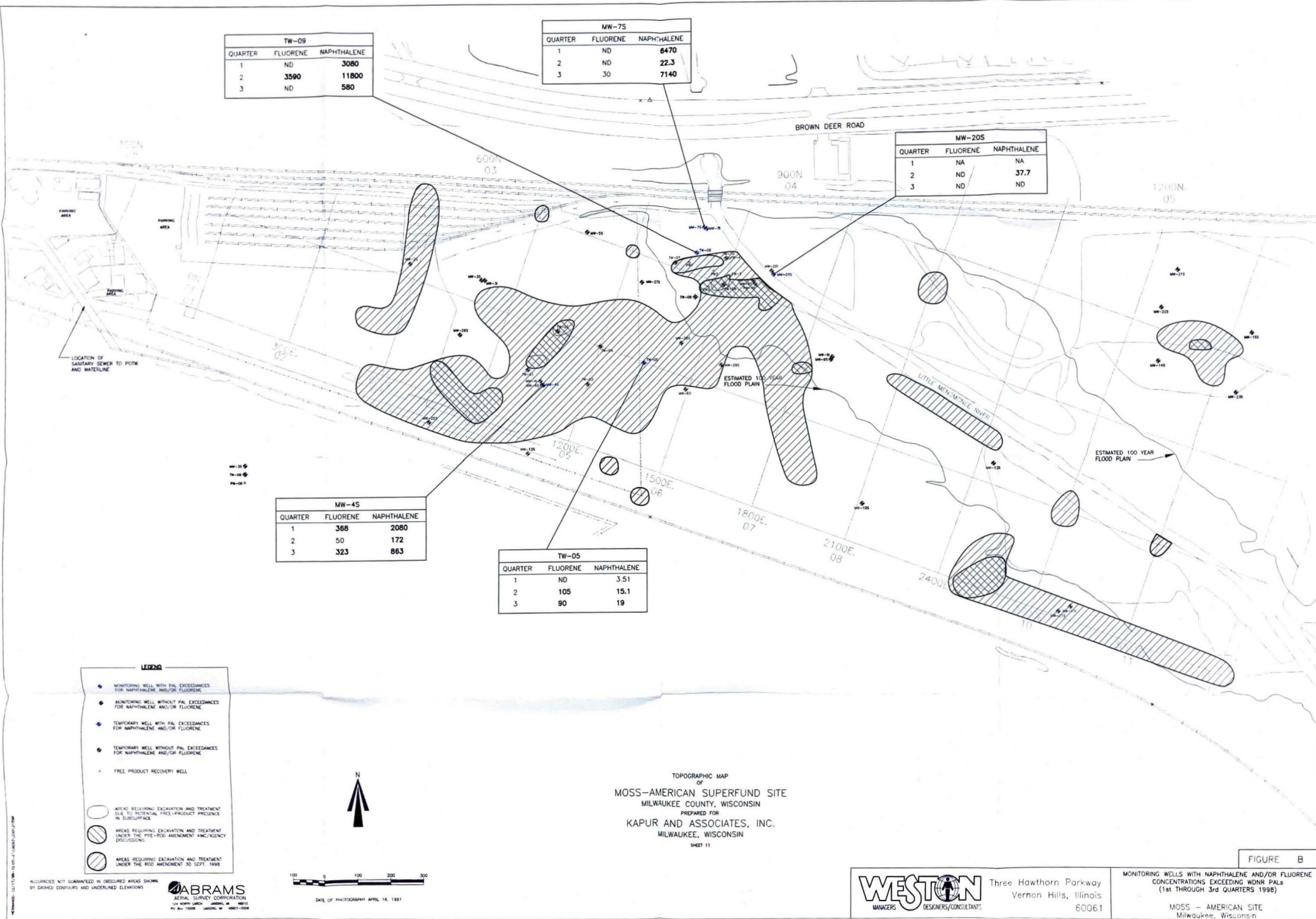
TW-09		
QUARTER	FLUORENE	NAPHTHALENE
1	ND	3080
2	3590	11800
3	ND	580

MW-75		
QUARTER	FLUORENE	NAPHTHALENE
1	ND	6470
2	ND	22.3
3	30	7140

MW-20S		
QUARTER	FLUORENE	NAPHTHALENE
1	NA	NA
2	ND	37.7
3	ND	ND

MW-4S		
QUARTER	FLUORENE	NAPHTHALENE
1	368	2080
2	50	172
3	323	863

TW-05		
QUARTER	FLUORENE	NAPHTHALENE
1	ND	3.51
2	105	15.1
3	90	19



LOCATION OF SANITARY SEWER TO POTW AND WATERLINE

MW-25  
TW-08  
PW-08

1200E. 05  
1500E. 06  
1800E. 07  
2100E. 08  
2400E. 09

ESTIMATED 100 YEAR FLOOD PLAN

**LEGEND**

- ◆ MONITORING WELL WITH PAL EXCEEDANCES FOR NAPHTHALENE AND/OR FLUORENE
- ◆ MONITORING WELL WITHOUT PAL EXCEEDANCES FOR NAPHTHALENE AND/OR FLUORENE
- ◆ TEMPORARY WELL WITH PAL EXCEEDANCES FOR NAPHTHALENE AND/OR FLUORENE
- ◆ TEMPORARY WELL WITHOUT PAL EXCEEDANCES FOR NAPHTHALENE AND/OR FLUORENE
- FREE PRODUCT RECOVERY WELL
- AREAS REQUIRING EXCAVATION AND TREATMENT DUE TO POTENTIAL FREE-PRODUCT PRESENCE IN SUBSURFACE
- AREAS REQUIRING EXCAVATION AND TREATMENT UNDER THE PRE-REQ. AMENDMENT AND/AGENCY DISCUSSIONS
- AREAS REQUIRING EXCAVATION AND TREATMENT UNDER THE REQ. AMENDMENT TO RCRA 1980



DATE OF PHOTOGRAPHY APRIL 16, 1991

TOPOGRAPHIC MAP  
OF  
MOSS-AMERICAN SUPERFUND SITE  
MILWAUKEE COUNTY, WISCONSIN  
PREPARED FOR  
KAPUR AND ASSOCIATES, INC.  
MILWAUKEE, WISCONSIN  
SHEET 11

ACCURACIES NOT GUARANTEED IN DISCLOSED AREAS SHOWN BY SHADING, CONTOURS AND UNDERLINED ELEVATIONS

**ABRAMS**  
ACTUAL SURVEY CORPORATION  
124 NORTH LAMAR, MILWAUKEE, WI 53212  
PO BOX 10008, MILWAUKEE, WI 53210-0008

**WESTON**  
MARKERS DESIGNERS/CONSULTANTS

Three Hawthorn Parkway  
Vernon Hills, Illinois  
60061

MONITORING WELLS WITH NAPHTHALENE AND/OR FLUORENE CONCENTRATIONS EXCEEDING WDNR PALS (1st THROUGH 3rd QUARTERS 1998)

MOSS - AMERICAN SITE  
Milwaukee, Wisconsin

FIGURE B