



## I-69 EVANSVILLE TO INDIANAPOLIS TIER 2 STUDIES

### Section 5—Final Environmental Impact Statement

# APPENDIX Y FINAL KARST REPORT (REDACTED)

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# Appendix H

ICS Data

Redacted for confidential reasons related to karst.



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**Interstate 69 Evansville to Indianapolis  
Tier 2 Studies: Section 5 Cave Fauna**

**Final Report**

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## Introduction

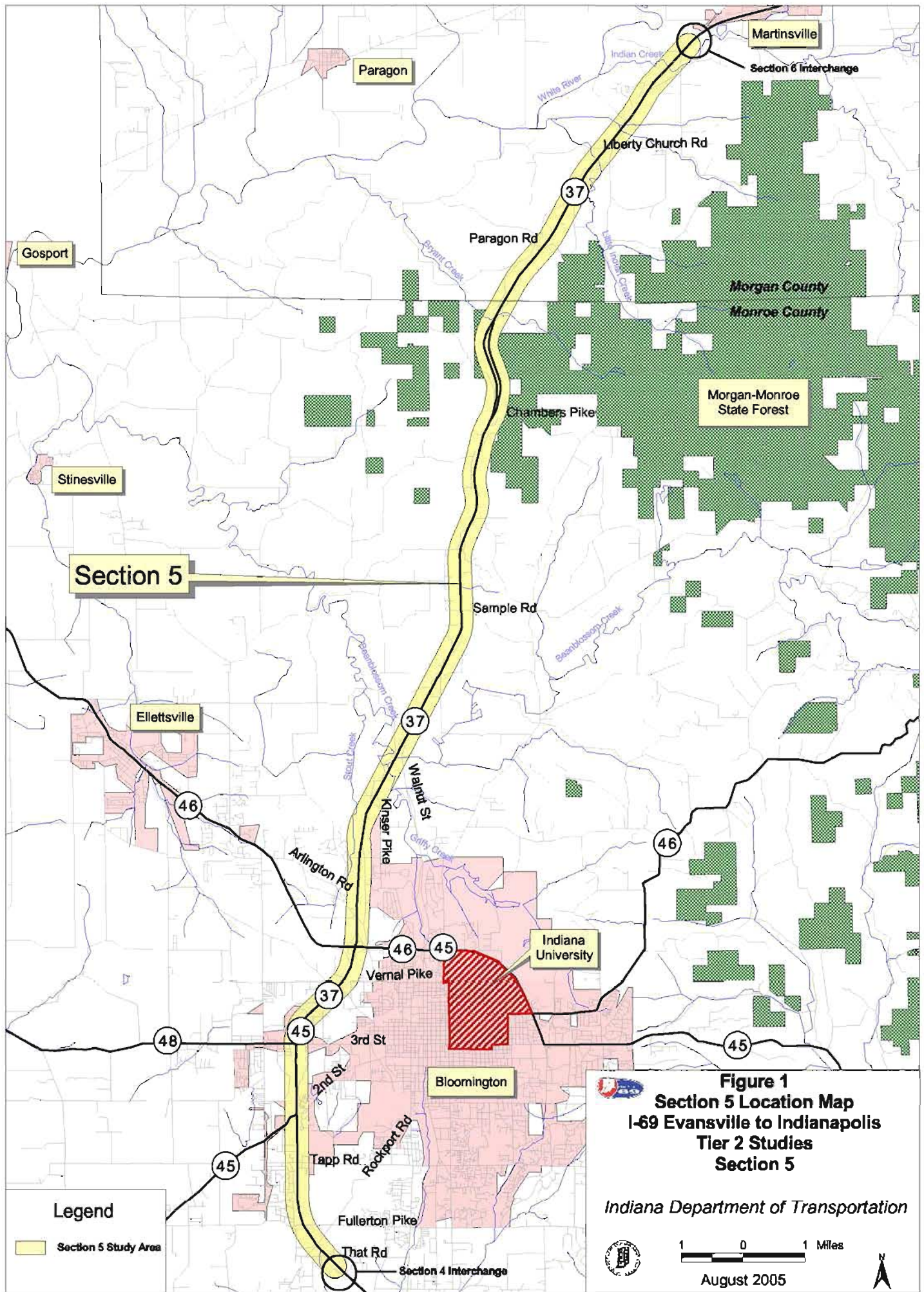
The following biological survey was conducted in support of the I-69 Tier 2, Section 5 Environmental Impact Statement (EIS) and applicable portions of the 1993 Memorandum of Understanding (MOU) as entered into by the Indiana Department of Transportation (INDOT), the Indiana Department of Natural Resources (IDNR), the Indiana Department of Environmental Management (IDEM), and the U.S. Fish and Wildlife Service (USFWS) to delineate guidelines for construction of transportation projects in karst regions of the state.

The study was prepared by Lewis and Associates, LLC (Dr. Julian J. Lewis), of Borden, Indiana under contract with Ozark Underground Laboratory (OUL) of Protem, Missouri, under the prime contractor Michael Baker, Jr. Inc. (Baker), of Crown Point, Indiana.

Section 5 EIS studies were centered in an approximately 2,000-foot wide corridor along State Route 37 (SR 37) from just south of Bloomington in Monroe County, Indiana to just south of Martinsville in Morgan County, Indiana (see Figure 1). As part of these studies, biological surveys were conducted of accessible caves that were linked to the corridor either hydrologically or by logical inference. The Section 5 accessible caves included:

- - cave passages have been mapped that extend under SR 37 (Roy and Wells 1959), and four dye traces from the Section 5 corridor were detected at its spring. A state-listed crayfish was observed in during the reconnaissance survey.
- - is a tributary to and receives runoff from the Section 5 corridor.
- - has been linked by logical inference to the Section 5 corridor due to its location immediately adjacent to the corridor and because the direction of observed flow indicates that its recharge area is located within the corridor. is a submerged cave accessible via a karst window.

The preliminary extent of minimum and maximum recharge areas for the system are shown on Figure 2. The system and cave entrance locations are classified as Confidential and are not shown on mapping for this report.







## **Methodology**

### **General Sampling Methodology**

Sample method type, timing, and location selection were based upon the conditions encountered in the caves, methods developed during sampling of numerous similar caves, and the professional judgment of the cave biologist, Dr. Lewis. All of the samples collected as part of this study were maintained in the custody of the sampler (Dr. Lewis) during collection, transport, preparation and examination.

The investigation included:

- Manual collection,
- Pitfall traps,
- Leaf litter collection and Berlese extraction,
- Shrimp-baited jars,
- Karaman-Chappuis extraction of interstitial aquatic fauna, and
- Taxa identification.

#### *Manual Collection*

Manual collection was conducted by Dr. Lewis throughout the sampled portions of all three caves including:

- Observation of cave passage surfaces;
- Overturning of rocks and gravels within the passages;
- Temporary capture, identification, measurement, taxa and sex determination, documentation, and release of selected cave fauna (e.g., crayfish); and
- Hand sampling of surfaces with a water color brush and transfer of specimens to a four-dram vial with 70% isopropyl alcohol for later identification.

Shrimp-baited jars and Karaman-Chappuis extraction samples were placed in a cooler and transported to the laboratory where samples were placed in petri dishes and examined for living fauna under a dissecting microscope.

#### *Pitfall Traps*

Five pitfall traps were placed throughout the accessible portion of Cave and two rounds of pitfall trapping were conducted in Cave passages during the sampling events. The first was comprised of 12 pitfalls, 6 in each of the two passages. The second round of pitfalls consisted of a line of 10 traps placed in the southern stream passage. The pitfall traps were distributed to provide representative coverage of the passages and were placed at locations conducive to the capture of obligate subterranean species.

Upon selection of a sampling location, a small excavation was made with a garden trowel in the mudbank. A four-ounce glass specimen jar was placed in the excavation and the annular space was filled to grade. The jar contained 70% isopropyl alcohol, for use as a preservative, and was prepared prior to entry into the cave. The edge of the jar was

baited with limburger cheese spread and the jar was usually loosely covered with a local flat stone.

Pitfall traps were left in place for five to ten days before collection. Collection consisted of:

- Observation of the cave surfaces around the jar by Dr. Lewis,
- Hand sampling of surfaces with a small brush and transfer to a four-dram vial with 70% isopropyl alcohol for later identification,
- Documentation of the jar condition and observations,
- Placement of sample identification in the jar and sealing of the jar lid,
- Transfer of the jar to a bag for retrieval from the cave, and
- Transport of the samples to the laboratory under custody of the sampler (Dr. Lewis).

#### *Collection of Leaf Litter*

Leaf litter taken from the three caves were placed in a Berlese funnel (with overhead light/heat) for extraction of the invertebrates into a vial of 70% isopropyl alcohol as follows:

- Transfer of the leaf litter to a bag for retrieval from the cave,
- Upon return to the surface, placement of the samples into a cooler on ice, and
- Transport of the samples to the laboratory under custody of the sampler (Dr. Lewis).

#### *Shrimp-Baited Jars*

Either a jar or larger bait bucket were baited with two uncooked shrimp and lowered to the bottom of the Cave karst window. The baited jar/buckets were retrieved 8 to 12 hours following placement as follows:

- Placement of sample identification in the jar and sealing of the jar lid,
- Transfer of the jar to a bag for retrieval from the cave,
- Upon return to the surface, placement of the samples into a cooler on ice, and
- Transport of the samples to the laboratory under custody of the sampler (Dr. Lewis).

#### *Extraction of Interstitial Aquatic Fauna*

An appropriate location for the extraction of interstitial aquatic fauna from the underground stream channel in both the north and south Cave passages were selected by Dr. Lewis. The extraction of interstitial aquatic fauna was conducted via the Karaman-Chappuis method as follows:

- Excavation of stream sediments with a garden trowel and transfer to a pre-rinsed bucket,
- Washing of Detritus in the bucket with water from the stream,

- Pouring of water from the bucket through a plankton net,
- Transfer of residual material in the net to a four-ounce glass specimen jar,
- Placement of identification on the sample jar and sealing of the jar lid,
- Transfer of the jar to a bag for retrieval from the cave,
- Upon return to the surface, placement of the samples into a cooler on ice, and
- Transport of the samples to the laboratory under custody of the sampler (Dr. Lewis).

### *Taxa Identification*

The contents of the sample jars and vials were placed in a cooler and transported to the laboratory where samples were placed in petri dishes and examined for living fauna under a dissecting microscope by Dr. Lewis. Specimens of each taxon were placed in 3 or 4 dram vials of 40% isopropyl alcohol and labeled per cave of origin, state, county, distance to nearest town, date and collector, as described above.

Some taxa required the use of outside taxonomists for specific identification. These taxonomists were part of the Lewis project team (see Appendix H for affiliations). The identification of specimens was performed by appropriate taxonomists with expertise with the taxa to be identified:

- Dr. Thomas C. Barr, Jr. (carabid beetles), professor emeritus, University of Kentucky;
- Dr. J. P. Battigelli (collembolans), consultant, Earthworks Research Group;
- Dr. Lynn Ferguson (diplurans), professor, Longwood University;
- Dr. Robert Hershler (aquatic snails), curator, Department of Invertebrate Zoology, Smithsonian Institution;
- Dr. John R. Holsinger (amphipods), professor, Department of Biological Sciences, Old Dominion University;
- Dr. Pierre Paquin (spiders), post-doctoral fellow, Department of Biological Sciences, San Diego State University; and
- Dr. Janet Reid (copepods), research associate, Virginia Museum of Natural History.

Samples were prepared as appropriate for taxa specific identification and shipped in accordance with the requirements of the recipient facility and state, federal, and international regulations.

### **Cave Specific Sampling Methodology and Narrative**

consisted of a small karst window covered by a limestone well house where about 13 steps lead down to a water-filled hole (approximately one meter in diameter). The actual cave is a conduit completely filled with water. On May 23, 2005 specimens of the Packard's groundwater amphipod (*Crangonyx packardii*) and Northern cave isopod (*Caecidotea stygia*) were found on rocks on a ledge at the water's edge. Two pitfalls

baited with limburger cheese were placed in mudbanks next to the water. A jar baited with two uncooked shrimp was lowered to the bottom of the water. Water clarity at that time was about one meter. The pitfalls and baited jar were retrieved on May 26, 2005. One cyclopoid copepod was taken from the jar. The pitfalls produced several cave dung flies (*Spelobia tenebrarum*) and one springtail (Entomobryid Collembolan). Around the periphery of the top of the karst window were two crayfish (*Cambarus tenebrosus*) (approximately 45 and 80mm) and two cave crayfish (*Orconectes inermis testii*) (approximately 35 and 40mm).

The cave was revisited on June 3, 2005. A jar baited with shrimp was placed within a larger bait bucket, weighted and lowered to the bottom of the karst window. It was retrieved about eight hours later. One cave crayfish (approximately 35 mm) was noted on the wall of the passage. Water clarity was less than one meter. Several Indiana cave amphipods (*Crangonyx indianensis*) were found in the shrimp-baited jar.

The water from the karst window emerges at approximately 1-2 gpm from a pipe about 210 feet downslope from the entrance to the karst window. Soil from the hillside has slumped over the pipe and the spring habitat is primarily mud with a little limestone gravel. On May 23 and 24, 2005 no fauna was appreciated in the spring.

This cave was reported in the Indiana Cave Survey as having 300 feet of walking-height passage. On May 23, 2005 the cave was entered and about 30 feet of passage was found. The cave ended in mud fill with a bank of detritus. A small stream comprised of gray water with a distinct sewage odor was flowing into the cave. The stream sank about 15 feet inside the entrance. No fauna was found in the stream.

The most common animals noted in the cave were psychodid flies, which are frequently associated with contaminated water. Six cave salamanders (*Eurycea lucifuga*) were noted. Six pitfalls baited with limburger cheese were placed in the cave. It seemed apparent that this cave would flood with any rain, so the pitfalls were retrieved on May 26, 2005. The pitfalls were mostly populated with cave dung flies and cave hump-backed flies (*Megaselia cavernicola*), although a few entomobryid springtails, one terrestrial isopod (Rathke's pillbug [*Trachelipus rathkei*]) - a wolf spider (*Meta ovalis*), a staphylinid beetle (probably *Aleochara*) and a braconid wasp (*undetermined species*) were also taken.

Berlese extraction of the leaf litter demonstrated entomobryid springtails, psychodid flies, one pseudoscorpion (*Kleptochthonius*), the staphylinid beetle (*Lesteva pallipes*), a spider (*Scotinella fratrella*) and a fragile dipluran (*Campodea fragilis*).

The overall picture of the fauna occurring at this site is primarily that of a disturbed area with a contaminated stream. The only troglobite noted was the ubiquitous cave dung fly.

The stream flowing into the cave was inspected on July 22, 2005 after a rainfall of 0.34 inches recorded the previous evening in Bloomington. The water at that time had a discernible sewage odor, but was clearer in appearance.

Reported in the literature from this cave were the northern cave isopod (*Caecidotea stygia*) (Fleming 1973); Indiana cave amphipods, Packard's groundwater amphipods, and crayfish (Eberly 1955, Hobbs & Barr 1972, Hobbs et al., 1977); and Barr's cave crayfish ostracod (*Sagittocythere barri*), and the Mayfield Cave ground beetle (*Pseudanophthalmus shilohensis mayfieldensis*) (Barr 1960).

was first sampled for this project on May 23, 2005. At that time 10 pitfall traps baited with limburger cheese were placed: five in the south passage and five in the north. About 100 feet inside the entrance a ladder was required to scale a waterfall about eight feet in height. Beyond the waterfall the cave branched into two passages, each containing a shallow stream. Heading upstream the passage to the right (south passage) appeared to be the more heavily traveled, with graffiti on the walls and refuse in and along the stream. Northern cave isopods, Indiana cave amphipods and Packard's groundwater amphipods were found in the stream. No stygobitic crayfish were noted between the origin of the passage and the signature room, a high ceiling room with walls covered with spray paint and much refuse scattered about. About 600 feet of the south passage was examined for fauna. One Mayfield cave ground beetle was found in gravels adjacent to the stream. Other troglobites noted were the cave dung fly, Bollman's cave millipede (*Conotyla bollmani*) and the subterranean sheet-web spider (*Phanetta subterranean*).

In the north passage all crayfish from the passage origin to the point where the passage lowered to a height of about three feet (approximately 900 feet into the cave) were captured, identified, sexed, measured and released. Eight crayfish were found: *Cambarus tenebrosus* 42mm ♀, 63mm ♂, and *Orconectes inermis testii* 47mm ♂, 45mm ♂, 39mm ♀, 52mm ♂, 42mm ♀, 47mm ♂. Northern cave Isopods also were common under stones in this stream. Also present were the Indiana cave and Packard's groundwater amphipods.

The cave was visited again on June 3, 2005. At that time the pitfalls were retrieved. All five from the south passage were intact and four were intact from the north passage (the fifth trap was found in the stream, presumably dislodged by a raccoon). Although pitfalls are not quantitative sampling devices, an inference of the relative abundance can be made. In the five pitfalls from the south passage the predominant species present was the cave dung fly, followed by the cave hump-backed fly. In addition, one greenhouse millipede (*Oxidus gracilis*) and two Bollman's cave millipeds (*Conotyla bollmani*) were taken. A few entomobryid springtails were also collected. In general, the fauna sampled was sparse, consistent with the pitfall placement in the dark zone of a typical nutrient poor cave environment.

The fauna taken in the four pitfalls in the north passage also was sparse, consisting of a few cave dung flies and springtails.

Many stones were turned in the stream in the south passage to search for crayfish. None were appreciated. A shallow trough was dug in a gravel bar to conduct Karaman Chappuis faunal extraction of interstitial species. This yielded Packard's groundwater amphipod. In the adjacent riffle area gravel and sand were dug from the stream substrate, placed in a bucket, washed with stream water and the supernatant poured through plankton net. This produced two hydrobiid snails (hidden spring snail [*Fontigens cryptica*]), northern cave isopods, a slender spring flatworm (*Phagocata gracilis*), and Packard's groundwater and Indiana cave amphipods.

In the north passage a riffle area was also sampled for interstitial fauna using the same technique. This produced northern cave isopods, and Packard's groundwater and Indiana cave amphipods.

A census of surficial crayfish present in the north passage was conducted and the following were noted: *Cambarus tenebrosus* 89mm ♂, *Orconectes inermis testii* 46mm ♂, 45mm ♂, 50mm ♀, 45mm ♂.

The cave was visited again on July 22, 2005 primarily for the purpose of placing pitfall traps to further evaluate the terrestrial fauna. Ten pitfalls were placed in riparian mudbanks the south passage of the cave. The pitfalls were all put in the dark zone of the cave, the first upstream of the junction of the two stream passages and the last where the passage lowers to about one foot above the cave stream.

At that time, examination of about 20 stones in the same riffle that had previously produced the hidden spring snails revealed the presence of one adult snail on the underside of a rock. Further upstream, approximately 50 more rocks were turned and one juvenile hidden spring snail about 1mm in length was noted on the underside of a stone. Only one crayfish was found, a *Cambarus tenebrosus* – no *Orconectes* were found in the south passage stream.

was visited on July 29, 2005 for the purpose of pulling the pitfalls, all of which were recovered intact. The traps were more populated than the previous May 23 and June 3, 2005 series of pitfalls. The predominant animal in these pitfalls was the cave dung fly, of which a total of 227 individuals were taken. Other flies in the pitfalls were six cave hump-backed flies, four mycetophils and four psychodids.

The next most common animals in the pitfalls were collembolans. Six specimens of a lightly pigmented entomobryid springtail were present in the first trap, which was placed in a short side passage upstream of the main waterfall. Two *Sinella* were taken in trap eight and one *Arrhopalites* in trap 10. The only other fauna appreciated were three ground beetles (*Platynus*), one each in the first three traps, and a total of four Bollman's cave millipedes.

## **Sampling Results**

None of the species found in caves in I-69 Section 5 were listed on the Federal List of Threatened/Endangered Species.

The results of the survey identifications are defined, detailed and summarized in the following four tables:

- Table 1 defines the ecological classification system of cave species,
- Table 2 defines the state or federal global rank of rarity,
- Table 3 details the species identified during the survey by its: taxonomy, scientific name, original author of the species, ecological classification, descriptive common name, cave name in which it was found, the state/global rank, and a narrative about the species.
- Table 4 summarizes the obligate subterranean species in the caves by common and scientific names, global rarity rank, listing and ecological status, and cave name.



**Table 1 Ecological Classification System or Cave Species**

Classification	Abbreviation	Definition
Troglobite	TB	terrestrial, morphologically adapted and restricted to caves, must feed and reproduce in the cave environment
Troglophile	TP	terrestrial, +/- morphologically adapted to caves, not restricted to caves, but can feed and reproduce in the cave environment
Trogloxene	TX	terrestrial, not usually morphologically adapted to caves, usually leaves the cave to either feed or reproduce
Stygobite	SB	aquatic, morphologically adapted and restricted to caves, must feed and reproduce in the cave environment
Stygophile	SP	aquatic, +/- morphologically adapted to caves, not restricted to caves, but can feed and reproduce in the cave environment
Stygoxene	SX	aquatic, not usually morphologically adapted to caves, usually leaves the cave to either feed or reproduce
Accidental	AC	fall or wash into the caves with no demonstrable affiliation, with the habitat
Parasite/commensal	PS	lives on or parasitizes a host animal

**Table 2 – Definition of State and Global Ranks of Rarity**

State/Global Rank	Number of sites in state/globally	Characterization
G1	1-5	critically imperiled
G2	6-20	imperiled
G3	21-100	vulnerable
G4	100+	apparently secure
G5		secure
SE		exotic species

References to state listed species come from the Indiana Department of Natural Resources (IDNR), Division of Nature Preserves, Natural Heritage Program of endangered, threatened, rare and extirpated vertebrates and invertebrates of Indiana dated January 18, 2002 available at: <http://www.in.gov/dnr/naturepr/pdf/vertinve.pdf>.

The IDNR Division of Fish & Wildlife maintains a list of species of concern, threatened or endangered available at: <http://www.in.gov/dnr/fishwild/endangered/rare.pdf>. Vertebrates, mollusks and crustaceans that are listed as endangered in Indiana are protected from taking pursuant to the Nongame and Endangered Species Act of 1973 (IC 14-22-34) and Fish and Wildlife Administrative Rules (312 IAC).

Table 3 - Species Identified

PHYLUM	CLASS	ORDER	FAMILY	Species	Source	Ecological Classification	Common Name	Cave	State/Global Rank	Narrative
PLATYHELMINTHES	TURBELLARIA	TRICLADIDA	PLANARIIDAE	<i>Phagocata gracilis</i>	Haldeman	SP	Slender spring flatworm		S4/G4	This flatworm is ubiquitous in springs and caves of the eastern U.S. (Kenk 1972). It is also common in cave streams and in some populations the worms are depigmented and nearly white in color, as is the case in Cave. Hyman (1937) described the unpigmented <i>Phagocata</i> in Donaldson's Cave, Lawrence Co., Indiana as <i>Phagocata subterranea</i> which Kenk (1970) synonymized with <i>Phagocata gracilis</i> .
MOLLUSCA	GASTROPODA	MESOGASTROPODA	HYDROBIIDAE	<i>Fontigens cryptica</i>	Hubricht	SB	Hidden spring snail		S1/G1	Two of these snails were initially taken from the interstices of gravel in a stream riffle in Cave by Karaman Chappuis extraction. On a subsequent trip one snail was found on the underside of a stone in the same riffle and a juvenile was found under a stone in a different riffle. The snails are completely unpigmented and the shell is white/translucent. This is the only known species of the genus in Indiana. <i>Fontigens cryptica</i> was first found in a small spring in Clark County, Indiana (Hubricht 1963). This locality and the vicinity has been searched by Dr. Robert Hershler (Smithsonian Institution) and me repeatedly without finding the snail. An equivocal site was represented by a dead shell brought up from a depth of one meter by a Bou-Rouch sampling pumpwell placed in a gravel bar on the Blue River (Lewis 1999). A sight record also exists for <i>Fontigens</i> from another Harrison Cave Spring in Harrison County (Lewis 1999). <i>Fontigens cryptica</i> is listed as a State Endangered Species. The only known extant population of this species is in Cave.
		SIGMURETHRA	DISCIDAE	<i>Anguispira alternata</i>	Say	TX	Alternate terrestrial		S3/G4	This species is reported to have a wide habitat tolerance ranging from woodlands, rocky areas, weedy road and railroad sides and urban areas in vacant lots and gardens (Hubricht, 1985). This species is a common threshold troglone in Indiana caves (Lewis, Burns and Rafail 2003).
ARTHROPODA	CRUSTACEA	EUCOPEPODA	CYCLOPIDAE	<i>Macrocyclops albidus</i>	Jurine	SX	copepod		S4/G4	The copepods were attracted to shrimp-baited jars lowered into the karst window.
				<i>Megacyclops latipes</i>	Lowndes	SX	Copepod		S4/G4	The specimens were sampled from the interstices of gravel in stream riffles.
		OSTRACODA	ENTOCYTHERIDAE	<i>Attheyella illinoisensis</i>	Forbes	SP	Copepod		S4/G4	This is a widespread species that occurs in many habitats (Reid, in litt. 2005).
				<i>Sagittocythere barri</i>	Hart & Hobbs	SB/PS	Barr's cave crayfish ostracod		S3/G4	Hart & Hobbs (1961) reported this species from Cave. It is commensal on cave crayfish
		ISOPODA	ASELLIDAE	<i>Caecidotea stygia</i>	Packard	SB	Northern cave isopod		S4/G5	This isopod is common in Cave and occurs under stones around the mouth of the karst window in Cave. Fleming (1972) reported the species from Cave, but erroneously reported the cave to be in Washington County. <i>Caecidotea jordani</i> is a subterranean species also known from Monroe County, but it is known only from two sites, both of which consist of groundwater in the interstices of unconsolidated deposits. It has never been found in caves (Lewis 1998). It is one of the most wide ranging subterranean members of the genus, recorded from southwestern Ohio, most of Kentucky, southern Illinois and a small area of eastern Missouri (Lewis & Bowman, 1981).
				<i>Lirceus fontinalis</i>	Rafinesque	SX	Bluegrass spring isopod		S4/G4	This species occurred in the entrance area of Cave. Hubricht and Mackin (1949) reported this species from about 45 localities in southern Indiana, Kentucky, southwestern Ohio and northern Tennessee. The isopod is a threshold troglone, primarily occurring in springs.
			ARMADILLIDIIDAE	<i>Armadillidium vulgare</i>	Latreille	TX	Common pillbug		SE	This terrestrial isopod typically occurs under boards and stones around houses or other structures. In Cave they were common under the stone roof of the well house.
			PORCELLIONIDAE	<i>Trachelipus rathkei</i>	Brandt	TX	Rathke's pillbug		SE	Native to Europe, this species has become widespread in North America where it is a characteristic component of deciduous forests (Harding & Sutton, 1985)
			TRICHONISCIDAE	<i>Haplophthalmus danicus</i>	Budde-Lund	TP	Danish pillbug		SE	This terrestrial isopod was common in debris in a room containing trash and vandalism in Cave. This species is native to Europe, but is widespread in several continents now (Harding & Sutton 1985). It commonly occurs in caves.
				<i>Hyloniscus riparius</i>	Koch	TX	Riparian pillbug		SE	This species is native to Europe, but has been widely established in the eastern U.S. As the name implies, it typically occurs along streams with much leaf litter or detritus (Schultz 1965).
		AMPHIPODA	CRANGONYCTIDAE	<i>Crangonyx barri</i>	Zhang & Holsinger	SB	Barr's cave amphipod		S3/G3	This species was taken from the undersides of stones at the mouth of the karst window. <i>Crangonyx barri</i> occurs from central Kentucky north into southern Indiana, where its range was previously thought to terminate in the counties of the Blue River area. The occurrence in Monroe County is a range extension of some zoogeographic interest. <i>Crangonyx barri</i> is recorded as <i>Crangonyx</i> sp. 1 (undescribed cave amphipod) and classified as a rare species on the state list of endangered, threatened, rare and extirpated vertebrates and invertebrates of Indiana. Since the state list was last updated the description of the species was published by Zhang and Holsinger (2003) and continued sampling has indicated that it is somewhat more abundant than the state list classification as S2/G2.
				<i>Crangonyx indianensis</i>	Zhang & Holsinger	SB/SP	Indiana cave amphipod		S3/G3	This species was taken from gravels in Cave. In Cave it was found roaming the surfaces of stones as well as coming to shrimp-baited jars placed on the bottom of the karst window. This amphipod is endemic to the karst of Indiana, where it is reported only from caves and spring orifices. With one exception (in the southeastern Indiana karst), all of the known localities are in the southcentral karst area. Zhang & Holsinger (2003) reported it from Cave.
<i>Crangonyx packardii</i>	Smith			SB	Packard's groundwater amphipod		S3/G4	This amphipod was taken from the interstices of gravel as well as from under stones in both of the main passages in Cave. This species, first described from a well in Orleans, Orange Co., Indiana, is now known from Indiana west to Kansas (Zhang & Holsinger 2003). <i>Crangonyx packardii</i> is typically found deeper in the interstices of stream gravels while <i>Crangonyx indianensis</i> occurs on the surface of the substrate. <i>Crangonyx packardii</i> also occurs in drip pools and ephemeral cave streams. Lewis (1998) found it a meter deep in gravel interstices of the Blue River. Zhang & Holsinger (2003) reported it from Cave. <i>Crangonyx packardii</i> is listed as a State Rare Species and is categorized as S2/G3. Lewis (2002a) classified this species as S3/G3 for the USDA Forest Service Region 9 conservation assessment of the species.		
DECAPODA	CAMBARIDAE	<i>Orconectes inermis testii</i>	Hay	SB	Cave crayfish		S2/G3	This crayfish has long been known from Cave (Eberly 1955, Hobbs & Barr 1972, Hobbs et al. 1977). This crayfish subspecies was reported from 21 caves by Hobbs et al. 1977. It occurs deep in the dark zone of the left stream passage in Cave. In Cave it comes to the periphery of shrimp bait and is seen at the top of the karst window on rocks and the walls of the passage. <i>Orconectes inermis testii</i> is listed as a State Threatened Species and is categorized as S2/G3.		
		<i>Cambarus tenebrosus</i>		SP	Crayfish	Monroe Cave	S4/G4	This species is common in Indiana caves. In Cave it has been found from the entrance passage far into the dark zone in the left stream passage. It has been observed in Cave at the top of the karst window on rocks and the walls of the passage.		

Table 3 - Species Identified

PHYLUM	CLASS	ORDER	FAMILY	Species	Source	Ecological Classification	Common Name	Cave	State/Global Rank	Narrative		
ARTHROPODA	DIPLOPODA	CHORDEUMATIDA	CONOTYLIDAE	<i>Conotyia bollmani</i>	McNeill	TB/TP	Bollman's cave milliped		S3/G3	Described as <i>Trichopetalum bollmani</i> by McNeill (1887) from Mayfield's Cave, Monroe Co., Indiana. Bollman (1889) redescribed it as <i>Scotherpes wyandotte</i> from "near Wyandotte Cave". Lewis (1998) reported sampling almost 200 caves in the Blue River basin containing Wyandotte Cave and never found <i>Conotyia</i> . Shear (1971) reported the "near Wyandotte Cave" record as a surface localities along with one other site to the north, but failed to specify where or the habitat. I have examined the single depauperate type specimen of <i>Scotherpes wyandotte</i> now in the collection of the Smithsonian Institution and put little stock in the validity of the record, since it fails to specify <i>how near</i> the specimen was taken from Wyandotte Cave – it could have come from 20 miles away. Regardless of its ecological classification, it certainly occupies the niche of troglitic milliped in the caves where it occurs. Hoffman and Lewis (1997) and Lewis (2003) summarized the range of this Indiana endemic, which occurs in caves in southcentral Indiana in the East Fork of White River drainage (Orange, Lawrence, Monroe, Martin, Owen counties). <i>Conotyia bollmani</i> is listed as a State Rare Species and is categorized as S2/G3. Lewis		
		JULIDA	JULIDAE	<i>Ophiulus pilosus</i>	Newport	TP	Milliped		SE	This species is an exotic, probably native to Italy, that is widespread in the northeastern U.S. (Hoffman 1999). It has been reported from caves in Clark, Harrison, Lawrence and Orange counties (Lewis 1983, 1994, 1996, 1998, 2003) and is particularly common in the caves of the Tincher Special Karst Area in Lawrence County.		
		POLYDESMIDA	PARADOXOSOMATIDAE	<i>Oxidus gracilis</i>	Koch	TX	Greenhouse milliped		SE	This species probably originated in Japan, but has spread nearly worldwide in temperate countries and at higher elevations in the tropics. It is found across North America and is present in astronomical numbers in many parts of the eastern U.S. (Hoffman 1999). It is frequently present in noxious numbers in caves.		
	ARACHNIDA	PSEUDOSCORPIONIDA	CHTHONIIDAE	<i>Kleptochthonius</i>	sp.	TX	Pseudoscorpion				One specimen of a 4-eyed (i.e., epigeal) pseudoscorpion was taken from leaf litter with Berlese extraction. There remain many undescribed species in this genus; this specimen does not match any of the species reported from Indiana caves ( <i>K. packardi</i> , <i>K. lewisorum</i> , <i>K. griseomanus</i> , Muchmore 2000).	
		ARANEAE	AMAUROBIIDAE	<i>Coras</i>	sp.			Spider				
					<i>Centromerus cornupalpis</i>	O.P.-Cambridge	TX	Sheet-web spider		S4/G4	This species was reported by Lewis (1994, 1995, 1998; Lewis et al 2004) from caves in Harrison, Jennings and Orange counties, where it was usually a threshold troglaxene.	
			LINYPHIIDAE	<i>Phanetta subterranea</i>	Emerton	TB	Subterranean sheet-web spider		S4/G5	This tiny spider is ubiquitous in Indiana caves, where it has been found in Clark, Crawford, Decatur, Dubois, Jefferson, Jennings, Lawrence, Monroe, Orange, Ripley, Monroe, Orange and Washington counties (Lewis 1983, 1994, 1995, 1996, 1998; Lewis and Rafail 2002; Lewis, Burns and Rafail 2002). Originally described from Wyandotte Cave, Crawford Co., the species was redescribed by Millidge (1984) and reported from a range between Alamama and Pennsylvania, west to Indiana. Peck & Lewis (1978) reported this species from Illinois and Missouri.		
					<i>Bathypantes</i>	sp.		Sheet-web spider				
			LIOCRANIDAE	<i>Scotinella fratella</i>	Gertsch	AC	Spider		S5/G5	This species is frequently found in old fields or disturbed areas (Young & Edwards 1990; Haskins & Shaddy 1986), and is indicative of the suburban environment in which this cave entrance occurs.		
			LYCOSIDAE	<i>Meta ovalis</i>	sp.	TX	Wolf spider			Wolf spiders are common around cave entrances where they frequently occur around wet detritus near streams.		
			TETRAGNATHIDAE		Gertsch	TP	American cave orb weaver		S4/G5	This species is ubiquitous in caves of the eastern U.S. (Marusik and Koponen, 1992). It has been recorded from essentially every county in Indiana that has caves (Blatchley 1897; Banta 1907; Lewis 1983, 1994, 1995, 1996, 1998, 2001; Lewis & Rafail 2002; Lewis, Burns & Rafail 2003).		
		PISAURIDAE	<i>Dolomedes scriptus</i>	Hentz	TX	Fishing spider	well cave	S4/G5	This spider was found on the wall of the Cave well house. These spiders typically occur around streams where they usually occur on rocks or boulders (Carico 1973).			
		COLLEMBOLA		<i>Pseudosinella collina</i>	Wray	TP	Hilly springtail		S2-G3/4	This species was is known primarily from caves, where in Indiana it has been recorded from Martin, Monroe, Orange and Washington counties (Lewis, 1998, Lewis et al. 2004; Christiansen & Bellinger, 1998c). In Cave this species was taken in the dark zone of the cave on mudbanks in the main stream passage. Many of the other collection sites in Indiana were in cave entrance leaf litter in sheltered sinkhole floor or twilight zone habitat.		
				<i>Pseudosinella</i>	sp.	TP	Springtail			A single specimen of this springtail was taken from a pitfall trap placed in Cave.		
				<i>Sinella alata</i>	Christiansen	TP/TX	Indiana cave springtail		S3/G3	These springtails were found under stones and debris in the dark zone of the cave. This species is endemic to Indiana, where it has been found in caves in Clark, Crawford, Harrison, Jennings, Lawrence, Monroe, Orange and Washington counties (Lewis, 1983; 1994; 1995; 1998; 2002; Lewis et al. 2004). <i>Sinella alata</i> is classified as a state endangered species. This classification is an administrative artifact from its placement on the list at a time when the species had not yet been found in the numerous localities cited above – steps are being taken to de-list.		
				<i>Ceratophysella</i>	sp.		Springtail			The taxonomy of this group is too confused at present to allow specific identification.		
				<i>Isotoma viridis</i>	Bourlet	TX	Springtail		S5/G5	This ubiquitous species is occasionally found in leaf litter or detritus in cave entrances, where it was found in Cave.		
				<i>Arrhopalites</i>	sp.	TP	Springtail			A single specimen was taken in a pitfall trap in the dark zone of the cave.		
	INSECTA	DIPLURA	CAMPODEIDAE	<i>Campodea fragilis</i>	Meinert	TX	Fragile dipluran		S5/G5	This is a cosmopolitan species that occurs across North American, Europe, South Africa and Australia. It occurs occasionally in caves (Ferguson email 2005).		
		ORTHOPTERA	GRYLLACRIDIDAE	<i>Ceuthophilus brevipes</i>		TX	Cave cricket		S4/G4	This species replaces <i>C. stygius</i> in the northern part of the Indiana karst and occurs sporadically in other Indiana caves. Hubbell (1936) reported it from seven localities in Indiana, including Mayfield's Cave, Monroe Co., as well as 20 states in the eastern U.S and Canada.		
		COLEOPTERA	CARABIDAE	<i>Pseudanopthalmus shilohensis mayfieldensis</i>				Mayfield Cave ground beetle		S1/G1	This species occurs from northern Lawrence County through Monroe County into Owen County, but the subspecies <i>P. s. mayfieldensis</i> has been reported from four caves in Monroe County including Cave (Barr 1960, Lewis & Rafail 2003). In Cave the beetle was found on moist riparian stream gravel. <i>Pseudanopthalmus shilohensis mayfieldensis</i> is classified as a state endangered species.	
				<i>Bembidion</i>	sp.	TX	Ground beetle			This is probably <i>Bembidion texanum</i> , a widespread and common beetle in eastern U.S. caves. A male specimen would be necessary for specific identification.		
				<i>Platynus</i>	sp.	TX	Ground beetle			This is probably <i>Platynus tenuicollis</i> , a widespread and common beetle in eastern U.S. caves.		
			STAPHYLINIDAE	<i>Lesteva pallipes</i>		TX	Rove beetle		S4/G4	This species frequents caves where it is frequently found in abundance under rocks along streams.		
				<i>Quedius erythrogaster</i>		TX	Rove beetle		S5/G5	This species commonly occurs in caves.		
		<i>Aleochara</i>	sp.	TX	Rove beetle			This beetle is probably the trogliphile <i>Aleochara lucifuga</i> , which occurs in caves and animal burrows in the eastern U.S. (Klimaszewski and Peck 1986).				

Table 3 - Species Identified

PHYLUM	CLASS	ORDER	FAMILY	Species	Source	Ecological Classification	Common Name	Cave	State/ Global Rank	Narrative
ARTHROPODA		DIPTERA	HELEOMYZIDAE	<i>Aecothea specus</i>		TX	Heleomyzid fly		S4/G4	This species occurs on the walls and ceilings of caves. The ecology of heleomyzid flies in an Indiana cave was discussed in some detail by Busacca (1975).
			PHORIDAE	<i>Megaselia cavernicola</i>	Brues	TP	Cave hump-backed fly		S5/G5	This species is ubiquitous in caves of the eastern U.S. and has also been reported from surface collections (Borgmeier 1965). It probably occurs in nearly every cave in Indiana that is of any length (Lewis 1994; 1995; 1996; 1998; 2001; Lewis & Rafail 2002; Lewis, Burns & Rafail 2003) and comes to baited pitfalls in abundance.
			SPHAEROCERIDAE	<i>Spelobia tenebrarum</i>	Aldrich	TB	Cave dung fly		S5/G5	This fly is ubiquitous in Indiana caves and comes readily to pitfall traps (Blatchley 1897; Banta 1907; Lewis 1994; 1995; 1996; 1998; 2001; Lewis & Rafail 2002; Lewis, Burns & Rafail 2003). It is particularly common on raccoon dung and has been found in essentially every cave in Indiana where baited pitfalls have been placed. The species occurs in caves across the eastern U.S. and is a mildly troglomorphic troglobite (Marshall & Peck 1985).
		HYMENOPTERA	BRACONIDAE	<i>Undetermined species</i>		TX	Braconid wasp			These wasps are parasites of flies larvae and are frequently found in caves. The taxonomy of this family is so confused that it precludes identification.
CHORDATA	AMPHIBIA	CAUDATA	PLETHODONTIDAE	<i>Eurycea lucifuga</i>	Rafinesque	TP	Cave salamander		S4/G5	Most of the records for the Cave salamander are from springs, spring-fed brooks or caves, but have also been found under stones on dry, open hillsides, under trash in an open field, and in suburban yards (Minton 2001). Compared to the Longtail salamander, the range of the Cave salamander is relatively restricted. In Indiana it occurs only in the southern half of the state and a more compressed range essentially equal to the karst areas of the Appalachians, Interior Low Plateaus and Ozarks.
	AVES	PASSERIFORMES	TYRANIDAE	<i>Sayornis phoebe</i>	Latham	TX	Eastern phoebe		S5/G5	The Eastern phoebe constructs nests under overhangs.
	MAMMALIA	CHIROPTERA	VESPERTILIONIDAE	<i>Pipistrellus subflavus</i>	Cuvier	TX	Eastern pipistrelle		S5/G5	The Eastern pipistrelle is a common, permanent inhabitant of southern Indiana. Mumford and Whitaker (1982) reported that almost every cave visited contained at least one bat of this species, although only three caves had 50 or more (one of these was Dillon Cave). It was also noted that in small caves the pipistrelle was frequently the only bat species present. These bats always roost singly and usually occur on the walls or overhanging ledges rather than on the ceilings of caves. Pipistrelles occur in caves during all months of the year, although relatively few occur there during the summer months.
		CARNIVORA	PROCYONIDAE	<i>Procyon lotor</i>	Linnaeus	TX	Raccoon		S5/G5	Evidence of raccoons in these caves consists of footprints, wall scratch marks and latrines, the latter are important sources of food for the invertebrate community.

**Table 4 Obligate Subterranean Species Summary**

Common Name	Scientific Name	Global Rarity Rank	Listing Status	Ecological Status			
Hidden spring snail	<i>Fontigens cryptica</i>	G1	State Endangered	Stygobite	X		
Northern cave isopod	<i>Caecidotea stygia</i>	G5		Stygobite	X		X
Indiana cave amphipod	<i>Crangonyx indianensis</i>	G3		Stygobite	X		X
Packard's groundwater amphipod	<i>Crangonyx packardi</i>	G3	State Rare	Stygobite	X		
Barr's cave amphipod	<i>Crangonyx barri</i>	G3	State Rare	Stygobite			X
Cave crayfish	<i>Orconectes inermis testii</i>	G3	State Threatened	Stygobite	X		X
Barr's cave crayfish ostracod	<i>Sagittocythere barri</i>	G3		Stygobite/Commensal	X		
Subterranean sheet-web spider	<i>Phanetta subterranea</i>	G5		Troglobite	X		
Bollman's cave milliped	<i>Conotyla bollmani</i>	G3	State Rare	Troglobite	X		
Indiana cave springtail	<i>Sinella alata</i>	G3	State Endangered	Troglobite	X		
Mayfield cave beetle	<i>Pseudanophthalmus shilohensis mayfieldensis</i>	G1	State Endangered	Troglobite	X		
Cave dung fly	<i>Spelobia tenebrarum</i>	G5		Troglobite	X	X	X

**Comparative Evaluation**

The following is a list of the top faunal caves in Indiana, from cave bioinventories that surveyed about 484 caves (Lewis 1983, 1994, 1995, 1996, 1998; Lewis & Rafail 2002, 2003; Lewis, Burns & Rafail 2004). The list is rank-ordered by the number of obligate subterranean species (troglobites and stygobites) and species of high global rarity.

Cave	<u>Obligate Subterranean</u>	<u>G1-G3</u>
	19	17
	18	15
	15	13

12	10
12	9
11	9
11	9
11	9
<b>11</b>	<b>8</b>
11	8
11	7

Cave ranked 9<sup>th</sup> out of the 484 caves included in this list.

**Conclusions**

There were no federally listed species identified during the biological survey of

are areas of special concern due to biological significance from diverse troglobitic (obligate cave dwellers) fauna, and state-listed threatened and endangered species. Mapped cave passage extended under SR 37 (Roy and Wells 1959), and the minimum groundwater recharge area of the cave extended across SR 37 and the Section 5 corridor.

The cave’s biological community appeared to be in relatively good health despite historical and current aquatic impacts from SR 37, which were not directly assessed.

Planning and design of I-69 Section 5 should attempt to minimize potential additional impacts from water derived from Section 5. Further studies may be warranted to refine the recharge area and provide the data necessary to evaluate the alternative drainage and treatment/mitigation options.

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**APPENDIX Y  
FINAL KARST REPORT (REDACTED)**

**TECHNICAL REPORT APPENDICES**

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APPENDIX A	Memorandum of Understanding
APPENDIX B	Tabular results for activated carbon and water samples
APPENDIX C	Ozark Underground Laboratory Procedures and Criteria
APPENDIX D	Sampling Station Index and Karst Feature Index
APPENDIX E	Sampling Station and Select Feature Photographs
APPENDIX F	Individual Dye Trace Reports, Summary Table, and Figures
APPENDIX G	Documentation Graphs for All Analyzed Samples
APPENDIX H	Precipitation and Discharge Data from Illinois Central Spring
APPENDIX I	CONFIDENTIAL Data
APPENDIX J	Cave Fauna of the Section 5 Corridor of I-69
<b>APPENDIX K</b>	<b>Indiana Bat Hibernacula Cave Reconnaissance</b>
APPENDIX L	Pollutant Loading Estimate Tables and FHWA Methodology
APPENDIX M	IDNR Water Well Data
APPENDIX N	Detail Maps of Preferred Alternative and Resources

# Appendix K

Indiana Bat Hibernacula Reconnaissance  
Redacted for confidential reasons related to karst.



**APPENDIX Y  
FINAL KARST REPORT (REDACTED)**

**TECHNICAL REPORT APPENDICES**

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<b>APPENDIX A</b>	<b>Memorandum of Understanding</b>
<b>APPENDIX B</b>	<b>Tabular results for activated carbon and water samples</b>
<b>APPENDIX C</b>	<b>Ozark Underground Laboratory Procedures and Criteria</b>
<b>APPENDIX D</b>	<b>Sampling Station Index and Karst Feature Index</b>
<b>APPENDIX E</b>	<b>Sampling Station and Select Feature Photographs</b>
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sp122	Spring	2143+00	0.247	0	430	430	0.479	0.200	0.354	83.099	78.908	356.173	3.630	49.298	358.351	1.272	0.648	105.073	3.434	0.039	0.055	0.001
sp125	Spring	2145+50	0.164	0	286	285	0.331	0.154	0.270	0.000	56.891	318.077	2.839	41.186	330.395	1.084	0.322	98 989	0.595	0.033	0.048	0.001
sp127	Spring	2146+00	0.164	0	286	285	0.331	0.154	0.270	0.000	56.891	318.077	2.839	41.186	330.395	1.084	0.322	98 989	0.595	0.033	0.048	0.001
sp128	Spring	2148+00	0.164	0	286	285	0.331	0.154	0.270	0.000	56.891	318.077	2.839	41.186	330.395	1.084	0.322	98 989	0.595	0.033	0.048	0.001
sp136	Spring	2162+00	0.028	0	49	49	0.090	0.079	0.131	0.000	20.900	255.804	1.546	27.926	284.696	0.776	0.000	89.045	0.000	0.023	0.038	0.000





sp122	Spring	2143+00	0.247	0	430	248	0.293	0.142	0.248	0.000	51.129	308.108	2.632	39.063	323.079	1.035	0.237	97 397	0.000	0.031	0.047	0.001
sp125	Spring	2145+50	0.164	0	286	164	0.208	0.116	0.199	0.000	38.462	286.191	2.177	34.397	306.995	0.926	0.050	93 897	0.000	0.028	0.043	0.000
sp127	Spring	2146+00	0.164	0	286	164	0.208	0.116	0.199	0.000	38.462	286.191	2.177	34.397	306.995	0.926	0.050	93 897	0.000	0.028	0.043	0.000
sp128	Spring	2148+00	0.164	0	286	164	0.208	0.116	0.199	0.000	38.462	286.191	2.177	34.397	306.995	0.926	0.050	93 897	0.000	0.028	0.043	0.000
sp136	Spring	2162+00	0.028	0	49	28	0.069	0.073	0.119	0.000	17.757	250.366	1.433	26.768	280.706	0.749	0.000	88.176	0.000	0.022	0.037	0.000



sp122	Spring	2143+00	0.247	0	430	282	0.327	0.153	0.267	0.000	56.301	317.057	2.817	40.969	329.646	1.079	0.314	98 827	0.519	0.033	0.048	0.001
sp125	Spring	2145+50	0.164	0	286	187	0.231	0.123	0.212	0.000	41.894	292.128	2.300	35.661	311.352	0.956	0.100	94 846	0.000	0.029	0.044	0.000
sp127	Spring	2146+00	0.164	0	286	187	0.231	0.123	0.212	0.000	41.894	292.128	2.300	35.661	311.352	0.956	0.100	94 846	0.000	0.029	0.044	0.000
sp128	Spring	2148+00	0.164	0	286	187	0.231	0.123	0.212	0.000	41.894	292.128	2.300	35.661	311.352	0.956	0.100	94 846	0.000	0.029	0.044	0.000
sp136	Spring	2162+00	0.028	0	49	32	0.072	0.074	0.122	0.000	18.342	251.379	1.454	26.984	281.449	0.754	0.000	88.338	0.000	0.022	0.037	0.000



sp122	Spring	2143+00	0.247	0	430	430	0.479	0.200	0.354	83.203	78.933	356.217	3.630	49.307	358.383	1.273	0.649	105.080	3.437	0.039	0.055	0.001
sp125	Spring	2145+50	0.164	0	286	286	0.331	0.154	0.270	0.000	56.907	318.106	2.839	41.192	330.416	1.084	0.323	98 994	0.597	0.033	0.048	0.001
sp127	Spring	2146+00	0.164	0	286	286	0.331	0.154	0.270	0.000	56.907	318.106	2.839	41.192	330.416	1.084	0.323	98 994	0.597	0.033	0.048	0.001
sp128	Spring	2148+00	0.164	0	286	286	0.331	0.154	0.270	0.000	56.907	318.106	2.839	41.192	330.416	1.084	0.323	98 994	0.597	0.033	0.048	0.001
sp136	Spring	2162+00	0.028	0	49	49	0.090	0.079	0.131	0.000	20.903	255.809	1.546	27.927	284.700	0.776	0.000	89.046	0.000	0.023	0.038	0.000



sp026	Spring	1584+00	0.040	0	115	115	0.157	0.100	0.170	0.000	30.958	273.207	1.907	31.632	297.467	0.862	0.000	91.824	0.000	0.026	0.041	0.000
sp028	Spring	1586+00	0.040	0	115	115	0.157	0.100	0.170	0.000	30.958	273.207	1.907	31.632	297.467	0.862	0.000	91.824	0.000	0.026	0.041	0.000
sp032	Spring	1632+00	0.076	0	218	218	0.263	0.133	0.230	0.000	46.671	300.394	2.472	37.421	317.418	0.997	0.171	96.166	0.000	0.030	0.045	0.001
sp083	Spring	1939+50	0.047	0	135	135	0.178	0.107	0.182	0.000	34.014	278.494	2.017	32.758	301.347	0.888	0.000	92.668	0.000	0.027	0.042	0.000
sp112	Spring	2110+00	0.079	0	227	227	0.271	0.136	0.235	0.000	47.980	302.660	2.519	37.903	319.081	1.008	0.190	96.527	0.000	0.030	0.046	0.001
sp122	Spring	2140+00	0.229	0	658	658	0.711	0.272	0.487	226.261	113.449	415.938	4.870	62.023	402.209	1.568	1.160	114.617	7.888	0.048	0.064	0.002
sp124	Spring	2145+00	0.057	0	164	164	0.207	0.116	0.199	0.000	38.378	286.046	2.174	34.366	306.889	0.926	0.048	93.874	0.000	0.028	0.043	0.000
sp128	Spring	2150+00	0.254	0	730	729	0.784	0.294	0.529	271.487	124.360	434.817	5.262	66.043	416.063	1.661	1.321	117.632	9.295	0.051	0.067	0.002
sp136	Spring	2161+50	0.026	0	75	75	0.116	0.088	0.147	0.000	24.848	262.635	1.688	29.381	289.709	0.810	0.000	90.136	0.000	0.024	0.039	0.000





sp026	Spring	1584+00	0.040	0	115	66	0.107	0.085	0.142	0.000	23.544	260.378	1.641	28.900	288.053	0.799	0.000	89.775	0.000	0.024	0.039	0.000
sp028	Spring	1586+00	0.040	0	115	66	0.107	0.085	0.142	0.000	23.544	260.378	1.641	28.900	288.053	0.799	0.000	89.775	0.000	0.024	0.039	0.000
sp032	Spring	1632+00	0.076	0	218	126	0.168	0.104	0.176	0.000	32.583	276.018	1.965	32.231	299.530	0.876	0.000	92.273	0.000	0.026	0.041	0.000
sp083	Spring	1939+50	0.047	0	135	78	0.119	0.089	0.148	0.000	25.301	263.419	1.704	29.548	290.284	0.814	0.000	90.261	0.000	0.024	0.039	0.000
sp112	Spring	2110+00	0.079	0	227	131	0.173	0.105	0.179	0.000	33.336	277.322	1.993	32.508	300.487	0.883	0.000	92.481	0.000	0.026	0.042	0.000
sp122	Spring	2140+00	0.229	0	658	378	0.426	0.184	0.324	50.321	71.000	342.490	3.345	46.384	348.310	1.205	0.531	102.888	2.414	0.037	0.052	0.001
sp124	Spring	2145+00	0.057	0	164	94	0.136	0.094	0.158	0.000	27.812	267.764	1.794	30.473	293.473	0.835	0.000	90.955	0.000	0.025	0.040	0.000
sp128	Spring	2150+00	0.254	0	730	420	0.468	0.197	0.348	76.339	77.277	353.351	3.571	48.697	356.280	1.258	0.624	104.623	3.224	0.038	0.054	0.001
sp136	Spring	2161+50	0.026	0	75	43	0.084	0.078	0.128	0.000	20.028	254.296	1.515	27.605	283.589	0.769	0.000	88.804	0.000	0.023	0.038	0.000



sp026	Spring	1584+00	0.040	0	115	75	0.117	0.088	0.147	0.000	24 924	262.767	1.690	29.409	289.806	0.811	0.000	90.157	0.000	0.024	0.039	0.000
sp028	Spring	1586+00	0.040	0	115	75	0.117	0.088	0.147	0.000	24 924	262.767	1.690	29.409	289.806	0.811	0.000	90.157	0.000	0.024	0.039	0.000
sp032	Spring	1632+00	0.076	0	218	143	0.186	0.109	0.186	0.000	35 206	280.557	2.060	33.197	302.861	0.899	0.001	92.998	0.000	0.027	0.042	0.000
sp083	Spring	1939+50	0.047	0	135	88	0.130	0.092	0.155	0.000	26 923	266.226	1.762	30.145	292.344	0.828	0.000	90.709	0.000	0.025	0.040	0.000
sp112	Spring	2110+00	0.079	0	227	148	0.191	0.111	0.190	0.000	36.063	282.040	2.090	33.513	303.949	0.906	0.014	93.234	0.000	0.027	0.042	0.000
sp122	Spring	2140+00	0.229	0	658	430	0.479	0.200	0 354	83.081	78 904	356.166	3.629	49.296	358.346	1.272	0.648	105.072	3.434	0.039	0.055	0.001
sp124	Spring	2145+00	0.057	0	164	107	0.149	0.098	0.166	0.000	29.780	271.168	1.865	31.198	295.971	0.852	0.000	91.498	0.000	0.025	0.041	0.000
sp128	Spring	2150+00	0.254	0	730	477	0.527	0.215	0 382	112.675	86.044	368.520	3.886	51.927	367.412	1.333	0.754	107.045	4.354	0.041	0.057	0.001
sp136	Spring	2161+50	0.026	0	75	49	0.090	0.079	0.132	0.000	20 926	255.849	1.547	27.936	284.729	0.777	0.000	89.052	0.000	0.023	0.038	0.000



sp026	Spring	1584+00	0.040	0	115	115	0.157	0.100	0.170	0.000	30 965	273.219	1.907	31.634	297.476	0.862	0.000	91.826	0.000	0.026	0.041	0.000
sp028	Spring	1586+00	0.040	0	115	115	0.157	0.100	0.170	0.000	30 965	273.219	1.907	31.634	297.476	0.862	0.000	91.826	0.000	0.026	0.041	0.000
sp032	Spring	1632+00	0.076	0	218	218	0.263	0.133	0 230	0.000	46 684	300.416	2.472	37.426	317.434	0.997	0.171	96.169	0.000	0.030	0.045	0.001
sp083	Spring	1939+50	0.047	0	135	135	0.178	0.107	0.182	0.000	34.021	278.507	2.017	32.761	301.357	0.889	0.000	92.670	0.000	0.027	0.042	0.000
sp112	Spring	2110+00	0.079	0	227	227	0.271	0.136	0 236	0.000	47 993	302.683	2.519	37.908	319.098	1.008	0.191	96.531	0.000	0.030	0.046	0.001
sp122	Spring	2140+00	0.229	0	658	658	0.711	0.272	0.487	226.421	113.487	416.004	4.872	62.037	402.257	1.568	1.160	114.628	7.893	0.048	0.064	0.002
sp124	Spring	2145+00	0.057	0	164	164	0.207	0.116	0.199	0.000	38 388	286.062	2.174	34.369	306.901	0.926	0.048	93.877	0.000	0.028	0.043	0.000
sp128	Spring	2150+00	0.254	0	730	730	0.784	0.295	0.529	271.663	124.403	434.891	5.264	66.059	416.117	1.662	1.322	117.644	9.301	0.051	0.067	0.002
sp136	Spring	2161+50	0.026	0	75	75	0.116	0.088	0.147	0.000	24 852	262.642	1.688	29.382	289.714	0.810	0.000	90.137	0.000	0.024	0.039	0.000



Acute Aquatic Criterion, AAC (Table 2, 327 IAC 2-1-6)	0.262	0.042	0.254	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	860	n/a	0.011	3.679	n/a
Chronic Aquatic Criterion, CAC (Table 2, 327 IAC 2-1-6)	0.010	0.026	0.230	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	230	n/a	0.002	0.438	n/a
Point of Water Intake Human Health (Table 1, 327 IAC 2-1-6)	0.050	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	0.010	n/a	n/a	n/a	0.010	170.000	0.00014
<i>Values in shaded cells exceed one of the water quality standards</i>	<b>0.010</b>	<b>0.026</b>	<b>0.230</b>	<b>n/a</b>	<b>n/a</b>	<b>n/a</b>	<b>n/a</b>	<b>n/a</b>	<b>n/a</b>	<b>0.010</b>	<b>n/a</b>	<b>230</b>	<b>n/a</b>	<b>0.002</b>	<b>0.438</b>	<b>0.00014</b>
Number of features exceeding water quality standards	53	53	44							53		22		53		53
Highest concentration	2.847	1.205	2.132							9.040		1015.064		0.269	0.439	0.006
Highest concentration feature ID	i020	i020	i020							i182		i182		i182	i182	i020





Acute Aquatic Criterion, AAC (Table 2, 327 IAC 2-1-6)	0.262	0.042	0.254	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	860	n/a	0.011	3.679	n/a
Chronic Aquatic Criterion, CAC (Table 2, 327 IAC 2-1-6)	0.010	0.026	0.230	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	230	n/a	0.002	0.438	n/a
Point of Water Intake Human Health (Table 1, 327 IAC 2-1-6)	0.050	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	0.010	n/a	n/a	n/a	0.010	170.000	0.00014
<i>Values in shaded cells exceed one of the water quality standards</i>	<b>0.010</b>	<b>0.026</b>	<b>0.230</b>	<b>n/a</b>	<b>n/a</b>	<b>n/a</b>	<b>n/a</b>	<b>n/a</b>	<b>n/a</b>	<b>0.010</b>	<b>n/a</b>	<b>230</b>	<b>n/a</b>	<b>0.002</b>	<b>0.438</b>	<b>0.00014</b>
Number of features exceeding water quality standards	53	49	12							53		7		53		38
Highest concentration	0.668	0.331	0.574							3.302		383.524		0.098	0.163	0.001
Highest concentration feature ID	i020	i020	i020							i182		i182		i182	i182	i020



Acute Aquatic Criterion, AAC (Table 2, 327 IAC 2-1-6)	0.262	0.042	0.254	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	860	n/a	0.011	3.679	n/a
Chronic Aquatic Criterion, CAC (Table 2, 327 IAC 2-1-6)	0.010	0.026	0.230	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	230	n/a	0.002	0.438	n/a
Point of Water Intake Human Health (Table 1, 327 IAC 2-1-6)	0.050	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	0.010	n/a	n/a	n/a	0.010	170.000	0.00014
<i>Values in shaded cells exceed one of the water quality standards</i>	<b>0.010</b>	<b>0.026</b>	<b>0.230</b>	<b>n/a</b>	<b>n/a</b>	<b>n/a</b>	<b>n/a</b>	<b>n/a</b>	<b>n/a</b>	<b>0.010</b>	<b>n/a</b>	<b>230</b>	<b>n/a</b>	<b>0.002</b>	<b>0.438</b>	<b>0.00014</b>
Number of features exceeding water quality standards	53	45	11							53		4		53		37
Highest concentration	0.602	0.286	0.499							2.686		309.941		0.080	0.132	0.001
Highest concentration feature ID	i020	i020	i020							i182		i182		i182	i182	i020



Acute Aquatic Criterion, AAC (Table 2, 327 IAC 2-1-6)	0.262	0.042	0.254	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	860	n/a	0.011	3.679	n/a
Chronic Aquatic Criterion, CAC (Table 2, 327 IAC 2-1-6)	0.010	0.026	0.230	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	230	n/a	0.002	0.438	n/a
Point of Water Intake Human Health (Table 1, 327 IAC 2-1-6)	0.050	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	0.010	n/a	n/a	n/a	0.010	170.000	0.00014
<i>Values in shaded cells exceed one of the water quality standards</i>	<b>0.010</b>	<b>0.026</b>	<b>0.230</b>	<b>n/a</b>	<b>n/a</b>	<b>n/a</b>	<b>n/a</b>	<b>n/a</b>	<b>n/a</b>	<b>0.010</b>	<b>n/a</b>	<b>230</b>	<b>n/a</b>	<b>0.002</b>	<b>0.438</b>	<b>0.00014</b>
Number of features exceeding water quality standards	53	53	44							53		22		53		53
Highest concentration	2.872	1.216	2.150							9.116		1023.535		0.271	0.443	0.006
Highest concentration feature ID	i020	i020	i020							i182		i182		i182	i182	i020



sp128	Spring	2150+00	15.769	69,262	0.181	0.068	0.122	62.855	28.792	100.670	1.218	15.290	96.328	0.385	0.306	27.234	2.152	0.012	0.016	0.000
sp136	Spring	2161+50	0.534	2,345	0.794	0.599	1.002	0.000	169.881	1795.591	11.538	200.872	1980.692	5.538	0.000	616.242	0.000	0.165	0.268	0.001
Acute Aquatic Criterion, AAC (Table 2, 327 IAC 2-1-6)			0.262	0.042	0.254	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	860	n/a	0.011	3.679	n/a
Chronic Aquatic Criterion, CAC (Table 2, 327 IAC 2-1-6)			0.010	0.026	0.230	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	230	n/a	0.002	0.438	n/a
Point of Water Intake Human Health (Table 1, 327 IAC 2-1-6)			0.050	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	0.010	n/a	n/a	n/a	0.010	170.000	0.00014
<i>Values in shaded cells exceed one of the water quality standards</i>			<b>0.010</b>	<b>0.026</b>	<b>0.230</b>	<b>n/a</b>	<b>n/a</b>	<b>n/a</b>	<b>n/a</b>	<b>n/a</b>	<b>n/a</b>	<b>n/a</b>	<b>n/a</b>	<b>0.010</b>	<b>n/a</b>	<b>230</b>	<b>n/a</b>	<b>0.002</b>	<b>0.438</b>	<b>0.00014</b>
Number of features exceeding water quality standards			57	57	45									57		31		57	3	56
Highest concentration			5.197	1.946	3.497									10.932		1003.808		0.338	0.445	0.012
Highest concentration feature ID			i017	i017	i017									i017		b182		i017	i252	i017





sp128	Spring	2150+00	15.769	180,883	0.041	0.017	0.031	6.768	6.851	31.325	0.317	4.317	31.585	0.112	0.055	9.275	0.286	0.003	0.005	0.000
sp136	Spring	2161+50	0.534	6,125	0.219	0.203	0.335	0.000	52.432	665.721	3.965	72.268	742.409	2.013	0.000	232.480	0.000	0.060	0.099	0.000
Acute Aquatic Criterion, AAC (Table 2, 327 IAC 2-1-6)			0.262	0.042	0.254	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	860	n/a	0.011	3.679	n/a
Chronic Aquatic Criterion, CAC (Table 2, 327 IAC 2-1-6)			0.010	0.026	0.230	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	230	n/a	0.002	0.438	n/a
Point of Water Intake Human Health (Table 1, 327 IAC 2-1-6)			0.050	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	0.010	n/a	n/a	n/a	0.010	170.000	0.00014
<i>Values in shaded cells exceed one of the water quality standards</i>			<b>0.010</b>	<b>0.026</b>	<b>0.230</b>	<b>n/a</b>	<b>n/a</b>	<b>n/a</b>	<b>n/a</b>	<b>n/a</b>	<b>n/a</b>	<b>n/a</b>	<b>n/a</b>	<b>0.010</b>	<b>n/a</b>	<b>230</b>	<b>n/a</b>	<b>0.002</b>	<b>0.438</b>	<b>0.00014</b>
Number of features exceeding water quality standards			57	48	21									57	10		57	0	42	
Highest concentration			1.187	0.496	0.879									3.327	381.044		0.099	0.162	0.003	
Highest concentration feature ID			i017	i017	i017									i252	b182		i252	i252	i017	



sp128	Spring	2150+00	15.769	224,387	0.038	0.015	0.027	8.052	6.149	26.336	0.278	3.711	26.257	0.095	0.054	7.650	0.311	0.003	0.004	0.000
sp136	Spring	2161+50	0.534	7,599	0.190	0.168	0.278	0.000	44.161	539.930	3.264	58.954	600.877	1.639	0.000	187.931	0.000	0.049	0.080	0.000
Acute Aquatic Criterion, AAC (Table 2, 327 IAC 2-1-6)			0.262	0.042	0.254	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	860	n/a	0.011	3.679	n/a
Chronic Aquatic Criterion, CAC (Table 2, 327 IAC 2-1-6)			0.010	0.026	0.230	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	230	n/a	0.002	0.438	n/a
Point of Water Intake Human Health (Table 1, 327 IAC 2-1-6)			0.050	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	0.010	n/a	n/a	n/a	0.010	170.000	0.00014
<i>Values in shaded cells exceed one of the water quality standards</i>			<b>0.010</b>	<b>0.026</b>	<b>0.230</b>	<b>n/a</b>	<b>n/a</b>	<b>n/a</b>	<b>n/a</b>	<b>n/a</b>	<b>n/a</b>	<b>n/a</b>	<b>n/a</b>	<b>0.010</b>	<b>n/a</b>	<b>230</b>	<b>n/a</b>	<b>0.002</b>	<b>0.438</b>	<b>0.00014</b>
Number of features exceeding water quality standards			57	46	16									57	5		57	0	39	
Highest concentration			1.077	0.437	0.778									2.719	307.668		0.083	0.132	0.002	
Highest concentration feature ID			i017	i017	i017									i252	b182		i017	i252	i017	



sp128	Spring	2150+00	15.769	68,690	0.183	0.069	0.124	63.420	29.042	101.526	1.229	15.422	97.143	0.388	0.309	27.464	2.171	0.012	0.016	0.000
sp136	Spring	2161+50	0.534	2,326	0.801	0.604	1.011	0.000	171.327	1810.606	11.635	202.557	1997.236	5.585	0.000	621.386	0.000	0.166	0.270	0.001
Acute Aquatic Criterion, AAC (Table 2, 327 IAC 2-1-6)			0.262	0.042	0.254	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	860	n/a	0.011	3.679	n/a
Chronic Aquatic Criterion, CAC (Table 2, 327 IAC 2-1-6)			0.010	0.026	0.230	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	230	n/a	0.002	0.438	n/a
Point of Water Intake Human Health (Table 1, 327 IAC 2-1-6)			0.050	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	0.010	n/a	n/a	n/a	0.010	170.000	0.00014
<i>Values in shaded cells exceed one of the water quality standards</i>			<b>0.010</b>	<b>0.026</b>	<b>0.230</b>	<b>n/a</b>	<b>n/a</b>	<b>n/a</b>	<b>n/a</b>	<b>n/a</b>	<b>n/a</b>	<b>n/a</b>	<b>n/a</b>	<b>0.010</b>	<b>n/a</b>	<b>230</b>	<b>n/a</b>	<b>0.002</b>	<b>0.438</b>	<b>0.00014</b>
Number of features exceeding water quality standards			57	57	45									57	32		57	3	56	
Highest concentration			5.242	1.963	3.527									11.025	1012.181		0.341	0.449	0.012	
Highest concentration feature ID			i017	i017	i017									i017	b182		i017	i252	i017	

# FHWA HIGHWAY RUNOFF WATER QUALITY TRAINING COURSE

## SECTION 8: PREDICTION OF WATER QUALITY IMPACTS

Estimated Time for Section:

### The CONTENT of this Section

This section introduces impact prediction techniques developed by FHWA and others to assess highway runoff water quality impacts. Several specific procedures will be introduced either by lecture or by case study problems. Specific methods include estimating the highway runoff impact, maintenance practice impacts, groundwater impacts, and aquatic system impacts. Also, a brief overview of water quality models which have been developed to assess the impact of nonpoint pollution on watersheds relative to highway runoff will be provided.

### The GOAL of this Section

Participants will become familiar with predicting quality changes in water quality parameters associated with highway runoff water quality.

### The PURPOSE of this Section

To introduce participants to different qualitative and quantitative techniques for predicting highway runoff water quality impacts.

### Listing of Sessions

Time

Session 8.1	Impact Procedures and Data Requirements	
Session 8.2	Introduction to Highway Runoff Pollutant Characteristics Predictive Procedures	
Session 8.3	Prediction of Pollutant Loadings and Runoff Concentrations on Highway Surfaces - Case Study	
Session 8.4	Prediction of Loading Impacts of Highway Runoff - Case Study	
Session 8.5	Prediction of Maintenance Impacts	
Session 8.6	Prediction of Groundwater Impacts	
Session 8.7	Aquatic System Impacts	
Session 8.8	Introduction to Water Quality Models for Predicting Water Quality Impacts	

## SECTION 8: PREDICTION OF WATER QUALITY IMPACTS

### SESSION 8.1: IMPACT PROCEDURES AND DATA REQUIREMENTS

Estimated Time for Completion:

**OBJECTIVES:** Upon completion of this session, participants will:

- Be introduced to a procedure for the assessment of effects of stormwater runoff from operating highways on receiving waters.
- Be introduced to a general procedure for evaluating potential impacts of highway maintenance practices on water quality.
- Know what data may be required to assess impacts of highway stormwater runoff on quality.

#### **SESSION OVERVIEW:**

This session introduces general procedures for assessing potential water quality impacts of highway stormwater runoff and maintenance practices. The specific methods will be introduced in later sessions. An overview of data required to assess water quality impacts of highway stormwater runoff is also presented.



## 8.1: IMPACT PROCEDURES AND DATA REQUIREMENTS

### I. INTRODUCTION

Data requirements to assess the need to conduct impact analysis or the potential effects of highway operations on surface water quality are identified in Table 8.1.1. This check list may be supplemented by site-specific data requirements.

### II. ASSESSMENT OF HIGHWAY STORMWATER RUNOFF IMPACTS

Determining the need to assess the impact of highway stormwater runoff and the level of analysis depends on a number of factors. Selected factors include:

- The amount of traffic anticipated or currently traveling on the highway.
- The proximity of the highway site to receiving waters and their designated uses (e.g., drinking water, recreation, etc).
- Local and state requirements for control of nonpoint and stormwater point sources.
- Climatic factors, such as frequency and intensity of rainfall.
- The ratio of impervious surface to total watershed area upstream of project site.
- Local controversy.

Figure 8.1.1, illustrates a procedure for assessment of effects of stormwater runoff from operating highways on receiving waters. The first step in the procedure involves determining the anticipated impacts and/or the degree of controversy involved. Possible criteria useful in making the determination are:

- Traffic volumes in excess of 30,000 ADT.
- The highway site located near receiving stream where low dilutive capacities exist.
- Direct discharge of highway runoff to poorly flushed areas of lakes, wetlands, or coastal embayments.

If the decision is made to conduct an analysis, then either a seasonal/annual pollutant loading analysis or an event analysis should be made.

Table 8.1.1. Data for assessing water quality impacts of highway stormwater runoff.

Highway Design Features

- Length
- Number of lanes and lane widths
- Type of access
- Access ramps or intersecting roads
- Paving material
- Type of section(s) involved (at grade, cut, fill)
- Slopes (longitudinal and side)
- Median characteristics (width, paving, barrier type)
- Shoulder characteristics (width, paving, barrier type)
- Characteristics of area outside the shoulders but within the right-of-way (dimensions, topography, vegetation)
- Total impervious surface area

Operating Conditions

- Design average daily traffic (ADT)
- Projected vehicle composition
- Expected daily, weekly and seasonal traffic patterns
- Anticipated average speeds and braking characteristics
- Summary of applicable accident and spill data (from records on similar highways)

Drainage System Characteristics (to the extent available during environmental assessment)

- Channel types (closed conduit, paved open channel, bare open channel, vegetated open channel, unchanneled overland flow, etc.)
- Channel dimensions and slopes
- Soils and vegetation characteristics in flow path
- Discharge points
- Collection systems (type, dimensions and spacings of drop boxes, etc.)
- Design flow rates

Hydrologic Characteristics

- Average annual precipitation (rain and snow) and monthly distribution of precipitation
- Receiving water and ground water data --
  - Streams (base flow, annual average flow, peak flow, flood plain maps)
  - Lakes and reservoirs (surface area, mean depth, water residence time)
- Wetlands (surface area)
- Groundwater (locations of aquifers, recharge characteristics)
- Summary of available data on point and nonpoint source flows in the watershed

Water Quality and Aquatic Biological Data

- Summary of available receiving water and groundwater monitoring data (water quality; microflora; microfauna, aquatic plants, benthic macro-invertebrates; fish populations, migrations and spawning areas)
- Sensitive or unique habitats
- Threatened and endangered species
- Summary of available data on effluent quality of sources in the watershed
- Beneficial use classification
- Established water quality criteria

Surrounding Land Use Characteristics

- Total watershed area
- Percentage of total area in each land use category (organized as in Tables 3 and 4)

Projected Highway Maintenance Characteristics

- Sanding application (quantity, frequency, particle size description)
- Deicing agent application (type, quantity, frequency, additives used)
- Pesticide application (type, quantity, frequency, toxicity)
- Roadway maintenance (sweeping, washing)
- Right-of-way maintenance (mowing, ditch cleaning, fertilizing, irrigation)

Description of Special Features

- Construction on woodwaste fill
- Detention basins
- Oil and grease traps
- Other mitigative features

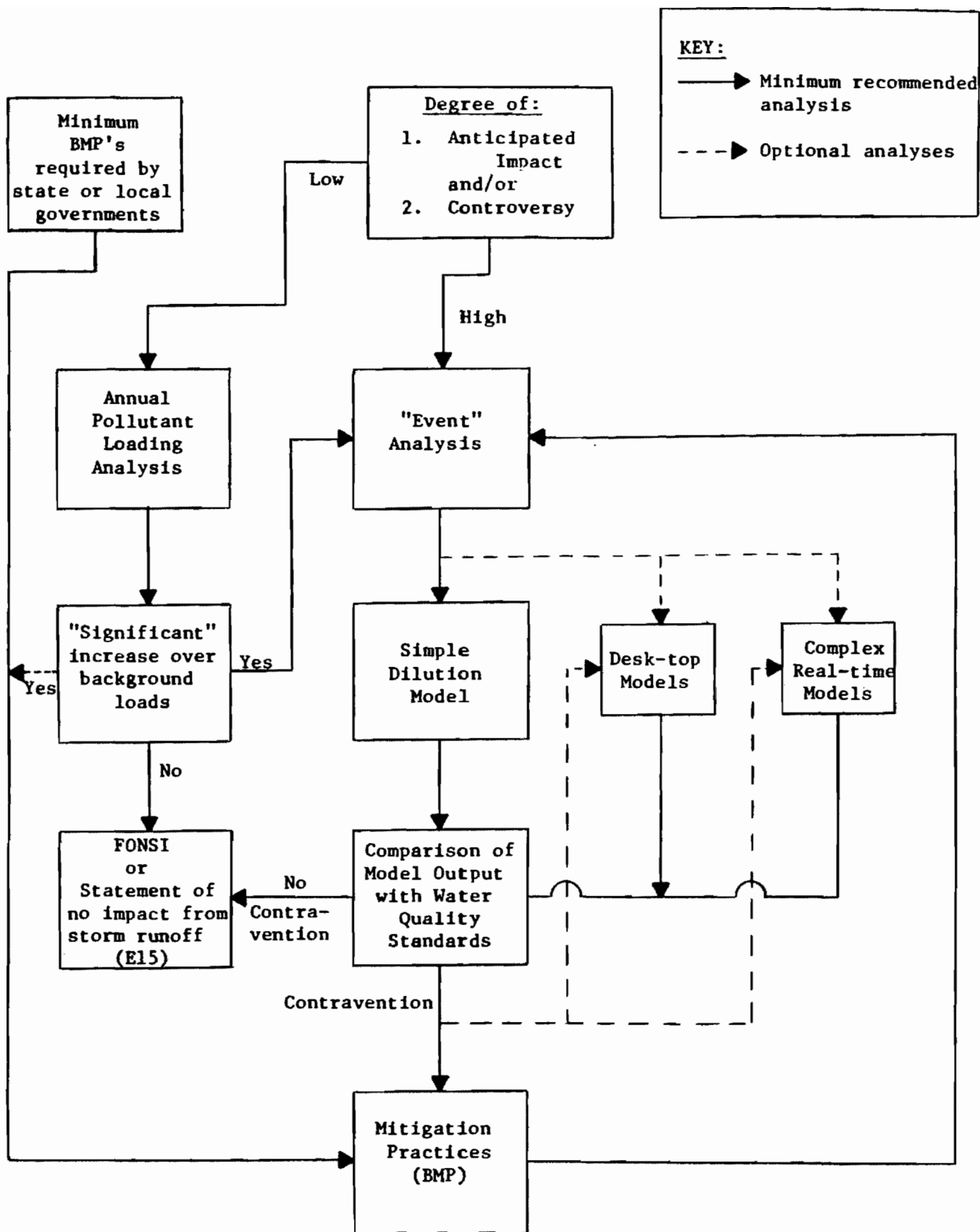


Figure 8.1.1. Simplified procedure for determining levels of analysis required to assess affects of stormwater runoff from operating highways on receiving streams.

Source: Dupuis and Kobriger, 1985.

## 8.1: IMPACT PROCEDURES AND DATA REQUIREMENTS

### A. SEASONAL/ANNUAL ANALYSIS

The seasonal/annual analysis determines the highway pollutant loadings relative to other loadings in the watershed. This seasonal/annual pollutant loading analysis may include either a simple determination of loadings (in pounds/yr), or the increase in stream pollutant concentration, using seasonal/annual highway pollutant input and mean flow conditions as a first cut on whether potential water quality problems may occur.

### B. EVENT ANALYSIS

If the seasonal/annual analysis indicates the potential for more elaborate analysis, an event analysis may require using predictive model procedures or a simple dilution procedure. The assumption implied in dilution models are conservative, and if they show a standards exceedance, violations are not likely to appear under more exacting conditions.

If a more complex modeling effort is required, several models have been developed that provide the necessary level of analysis. In the majority of cases, these complex, real-time dynamic models would not need to be used.

Which ever approach is used, the results are compared with state water quality standards or, if standards have not been established, then the results may be compared with water quality criteria, to determine if mitigation is required.

Because of the variety of pollutants in highway stormwater runoff and the limited knowledge of the chemical, biological and physical impacts, any results may be subject to a considerable amount of uncertainty. The approaches presented in this section of the training course are intended to provide reasonable estimates of impacts based on the available information to date, and to provide highway agencies with the qualitative and quantitative procedures to make prudent planning decisions regarding highway stormwater runoff and water quality.

### III. ASSESSMENT OF MAINTENANCE IMPACTS

Assessment of highway maintenance practice impacts is generally dependent on the extent and magnitude of the activity and its proximity to receiving waters. Session 2.1 provided an overview of when maintenance activity impacts should be assessed. Maintenance activities with potential impacts on water quality that need to be addressed are identified in Figure 8.1.2 with a general impact assessment method or procedure. This method is based on methods which are described in

## 8.1: IMPACT PROCEDURES AND DATA REQUIREMENTS

Sessions 8.5 and 8.7. As with many procedures, it contains some subjective aspects relative to determining potentially significant impacts. It is intended to quantify, to the extent possible, selected maintenance impacts relative to the resource value of the stream, and to evaluate when mitigation measures are warranted. Specific aspects of this general method will be described in later sessions.

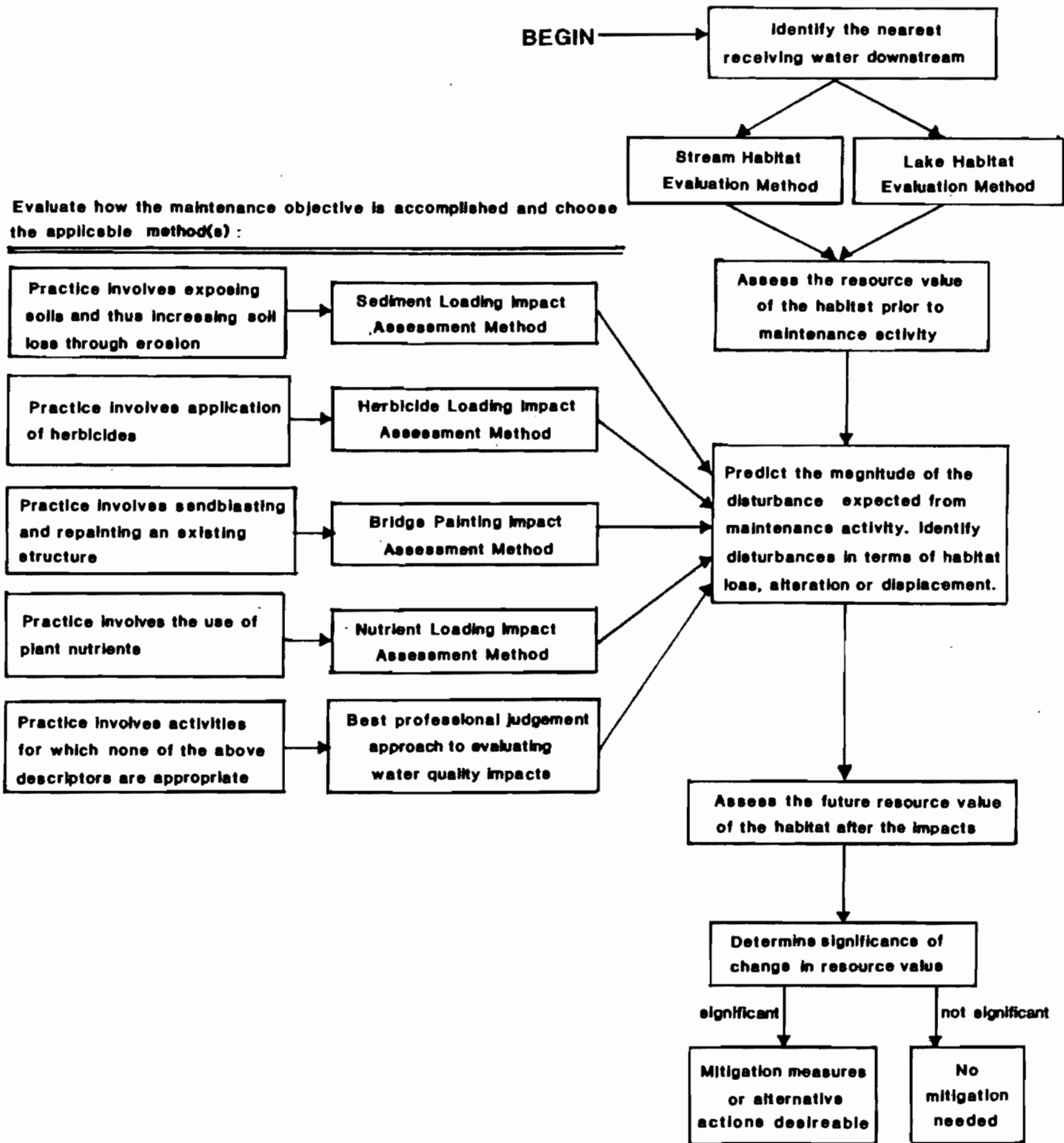


Figure 8.1.2. General impact assessment method for evaluating potential impacts to water quality from highway maintenance practices.

Source: Kratke et al., 1985

## SECTION 8: PREDICTION OF WATER QUALITY IMPACTS

### SESSION 8.2: INTRODUCTION TO HIGHWAY RUNOFF POLLUTANT CHARACTERISTICS PREDICTIVE PROCEDURES

Estimated Time for Completion:

**OBJECTIVES:** Upon completion of this session, participants will:

- Be familiar with the sections of FHWA's Predictive Procedure for Determining Pollutant Characteristics in Highway Runoff.
- Be familiar with other prediction methods developed to estimate highway runoff pollutant characteristics.
- Be knowledgeable about the limitations of the methods presented.

#### **SESSION OVERVIEW:**

A lecture will introduce the components of FHWA's Predictive Procedure not previously presented. Also, a brief overview of alternative methods will be examined to determine how they differ from FHWA's Procedure. The limitation of each method will also be discussed.

## 8.2: INTRODUCTION TO PREDICTIVE PROCEDURES

### I. FHWA PREDICTIVE PROCEDURE

#### A. INTRODUCTION

Previous sessions presented selected components of FHWA's procedure on rainfall evaluation and highway runoff evaluation. An overview of the entire manual procedure and a detailed description of the procedure's remaining component follows. The model procedure is computerized both for mainframe and for personal computer.

The development of the procedure is based upon the monitoring program conducted in 1976 and 1977 at sites in Milwaukee, Wisconsin; Harrisburg, Pennsylvania; Nashville, Tennessee; and Denver, Colorado. Complete details of the monitoring programs can be found in Kobriger et al. (1981c).

#### B. PURPOSE

The predictive procedure offers highway designers and other interested parties a simplified tool to estimate the quantity and quality of storm generated highway runoff. It consists of a series of equations which can be solved manually or by computer. The procedure is composed of four components corresponding to the following functions:

- Rainfall runoff
- Pollutant build-up
- Pollutant wash-off
- Constituent loadings

The predictive procedure can be used for Environmental Impact Statements (EIS) or to determine the loadings for pollutant discharge effects of various design storms at a particular site. The predictive procedure is not meant to be an all-inclusive model which predicts hydrographs and concentrations versus time, but rather an easy-to-use method of determining the total volume of runoff and total pounds of a pollutant discharged from a highway area. The highway area under consideration is defined as the paved roadway and total nonpaved area which contribute to a particular discharge point.

In addition to EIS applications, the procedure evaluates existing highway systems. Thus, the effects of increased traffic, changes in the curb or barrier configuration, or modifications to the nonpaved area can be determined as they relate to the total pollutant loading. Design storm analyses can be conducted on an existing highway drainage area using the predictive procedure. The pollutant loadings, as predicted for these storms, can then be used to evaluate different water quality impacts through mass balance or modeling analyses. In this manner, the pounds of a pollutant discharged from a highway drainage area can be compared to other pollutant sources within the watershed.



C. GENERAL OVERVIEW

In order to use this method, the following information is required:

- Rain event data including date, total rainfall, estimated rainfall duration, and number of dry days between rainfall events
- Average Daily Traffic (ADT)
- Length of highway expressed as miles
- Drainage area above the point of discharge expressed as acres
- Estimated initial pollution levels expressed as pounds
- Total solids accumulation rate (optional, since the rate may be estimated based on ADT)

All of the above information is readily available to the highway engineer and water quality scientist.

Figure 8.2.1 provides an overview of the FHWA procedure.

1. Pollutant Accumulation Equation

The pollutant accumulation equation of the predictive model is as follows:

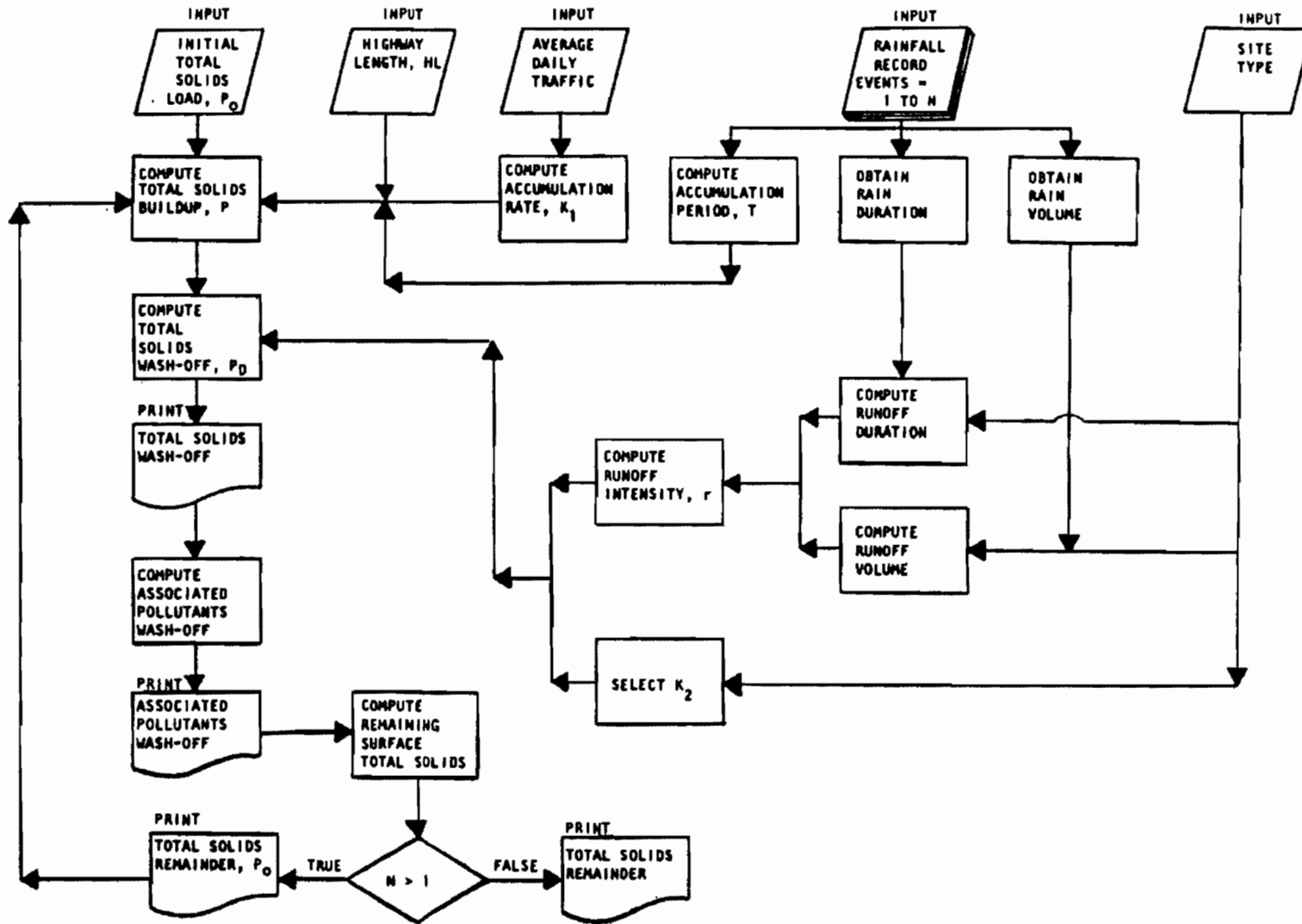
$$P = P_o + (K_1 * HL * T) \dots \dots \dots (2)$$

- Where:
- P = pollutant level after build-up, lb (kg)
  - P<sub>o</sub> = initial surface pollutant load, lb (kg)
  - K<sub>1</sub> = pollutant accumulation rate, lb/mi-day  
(kg/km-day)
  - T = time of accumulation, days (20 day maximum)
  - HL = highway length, mi (km)

This model predicts the highway surface pollutant load (P) which accumulates during a selected time period (T) at a specified rate (K<sub>1</sub>). Surface pollutants accumulate on the surface of all-paved sites (e.g., elevated bridge sections) and on the paved and unpaved surfaces of highway sections which have right-of-way areas (e.g. gravel shoulders, grassy areas, etc.). For purposes of the predictive model, pollutant load refers to that fraction of the total highway load available for wash-off.

The monitoring data from this study were "end-of-the-pipe" wash-off data, which are not a direct measure of pollutant build-up. Therefore, monitoring data could not be used to establish whether pollutant build-up

Figure 8.2.1 Predictive flow diagram



8-12

Source: Gupta, M.K. et al., 1981c

## 8.2: INTRODUCTION TO PREDICTIVE PROCEDURES

on highways is linear, exponential, or another mathematical function. The pollutant accumulation equation assumes that pollutants build up linearly during the accumulation period. This equation is similar to that used in Storage, Treatment, Overflow, Runoff Model (STORM) from Abbott (1976), which is based on a linear pollutant build-up relationship developed from a study on urban runoff in Chicago.

The surface pollutant accumulation variable  $K_1$  is the rate at which the carrier pollutant, total solids, accumulates in pounds per mile per day (kg/km/day). A carrier pollutant exhibits the highest degree of association with all other pollutants being considered. In many mathematical models, the predicted quantity of carrier pollutant is used to estimate the quantity of all other pollutants being modeled. This method eliminates the need for each pollutant to be predicted separately by the model, greatly reducing the number of calculations required. Total solids were chosen as the carrier pollutant for the predictive model developed in this study, because they showed the highest correlation with the other monitored quality parameters when regression analyses were performed. The term total solids (TS) refers to total suspended solids (TSS) plus total dissolved solids (TDS). Under the new nomenclature of Standard Methods, total solids as used in this study, are defined as total residue.

$K_1$  was developed from monitored data, and is expressed as pounds per mile - day (kg/km-day). The unit miles refers to the actual length of highway section in the contributing drainage area. This is in contrast to curb mile or lane mile, which is a multiple of the highway length.  $K_1$  is site specific, and its value may be based upon actual monitoring data, if it exists, or estimated from average daily traffic.  $K_1$  estimation based on average daily traffic is discussed at the end of this section.

The initial surface pollutant load ( $P_0$ ) is the pounds of pollutants on the surface at the beginning of the accumulation period. The accumulation period can be intervals within an actual rainfall record, intervals within a series of design storms, or the period prior to a single design storm event.

If an accumulation period follows a large storm event, the initial surface pollutant load will be considered zero ( $P_0=0$ ). The definition of a large storm is based upon that used in the Stormwater Management Model (SWMM) for the rate of pollutant removal during a storm event. For purposes of the predictive procedure, a large storm event is defined as one with greater than one inch (2.54 cm) of total rainfall, and having at least one hour in which the average intensity is 0.5 inches per hour (1.27 cm/hr). For such a storm, SWMM estimates that approximately 90 percent of the surface pollutants available for wash-off have been removed.

## 8.2: INTRODUCTION TO PREDICTIVE PROCEDURES

For succeeding rainfall events in a continuous rainfall record,  $P_0$  is the surface pollutant load remaining after wash-off from the previous rainfall event. For rainfall records which do not follow a large storm event or for design storms, the initial surface pollutant load must be estimated using a site specific  $K_1$  value, site length, and a specified period of build-up or estimate. An analysis of monitored wash-off data and rainfall records during the subject study suggests that dry periods greater than 20 days over-estimate the surface load, therefore, any dry periods exceeding 20 days are assumed to equal 20. The initial surface pollutant load for a site with a  $K_1$  of 80, and a site length of 5 miles would be:

$$80 \frac{\text{lbs}}{\text{mi-day}} * 5 \text{ mi.} * 20 \text{ days} = 8,000 \text{ lbs (3,629 kg)}$$

Any rainfall less than 0.05 inches (0.13 cm) is considered a trace of rain not producing runoff of sufficient volume and rate to effect pollutant wash-off. Figure 8.2.2. indicates the relationship between pollutant build-up and rainfall intensity and volume.

The minimum runoff duration that can be used in calculating average runoff intensity is 0.5 hours. Short duration flows, less than 0.5 hours, are often the result of small storms producing less than 0.1 inches (.25 cm) of flow. Using the high average runoff rates calculated from such storms gives more weight to the pollutant wash-off ability of a small storm that occurs. For this reason, all storms used in the predictive procedure were considered to have a duration of at least 0.5 hours, eliminating overestimates of total solids wash-off for short duration storms. For example, a storm producing 0.05 inches (.12 cm) of runoff in 0.17 hours (10 minutes) would have an average runoff rate calculated using an adjusted runoff duration of 0.5 inch/hr as follows:

$$\begin{aligned} \text{Average runoff rate} &= 0.05 \text{ inch of flow} \div 0.5 \text{ hours} \\ &= 0.10 \text{ inch/hr (0.25 cm/hr)} \end{aligned}$$

Otherwise, the average rate calculated from the actual runoff duration (0.17 hr) would be 0.29 inch/hr (0.73 cm/hr) and would cause a large overprediction of pollutant wash-off.

### 2. $K_1$ Variable

The total solids accumulation rate ( $K_1$ ) varies from location to location. Selected  $K_1$  previously reported in the literature are indicated in Table 8.2.1.

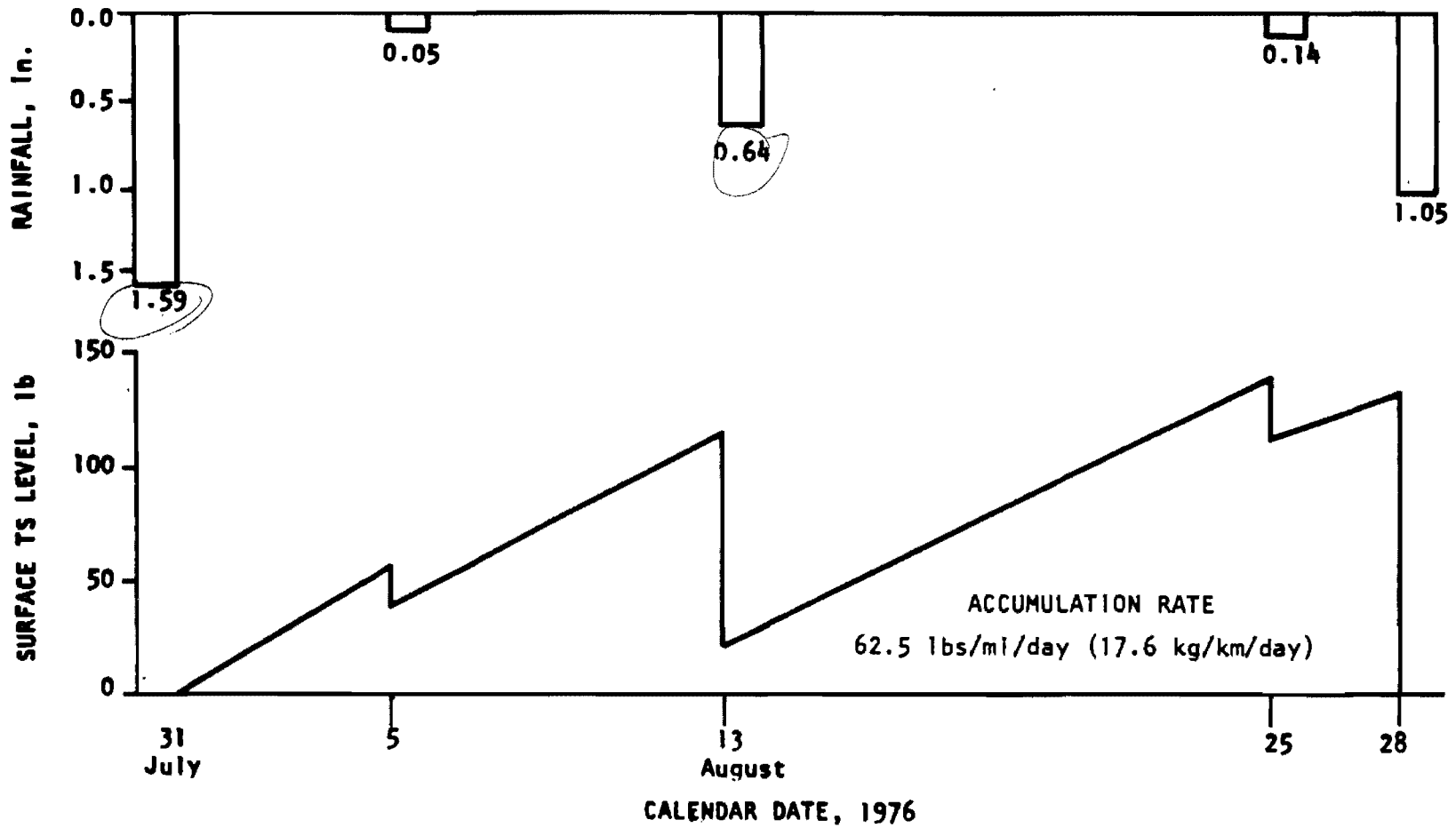


Figure 8.2.2. Surface total solids level, Milwaukee - Hwy 1-794.

## 8.2: INTRODUCTION TO PREDICTIVE PROCEDURES

Table 8.2.1. Published  $K_1$  values

Total solids accumulation rate, lb/mi-day	Location	Solids collection Techniques	Reference
1,580	Chicago City Sts.	Sweeping	American Public Works Association, 1969
1,180	11 U.S. City Sts.	Combined sweeping and flushing	Sartor, J.D. and G.B. Boyd, 1972
10.4	Seattle Highway	Runoff analysis	Sylvester, R.O. and F.B. DeWalle, 1972
382	Washington, D.C.	Vacuuming and	Shaheen, D.G., 1975
69.4	Seattle Highway	Runoff analysis	Municipality of Metropolitan Seattle, 1973
26.6	Seattle Highway	Runoff analysis	Municipality of Metropolitan Seattle, 1973a
236.9	Milwaukee (non-winter)	Mass balance for TS 250	Kobriger, N.P., 1984

metric units: lb x 0.454 = kg  
mi x 1.609 = km

The total solids accumulation rate was correlated with ADT for the sites included in the monitoring study (Figure 8.2.3). As a result, it is possible to calculate the appropriate solids build-up rate using the following equation, when site specific rates are not available:

$$K_1 = (ADT^{0.89}) 0.007$$

### 3. Wash-Off Coefficient ( $K_2$ )

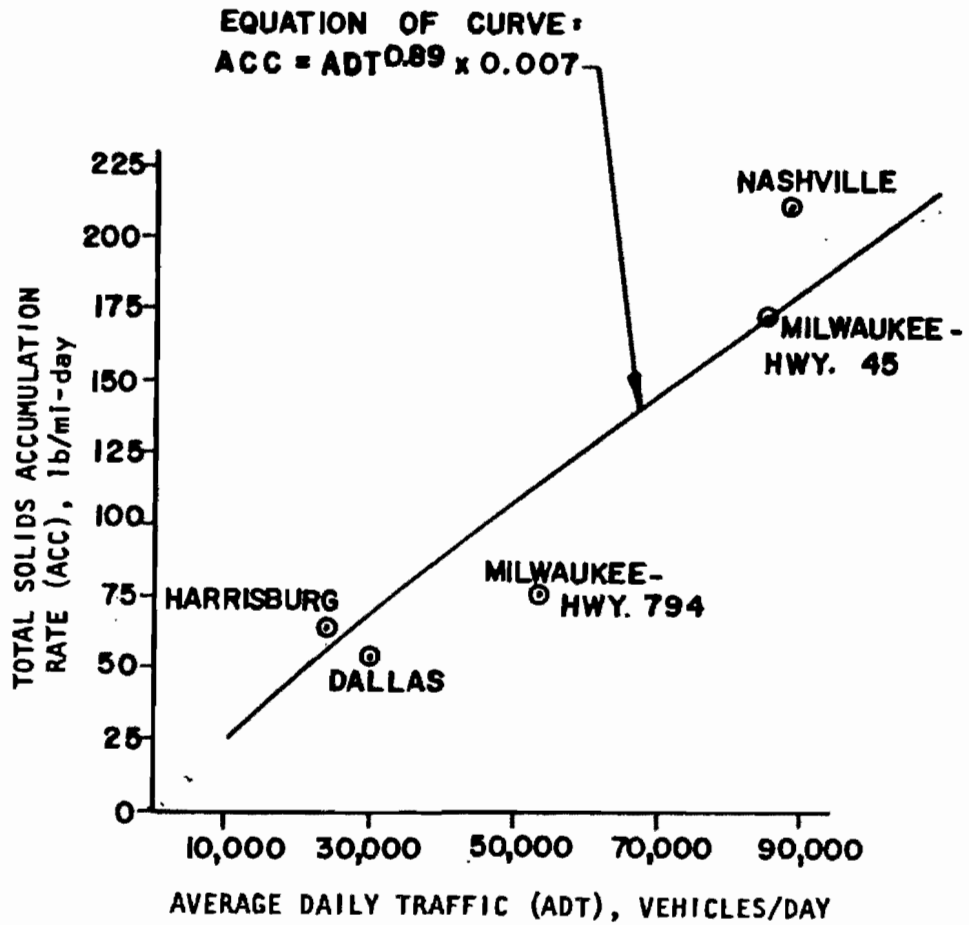
The coefficient  $K_2$  is used in the predictive procedure to remove a portion of the carrier pollutant from the surface of the drainage area. The general wash-off equation in the Corps of Engineer STORM model and U.S. EPA Stormwater Management Model (Huber, 1975) is used as part of this procedure.

$$P_D = P (1 - e^{-K_2 r})$$

Where:  $P_D$  = pounds (kilograms) of pollutant discharged  
 $P$  = surface load at start of the runoff event.  
 $K_2$  = wash-off coefficient  
 $r$  = average runoff rate, in./hr. (cm/hr)

For purposes of the predictive procedure, a single  $K_2$  value is required for each of the three site categories. Based upon the comparison of individual  $K_2$  values with actual monitoring data, a  $K_2$  value of 6.5 represents sites which contain some curb or barrier, structured drainage, and grassy right-of-way (Type II). A value of 12 represents a rural, flush shouldered site (Type III) which uses grassy

Figure 8.2.3. Selected total solids accumulation rates versus average daily traffic



Source: Kobriger, N.P. et al., 1981

## 8.2: INTRODUCTION TO PREDICTIVE PROCEDURES

ditch conveyance for the surface runoff. A  $K_2$  value of 5.0, selected for the Type I site, will be used for elevated bridge decks which are completely paved.

The Type III site requires the highest  $K_2$  value in order to wash-off larger amounts of the pollutant load per runoff volume than other sites. This site type's flush shoulder and the nonpaved drainage conditions probably account for the high, since the grassy areas adjacent to the roadway require more pollutant wash-off per event to remove the pollutant load. The Type I site has the lowest  $K_2$  value, indicating that pollutant wash-off is easier from a site that is all paved than a site with both paved and unpaved areas (Type II and III).

### 4. Constituent Loadings

The final component of the predictive procedure transforms the pounds of total solids washed off into pounds of lead, COD, suspended solids, or any other of the 16 quality constituents available in the model. The prediction of heavy metals, nutrients, solids and other parameters for individual storm events rely upon linear regression equations for predicting each parameter as a function of the total solids load for each site (Tables 8.2.2 and 8.2.3).

For example, the determination of the COD load for the Milwaukee I-794 site is as follows:

$$\text{COD (lb)} = 0.202 \text{ TS} + 5.47$$

where: TS = total solids in pounds

The asterisk in Tables 8.2.2 and 8.2.3 next to equations indicates significance at the 95 percent confidence limits (1). This indicates that one can be 95 percent confident that the sample was not selected from a population for which no correlation exists (i.e., that the correlation coefficient  $R$  is equal to zero). An equation may still provide good estimates even if the variables in that equation do not show a significant correlation at the 95 percent confidence level (Gupta et al., 1981c). An equation developed using regression techniques is the best fit of the data being analyzed.

The predictive procedure uses a separate constituent equation for each general site type. Individual equations account for differences between site drainage and solids retention characteristics.

### D. PREDICTIVE PROCEDURE RESULTS

Table 8.2.4. summarizes the application results of the procedure to the five monitoring sites, plus a sixth site not included in the development of the procedure.



Table 8.2.2 Constituent equations developed for Type I and Type III sites.

Parameter	Type I Milwaukee 1-794	Type III Harrisburg 1-40
SS	$0.53TS - 3.2^*$	$0.32TS - 36.8^*$
VSS	$0.191TS + 0.2^*$	$0.061TS - 3.3^*$
TVS	$0.221TS + 13.3$	$0.32TS - 32.3^*$
TKN	$3.3 \times 10^{-3} TS + 0.16$	$3.1 \times 10^{-3} TS + 0.55^*$
BOD	$0.023TS + 1.5^*$	N/A
TOC	$0.057TS + 0.80^*$	$0.068TS - 5.85^*$
COD	$0.202TS + 5.47^*$	$0.087TS + 0.65^*$
TN	$1.37 \times 10^{-3} TS + 0.12$	$1.83 \times 10^{-3} TS + 0.054^*$
TPO <sub>4</sub>	$1.0 \times 10^{-3} TS + 3.0 \times 10^{-4}$	$2.15 \times 10^{-3} TS - 0.245$
Cl <sup>-</sup>	$0.034TS + 2.59$	$0.135TS + 2.6^*$
Pb	$5.6 \times 10^{-3} TS - 0.024$	$4.1 \times 10^{-4} TS - 0.029^*$
Zn	$8.4 \times 10^{-4} TS + 0.014$	$2.67 \times 10^{-4} TS - 0.011^*$
Fe	$0.015TS + 0.59$	$0.014TS - 1.61^*$
Cu	$2.9 \times 10^{-4} TS + 7.3 \times 10^{-4}$	$7.4 \times 10^{-5} TS + 8.78 \times 10^{-3}^*$
Cd	$1.4 \times 10^{-4} TS - 1.4 \times 10^{-3}$	$4.0 \times 10^{-5} TS + 0.007$
Cr	$1.6 \times 10^{-4} TS + 1.2 \times 10^{-3}$	$2.3 \times 10^{-4} TS - 0.028$
Hg	$-7.6 \times 10^{-7} TS + 8.8 \times 10^{-4}$	$-5.8 \times 10^{-6} TS + 0.015^*$

Note: TS = total solids (lb)  
 \* - Variables correlate at the 95 percent confidence level.  
 metric units: lb x 0.454 = kg

Source: Gupta, M.K. et al., 1981c

Table 8.2.3 Constituent equations developed for Type II sites.

Parameter	Equation
SS	$0.63TS - 188$
VSS	$0.152TS + 13.5$
TVS	$0.263TS + 243$
TKN	$5.46 \times 10^{-3}TS + 1.28$
BOD	$3.0 \times 10^{-2}TS + 28.3$
TOC	$5.6 \times 10^{-2}TS + 25.2$
COD	$0.193TS + 275.3$
TN	$1.3 \times 10^{-3}TS + 0.713$
TPO <sub>4</sub>	$2.25 \times 10^{-3}TS - 0.32$
Cl	$0.042TS + 87$
Pb	$1.02 \times 10^{-3}TS + 0.04$
Zn	$5.84 \times 10^{-4}TS + 0.103$
Fe	$1.96 \times 10^{-2}TS - 5.0$
Ni	N/A
Cu	$3.16 \times 10^{-4}TS + 0.064$
Cd	$4.16 \times 10^{-5}TS + 0.021$
Cr	$4.3 \times 10^{-5}TS + 0.036$
Hg	$2.44 \times 10^{-6}TS + 1.006 \times 10^{-6}$

Note: TS = total solids (lb)  
 metric units:  $1b \times 0.454 = kg$

Source: Gupta, M.K. et al., 1981c

Table B.2.4. Summary of Model Versus Actual Monitored Non-Winter Total Pollutant Loads Used to Develop the Predictive Procedures (except the Dallas Site)

Site Location	Total Solids, lb	Suspended Solids, lb	TPO <sub>4</sub> , lb	COD, lb	Lead, lb <sup>1</sup>	Iron, lb
<b>Milwaukee I-794</b>						
Actual	1,862	570	1.03	271	5.17	22.94
Predicted	1,640	658	0.86	245	4.55	20.66
Predicted vs. Actual %	-11.9	+15.4	-16.5	-9.6	-12.0	-10.0
<b>Milwaukee Hwy 45</b>						
Actual	55,024	29,123	34.76	6,863	53.6	929.75
Predicted	63,478	36,665	137.11	17,205	65.47	1,115.14
Predicted vs. Actual %	+15.4	+25.9	+294.4	+150.7	+22.2	+24.2
<b>Nashville I-40</b>						
Actual	20,273	10,692	65.81	3,909	24.76	268.06
Predicted	23,325	11,369	30.62	6,294	24.53	367.97
Predicted vs. Actual %	+15.1	+6.3	-53.5	+61.0	-1.0	+37.3
<b>Harrisburg I-81</b>						
Actual	3,655	767	6.43	212	1.40	31.97
Predicted	3,689	835	5.64	170	1.22	36.59
Predicted vs. Actual %	+1.0	+8.9	-12.3	-19.8	-12.9	+14.5
<b>Denver I-25</b>						
Actual	11,016	7,263	13.66	4,338	11.99	252.43
Predicted	15,118	7,189	27.67	7,029	16.04	231.97
Predicted vs. Actual %	+37.2	-1.0	+117.2	+62.0	+33.8	-8.1
<b>Dallas I-45</b>						
Actual	468	204	NA	345	1.18	5.60
Predicted	626	307	NA	169	3.32	14.10
Predicted vs. Actual %	+33.8	+50.5	-	-51.0	+181.4	+151.8

<sup>1</sup>Caution must be used when interpreting the pollutant loadings of lead predicted by the model. The reduction in lead in gasoline has resulted in an estimated 50% reduction in lead loadings since the predictive procedure equation was developed.

## 8.2: INTRODUCTION TO PREDICTIVE PROCEDURES

As can be seen, the predicted versus the actual monitored data are within one order of magnitude for all values. Total solids and suspended solids in particular, are fairly close, although greater variation exists for other constituents. When predicted versus actual loadings on an event basis are compared, greater variation exists. Thus, the model is best suited for monthly or non-winter period evaluations.

The model is undergoing further evaluation and validation by FHWA in a study initiated in September, 1984, titled Design Procedures to Estimate Pollutant Loadings from Higher Stormwater Runoff. The study is to be completed in FY 1986.

### E. MODEL LIMITATIONS

The predictive procedure is a tool for evaluating the effects of increased traffic, changes in the highway configuration, or other design aspects, on the loading of solids or other constituents to the receiving water.

Because of the complex interaction of rainfall, runoff and traffic on a highway, the prediction model has certain limitations. Users of the procedure are encouraged to further study the Predictive Procedures to ensure a full understanding of the components of the model and aid in the interpretation of the results (Kobriger, 1981c).

Specific limitations of the procedure are as follows:

- Geographic locations with low intensity, frequent rainfalls, e.g., Washington state, should not use this procedure. Research (Horner et al., 1982) demonstrates situations where ADT is not a valid variable to estimate pollutant accumulation on the roadway surface. This method will not be acceptable for use in California and states with similar climatic conditions.
- The procedure should be limited to non-winter periods. As such, the results will reflect only a portion of the total loadings that can be expected from a roadway. As shown in a more recent study (Kobriger, 1984), winter pollutant accumulation can be significant, although the dispersion is more complex and highly variable.
- The predictive procedure is better suited to continuous simulation using daily rainfall records covering periods of at least one month, since it is unable to predict surface loads prior to individual events.
- The model assumes the highway area to be uniformly characterized by the three site types that are listed. Significant variations in a site may have widely varying results.

## 8.2: INTRODUCTION TO PREDICTIVE PROCEDURES

- The predicted pounds of total solids washed off during a rainfall event are dependent upon the model prediction of the surface load at the start of the storm. If the surface load is underestimated, the pounds discharged will be low.
- The use of average runoff rate to remove surface pollutants is the quickest and easiest method. Peak runoff intensities during the runoff hydrograph may be more accurate, but are too complex for this procedure.
- Long dry periods and overlapping storms present predictive problems in determining the pre-storm surface load.
- Construction activities are difficult to simulate unless monitoring data is available to determine  $K_1$  values.

### II. FHWA PROCEDURE FOR ESTIMATING POLLUTANT LOADS

1. Determine the pollutant accumulation rate for the project site being evaluated if site specific or other accumulation values are being used:

$$K_1 = (ADT^{0.89}) * 0.007$$

where:  $K_1$  = pollutant accumulation rate, lb/mi-day  
(kg/km-day)  
 $ADT$  = average daily traffic, vehicles/day

Example: If the site has an ADT of 30,000 vehicles per day, the  $K_1$  value that results would be:

$$\begin{aligned} K_1 &= (30,000^{0.89}) * 0.007 \\ &= 67.6 \text{ lb/mi-day (19.1 kg/km-day)} \end{aligned}$$

2. a. Using  $K_1$ , determine the pounds of total solids on the surface of the project site at the start of the storm event:

$$P = P_o + (K_1 * HL * T)$$

where:  $P_o$  = initial surface pollutant load, lb  
 $P$  = pollutant level after build-up, lb  
 $K_1$  = pollutant accumulation rate, lb/mi-day  
(kg/km-day)  
 $HL$  = highway length, mi(km)  
 $T$  = time of accumulation, days (20 days maximum)

## 8.2: INTRODUCTION TO PREDICTIVE PROCEDURES

The variable  $P_0$  is a function of the amount (load) of pollutants estimated to be left on the surface after the last rainfall event. If more than one event is being evaluated, e.g., monthly or seasonal loadings are being determined, the results of  $P_0$  are carried through the calculations on an iterative basis by subtracting the pounds washed off from the previous pollutant load. The build-up rate,  $K_1$ , is then used for each dry day to add to  $P_0$  until the pollutant load at the start of the next event is determined.

The initial estimation of a  $P_0$  is made easier if the first storm to be evaluated follows a storm of average rainfall intensity greater than 0.5 inches (1.27 cm) per hour. This large storm is assumed to wash-off essentially all of the available total solids load on the surface. The succeeding dry days are then used to build up the available surface load to the start of storm conditions. Further descriptions of  $P_0$  and  $K_1$  are included in the components description of this report.

Example: If the accumulation period is six days, the highway length is 6.5 miles,  $K_1$  is 67.6 lb/mi-day (19.1 kg/km-day) (predicted from the ADT of 30,000 vehicles/day) and  $P_0$  is zero (assume accumulation period started with a large storm). The pollutant level after build-up ( $P$ ) would be:

$$\begin{aligned} P &= P_0 + (K_1 * HL * T) \\ &= 0.0 + (67.6 \text{ lb/mi-day} * 6.5 \text{ miles} * 6 \text{ days}) \\ &= 0.0 + (2,636.4 \text{ lbs}) \\ &= 2,636.4 \text{ lbs (1,196 kg) of total solids} \\ &\quad \text{available at the start of event number one.} \end{aligned}$$

- b. If a large rainfall event does not occur at the beginning of the initial accumulation period of the month or period being evaluated,  $P_0$  must be estimated. One method is to evaluate local climatic data to determine the average number of dry days between rainfall events.  $P_0$  can then be estimated using the average number of dry days,  $K_1$  and highway length.

Another approach would be to estimate the pollutant load for the first event in the period, and determine the number of dry days since the last rain event prior to the start of the event period actually being evaluated. Note: The event used to establish the accumulation period for the first event in the period or month of concern must be rainfall, not snowfall, otherwise use the first approach. Assume that  $P_0 = 0$ . Then count the number of dry days to determine the load available for the first event for the period. This will slightly underestimate the pollutant load on the highway's surface if this previous event was less than 0.5 in./hr., since it will not account for the load left on the surface. This applies to the first approach as well.

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Example (1st approach): If a large storm did not precede the initial accumulation period, and if the average number of dry days between storms was determined to be four, the estimate of  $P_o$  would be calculated as follows:

$$\begin{aligned} P_o &= K_1 * HL * T \\ &= 67.6 * 6.5 * 4 \\ &= 1,758 \text{ lb (797 kg)} \end{aligned}$$

3. Calculate load wash-off using the average runoff rate ( $r$ ) using the following formula:

$$P_D = P(1 - e^{-K_2 r})$$

where:  $P_D$  = pollutant load discharged (total solids), lb (kg)  
 $P$  = pollutant load at the storm start, lb (kg)  
 $K_2$  = wash-off coefficient  $r$  = average runoff rate - inch/hr (cm/hr)

$K_2$  is selected based upon site characteristics as follows:

$K_2 =$	<u>Type 1</u>	<u>Type 2</u>	<u>Type 3</u>
	5.0	6.5	12.0

Example: Assuming the site is Type II, the pounds of total solids removed would be determined as follows ( $P = 2,636$  lbs;  $r = .019$  in./hr, assumed here;  $K_2 = 6.5$ )

$$\begin{aligned} P_D &= P(1 - e^{-K_2 r}) \\ &= 2,636 (1 - e^{-(6.5)(.019)}) \\ &= 306 \text{ lb of total solids discharged (139 kg)} \end{aligned}$$

4. Calculate the surface load remaining after the storm from the above example.

$$\begin{aligned} P_o &= P_o - P_D \\ &= 2,636 \text{ lb} - 306 \text{ lbs} \\ &= 2,330 \text{ lb of total solids remaining (1,057 kg)} \end{aligned}$$

Thus,  $P_o$  for the next event is 2,330 lb (1,057 kg). This amount is then added to  $P$  (pollutant load after build-up that is available for washoff by next rainfall event.)

5. To calculate loadings, use the equations in Tables 8.2.2 and 8.2.3 for each pollutant of interest for each site type. The results will be expressed as pounds of pollutants discharged at the highway site for each event.

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Example: From the previous example, it was determined that 306 lbs of total solids were washed off from the site. To calculate the amount of the pounds Zn washed off:

$$\begin{aligned} \text{Zn} &= 5.84 * 10^{-4} \text{TS} + 0.103 \\ &= 5.84 * 10^{-4} (306) + 0.103 \\ &= .28 \text{ lbs of Zn} \end{aligned}$$

6. Determine the average concentration of Zn in the highway runoff using the following formula (7.48 is a conversion factor to convert volume to gallons):

$$P_{\text{conc}} = (P_{\text{Zn}} * 454,000) / (Q_{\text{cf}} * 7.48 * 3.785)$$

Example: From the previous step, the loading of Zn was determined to be .28 lbs. Thus, the average concentration in the runoff would be (Assume  $Q_{\text{cf}} = 7,000$ ):

$$\begin{aligned} P_{\text{conc}} &= (P_{\text{Zn}} * 454,000) / (Q_{\text{cf}} * 7.48 * 3.785) \\ &= \frac{.28 \text{ lbs} * 454,000 \text{ mg/lbs}}{7,000 \text{ cf} * 7.48 * 3.785 \text{ liters/gallon}} \\ &= \frac{127,120 \text{ mg}}{198,182 \text{ liters}} \\ &= .641 \text{ mg/liter of Zn in highway runoff.} \end{aligned}$$

7. Repeat the above calculations to obtain the total solids wash-off for each event and pollutants.

### III. CALIFORNIA METHOD FOR ESTIMATING

#### A. INTRODUCTION

Caltrans has developed a different procedure for estimating highway runoff quality (Howell et al., 1982; Kerri et al., 1985). Its method reflects the findings of studies for sites located in California:

- The number of dry days between storm events and the corresponding cumulative traffic volume before the storm were found to be not statistically significant for estimating constituent loads.
- Equations used to estimate the cumulative loads of the following pollutants were found to be statistically significant at the .05 level, on a storm event basis when:



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- Correlated with vehicles during the storm: COD, Filterable Residue (Dissolved Solids), Lead (T), TKN, ZN(T).
- Correlated with total residue: COD, Nonfilterable Residue (Suspended Solids), ZN(T).
- No statistically significant correlations at the .05 level of significance were found with any of the independent variables examined: boron, cadmium, nitrate nitrogen, ammonia nitrogen, total phosphorus, dissolved orthophosphate, oil and grease. Thus, these pollutants cannot be estimated using the Caltrans procedure.
- The method is considered suitable on an event basis.
- The regression equations developed in this research can be used for calculating constituent loads from the paved travelled way and shoulder area. In order to assess the effects of the constituent load on nearby receiving waters - the load must be routed through the drainage system and ultimately to the receiving water - runoff from other sources may be encountered and must be included - highway runoff dilution factors in terms of the receiving water source must be accounted for.

### B. PROCEDURE FOR USING THE REGRESSION EQUATIONS

In using the Caltran procedure the following assumptions are made:

- The vehicle fleet and fuels used are relatively the same as the years of actual data collection (1979 through 1981) to build the regression equations.
- The highway is in an urban setting.
- The drainage area of the roadway surface is between 2.00 and 3.00 acres, as this was the smallest area from which data were collected to build the equations. (HL \* HW of pavement = 72<3 acres).
- The median, traveled lanes, and shoulders are 100 percent paved.
- The procedure should be used with highways having ADT exceeding 30,000 vehicles, and only when a sensitive receptor, e.g. stream, lake etc., is located adjacent to the facility.
- Runoff from the assumed drainage area is conveyed via open channels to a single point of discharge. (Runoff quantity and quality from the unpaved area adjacent to the paved area was excluded from the research.)

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- The storm chosen is an annual one-day rainfall event (two-year return interval) versus actual continuous events evaluation required by FHWA procedure.
  - A 24-hour storm is chosen as the storm duration, since a storm lasting 24 hours will be sufficient to wash-off the gutter load and will allow both the AM and PM peak traffic to travel through the site and contribute to the runoff load. A 24-hour storm is used because the future traffic prediction is a 24-hour value.
  - A runoff coefficient of 0.90 is used to compute the cumulative runoff volume because the drainage area is completely paved.
1. Using the projected average daily traffic (ADT), compute constituent loads using the linear regression equations below which were evaluated and found to be acceptable.

$$\text{Eq.1} \quad \text{Pb} = 14.3 + 0.00189 (\text{ADT})$$

$$\text{Eq.2} \quad \text{Zn} = 14.3 + 0.00060 (\text{ADT})$$

$$\text{Eq.3} \quad \text{FR} = 5360 + 0.140 (\text{ADT})$$

$$\text{Eq.4} \quad \text{COD} = 3590 + 0.221 (\text{ADT})$$

$$\text{Eq.5} \quad \text{TKN} = 150 + 0.00342 (\text{ADT})$$

Where: Pb, Zn, FR, COD, and TKN are the cumulative loads in grams for lead, zinc, filterable residue, chemical oxygen demand, and total Kjeldahl nitrogen, respectively, the intercepts represent initial dry loads in grams, while the slopes represent the washoff of a constituent in grams per ADT during storm.

2. To forecast an annual load, divide the depth (amount) of the total annual rainfall (2-year return interval, 365-day value) for the station by the 1-day depth. The result is the theoretical number of 1-day events per year. Multiply each of the daily loads by the number of 1-day events to arrive at an annual load.
3. The flow weighted concentration is computed by dividing the daily event load determined in Step 1 (above) by the 1-day cumulative runoff volume.
4. The following linear regression equations are used to calculate nonfilterable residue loads:

$$\text{Eq.6} \quad \text{Zn} = 11.5 + 0.00064 (\text{TR})$$

$$\text{Eq.7} \quad \text{COD} = 3600 + 0.214 (\text{TR})$$

$$\text{Eq.8} \quad \text{NR} = -760 + 0.65 (\text{TR})$$

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Where: TR is total residue in grams, Zn, COD, and NR are the cumulative loads in grams for zinc, chemical oxygen demand, and nonfilterable residue, respectively. The intercepts represent the initial dry loads in grams, while the slopes represent the fraction of constituent found in the total residue load washed from the pavement during the storm. Because total residue is an independent variable for which no easy future value can be obtained, the following procedure should be executed. Substitute values of the total zinc load computed from Equation 2 and the chemical oxygen demand load computed from Equation 4 in Equations 6 and 7 and compute two values of total residue. Then use the average value of total residue to compute the nonfilterable residue load using Equation 8. Compute the flow-weighted concentration as in Step 3 (above).

5. The final step is to check the computed loads and flow-weighted concentrations to make sure that the computed values are bound by the field observations. Table 8.2.5. shows the limits of the observed concentrations and loads.

Table 8.2.5. Limits of observed concentrations and loads of single events from monitored events in California.

Constituent	Concentration (mg/l)		Load (grams)	
	Low	High	Low	High
Total lead	0.17	4.10	4.0	304
Total zinc	0.10	1.80	2.0	84
Filterable residue	16	461	428	50,167
Chemical oxygen demand	23	724	382	26,344
Total kjeldahl nitrogen	0.1	14.0	34	1,070
Nonfilterable residue	18	2,660	143	55,259

Source: Howard et al., 1982

6. Final water quality assessment must be made using the values of loads and concentrations in a receiving water analysis.

### C. EXAMPLE PROBLEM USING CALTRAN PROCEDURE

The following example problem is taken directly from Howell (1982) and is reproduced here to demonstrate the use of the Caltran model.

## 8.2: INTRODUCTION TO PREDICTIVE PROCEDURES

Problem: An urban freeway has been proposed for year 2005 and will have the following dimensions:

46 feet of paved median	=	46 ft
Two 10-foot wide shoulders	=	20 ft
Four 12-foot wide lanes	=	48 ft
		<u>114 ft width</u>

The ADT for year 2005 is 56,800 vehicles. The project will cross a river used for recreation and fishing. Trout (Salmo gairdneri) inhabit the river. Average annual rainfall for the site is 22 inches.

Make the following assumptions:

- The paved width of 114 ft and each 750 ft of freeway length will be drained to a single discharge point.
- Runoff coefficient is 0.90; thus,  $.90 * \text{rainfall volume} = \text{runoff volume}$ .
- A 24-hour storm delivers 2.06 inches of continuous rainfall.
- The vehicle fleet (and fuel used) will be the same in 2005 as it was in 1980. The vehicles are operating normally, i.e., at speeds of 55 miles per hour with no accidents or spills.

Given the above data and assumptions compute:

- The area of the assumed catchment.
- The cumulative volume of runoff (in liters).
- The loads and flow-weighted concentrations of the constituents: lead (Pb), Zinc (Zn), filterable residue (FR), chemical oxygen demand (COD), and total Kjeldahl nitrogen (TKN), and nonfilterable residue, using equations 1 through 5.

1. 
$$\text{Area} = \text{length (ft)} * \text{width (ft)} \left( \frac{1 \text{ acre}}{43,560 \text{ ft}^2} \right) = \text{acres}$$
$$= 750 * 114 * \frac{1}{43,560} = 1.96 \text{ acres}$$

(1.96 acres approaches the lower limit of 2.0 acres, the smallest area from which data were collected to build the equations).

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$$2. \quad \text{Cumulative Runoff Volume} = \text{runoff coefficient} * \text{rainfall volume}$$

$$= [0.90] * [2.06 \text{ in}] * [1.96 \text{ ac}] * [3630 \text{ ft}^3/\text{ac-in}] [28.32 \text{ 1/ft}^3]$$

$$= 373,564 \text{ call } 373,500 \text{ liters}$$

3. First, compute the load in grams using the appropriate regression equation, then compute the flow-weighted concentration (conc.) in milligrams per liter:

$$\text{conc. (mg/l)} = \frac{\text{Load (grams)}}{\text{cumulative runoff volume (liters)}} * \frac{1000 \text{ milligrams}}{1 \text{ gram}}$$

Eq.1	Pb	= 14.3 + 0.00189 (56,800)	
		= 121.65	<u>122 grams</u>
	conc.	= 121.65/373,500 * 1,000	
		= 0.326	<u>0.33 mg/l</u>
Eq.2	Zn	= 14.3 + 0.00060 (56,800)	
		= 48.38	<u>48 grams</u>
	conc.	= 48.38/373,500 * 1,000	
		= 0.129	<u>0.13 mg/l</u>
Eq.3	FR	= 5,360 + 0.140 (56,800)	
		= 13,312	<u>13,300 grams</u>
	conc.	= 13,312/373,500 * 1,000	
		= 35.64	<u>35.6 mg/l</u>
Eq.4	COD	= 3,590 + 0.221 (56,800)	
		= 16,142	<u>16,150 grams</u>
	conc.	= 16,142/373,500 * 1,000	
		= 43.22	<u>43.2 mg/l</u>
Eq.5	TKN	= 150 + 0.00342 (56,800)	
		= 344.26	<u>344 grams</u>
	conc.	= 344.26/373,500 * 1,000	
		= 0.922	<u>0.92 mg/l</u>

Using the forecasted values of zinc (48 grams) and chemical oxygen demand (16,150 grams), an average value of total residue (TR) can be calculated using equations 6 and 7.

$$\text{Eq.6} \quad \text{Zn} = 11.5 + 0.000640 (\text{TR})$$

## 8.2: INTRODUCTION TO PREDICTIVE PROCEDURES

$$\text{Eq.7} \quad \text{COD} = 3600 + 0.214 (\text{TR})$$

$$\begin{aligned} &\text{Solve for total residue (TR):} \\ &\text{Using (6) TR} = 57,031 \text{ grams} \\ &\text{Using (7) TR} = \underline{58,645 \text{ grams}} \\ &\text{Sum} = 115,676 \text{ grams} \\ &\text{Avg} = 57,838 \quad \underline{57,840 \text{ grams}} \end{aligned}$$

Using Equation 8 and the average value of 57,840 grams for total residue (TR), solve for nonfilterable residue (NR):

$$\begin{aligned} \text{Eq.8} \quad \text{NR} &= -760 + 0.65 (57,840) \\ &= 36,836 \text{ grams} && \underline{36,840 \text{ grams}} \\ \text{conc.} &= 36,836/373,500 * 1000 \\ &= 98.62 && \underline{98.6 \text{ mg/l}} \end{aligned}$$

### 4. Check

The computed values within Table 8.2.5 to see if they are within the limits of the values recorded.

The results must be compared to established water quality criteria, and if any excessive values are found, mitigating measures (or transportation alternatives) may be needed.

## IV. WASHINGTON STATE DEPARTMENT OF TRANSPORTATION PROCEDURE FOR WATER QUALITY IMPACTS

### A. INTRODUCTION

The State of Washington has developed a procedure (Horner and March, 1982) to assess highway stormwater water quality, in-stream water quality and aquatic ecological impacts of operation highways. The procedure is based on a model (Chui et al., 1982) developed as part of an ongoing multi-year study, sponsored by the Washington Department of Transportation (WSDOT) and conducted by the Department of Civil Engineering of the University of Washington.

This model to estimate cumulative pollutant loadings is applicable when soils, climate, and land use are similar to those at the monitored highway sites used to develop the model. Thus, Oregon, Northern California, and Southern Idaho as well as Washington State, may find the model suitable for assessing the impact of highway stormwater runoff. The impact assessment component of the WSDOT procedure has been incorporated into the FHWA procedure (Session 8.4).

The model for estimating loadings differs in that it relies on vehicles during the storm (VDS) as the primarily independent variable to

estimate pollutant loads. Washington State experiences low intensity, long duration rainfall events unique to this portion of the country. This contrasts with other locations in the country where relatively intense but brief precipitation events occur. As has been shown in the State of Washington, the migration and transport of highway pollutants are more of a function of the kinetic energy provided by moving vehicles than by rainfall (Chui et al., 1982).

The model expresses cumulative runoff pollutant loadings as functions of highway geometry, drainage configuration, and, vehicles during the storm expressed as follows:

Eq.1  $TSS = (K) (VDS) (C)$

Eq.2  $Pollutant\ loading\ i = (Kp_1) (TSS\ Loading)$

where: TSS = loading of total suspended solids from runoff (lb/highway-mi)  
K = loading constant (lb/1000 VDS/highway-mi)  
VDS = vehicles during the storm (in thousands)  
C = runoff coefficient (ratio of runoff volume to precipitation volume)  
Kp<sub>1</sub> = ratio of pollutant i to TSS

The model, in addition to its geographic considerations, is limited in suitability for long-term (monthly or annually) versus individual event projections. This is similar to FHWA's Predictive Procedure (Kobriger, 1981). Loadings in a given locale are highly variable on an event basis, but more constant in a longer time frame when normalized for traffic and using a runoff coefficient.

#### B. WSDOT ANNUAL POLLUTANT LOADING ASSESSMENT PROCEDURE

The following procedure is taken directly from Horner and Mar (1982) and represents only one portion of the procedure. If based on the initial annual analysis described in the procedure, a monthly evaluation is required and presented here as an example of another possible approach, given the restrictions previously described. It also illustrates the variations between highway sites.

1. Estimate the hr/yr during which the roadway is expected to be wet as equal to the hr/yr of recorded precipitation. The reported hr/yr of recorded precipitation (<0.01 inch) represents the mean of a number of years of data (1948-1964). Trace quantities are eliminated from consideration, since they generally do not produce runoff. The tabulated data are recommended as an estimate of the hr/yr of wet roadway, recognizing that two counteracting factors are operating: (1) the highway remains wet for some time after precipitation stops; however (2) precipitation does not necessary fall throughout a recorded hour.

## 8.2: INTRODUCTION TO PREDICTIVE PROCEDURES

2. Estimate the total annual vehicles passing during storms (VDS/yr) as follows:

$$\text{VDS/yr} = \text{ADT} \frac{\text{wet hr/yr}}{24 \text{ hr/day}}$$

where: ADT = projected average daily traffic on highway lanes draining to receiving water.

3. Estimate annual highway runoff TSS loading according to:

$$\text{TSS (lb/highway - mi/yr)} = (K) \frac{\text{VDS/yr} (C)}{1000}$$

where: K = 6.4 lb TSS/highway-mi/1000 VDS for western Washington  
K = 26 lb TSS/highway-mi/1000 VDS for eastern Washington  
C = runoff coefficient for the site

The loading constants given apply to new highways and existing highways where traffic increase is anticipated. On existing highways the constants apply whether or not additional lanes are constructed, up to a maximum of four lanes in a single direction, representing the cases contributing to the data base (Little, 1982). With greater widths, pollutants deposited on innermost lanes may be transported less effectively into shoulder drainage, such that K would tend to decrease; however, there was no sampling to test this hypothesis.

Note: If the lanes in one direction only drain to the receiving water, adjust ADT accordingly.

4. Express total annual highway loading ( $L_H$ ) by multiplying by number of highway-mi.
5. If a mitigation device such as a detention basin is provided, reduce the TSS loading according to the solids removal capability of the device. If highway runoff is discharged to receiving water via a vegetated drainage course, multiply the estimated TSS loading by the appropriate fraction as follows in Table 8.2.6 (after Wang, 1981). Interpolate as necessary.
6. Estimate annual highway loadings of other pollutants from:

$$\text{Loading (lb/yr)} = (K_p) (\text{TSS Loading})$$

where:  $K_p$  = ratio of pollutant P to TSS (Table 8.2.7.)  
TSS Loading previously estimated



Table 8.2.6. Solids removal ability of vegetated drainage course.

<u>Length of Vegetated Drainage Course (ft)</u>	<u>Fraction of Pollutant Remaining</u>
<30	1
31- 60	0.50
61- 90	0.40
91-120	0.30
121-150	0.26
151-180	0.23
>180	0.20

Use the modified TSS loading in further calculations.

Source: Wang, 1981

Table 8.2.7  $K_p$  (Pollutant:TSS Ratios) for Various Contaminants in Highway Runoff.

Pollutant	Abbreviation	$K_p$
Chemical Oxygen Demand	COD	$K_{COD} = 0.4$
Lead (Western Washington) (Eastern Washington)	Pb	$K_{Pb} = 1.5 \times 10^{-4} + (8.7 \times 10^{-8})(ADT)$ $K_{Pb} = 5.3 \times 10^{-4} + (2.8 \times 10^{-9})(ADT)$ (Note 1)
Zinc (Western Washington) (Eastern Washington)	Zn	$K_{Zn} = 1.4 \times 10^{-4} + (3.0 \times 10^{-8})(ADT)$ $K_{Zn} = 2.0 \times 10^{-4} + (3.2 \times 10^{-7})(ADT)$
Copper	Cu	$K_{Cu} = 7.9 \times 10^{-5} + (2.7 \times 10^{-9})(ADT)$
Nitrate + Nitrite-Nitrogen	$NO_3+NO_2-N$	$K_N = 2.0 \times 10^{-3}$
Total Kjeldahl Nitrogen (Western Washington) (Eastern Washington)	TKN	$K_{TKN} = 2.7 \times 10^{-3}$ $K_{TKN} = 1.2 \times 10^{-3}$
Total Phosphorus	TP	$K_{TP} = 2.1 \times 10^{-3}$

Note: (1) Base predicted lead loading on the lead concentration in gasoline at the time in proportion to that during the years of research. During those years, the concentration was 0.13 grams/liter. That concentration is scheduled to be reduced under U.S. Environmental Protection Agency regulations, and that agency can provide information on adherence to the schedule. For estimation purposes, it should be assumed that the proportion of vehicles using leaded gasoline remains constant.

## 8.2: INTRODUCTION TO PREDICTIVE PROCEDURES

### SESSION QUESTIONS:

1. Based on the different procedures, what are the major differences between the predictive procedures presented?
2. What limitations restrict the use of the procedures presented?
3. In what ways may the most applicable procedure presented here be adopted to use in a particular state?

## SECTION 8: PREDICTION OF WATER QUALITY IMPACTS

### SESSION 8.4: PREDICTION OF LOADING IMPACTS OF HIGHWAY RUNOFF - CASE STUDY

Estimated Time for Completion:

**OBJECTIVES:** Upon completion of this session, participants will be able to:

- Calculate pollutant loadings from other land uses within a watershed, using the simplified method presented.
- Assess the loading impacts from the highway, relative to loadings from other land uses within the watershed.
- Recognize the problems of the method presented, and be introduced to other approaches that might be used when more sensitive analysis is required.

#### **SESSION OVERVIEW:**

One approach to assess the potential impacts of pollutant loadings from highways surfaces compares the area loadings from other land uses within the watershed to those loadings estimated from the highway right-of-way.

This session introduces a simplified procedure for conducting an impact analysis. Case Study 8.4 will be distributed and participants will complete the required analysis.

Participants will review questions at the end of the session and discuss the findings and other approaches used when more sensitive analysis is required.

## 8.4: PREDICTION OF LOADING IMPACTS OF HIGHWAY RUNOFF - CASE STUDY

### I. DETERMINATION OF BACKGROUND LOADINGS FOR THE DRAINAGE AREA

The following procedure is adapted from Horner and Mar (1982). This simplified procedure may be used for non-winter periods to determine background loadings for a watershed area, based on typical area pollutant loadings and typical runoff concentrations data for selected land uses reported in the literature. The actual loadings and runoff concentrations vary for each location, based on site characteristics (e.g., rural or urban), soil types, and other factors, and the results should be interpreted with caution. The procedure provides a relative indication of highway loads to background loadings, and may determine whether a more detailed evaluation using more complicated procedures is required. The steps of the procedure are:

1. If the receiving water is a stream and if a comprehensive water quality record exists for the stream, proceed to Step 2. Otherwise, go to Step 3.
2. Estimate the mean monthly loading of each pollutant transported by the stream, prior to the presence of the highway ( $L_s$ , lb/mo) according to:

$$L_s = 1,965 Q_s C_s$$

where:  $Q_s$  and  $C_s$  are average quantities for the month in question.

where:  $Q_s$  = average stream discharge (cfs)  
 $C_s$  = average pollutant concentration (mg/l)

The loadings for each month should be aggregated for the period, if the measured flow data are available.

$Q_s$  may be the discharge rate determined for a specific drainage area; however, then  $C_s$  must be a flow weighted average for the same flow rate.

If the stream is gaged, obtain  $Q_s$  in the U.S. Geological Survey Water Resources Data provided for the most recent water year. If the stream is not gaged, estimate  $Q_s$  from the record of a nearby stream with similar watershed characteristics, as follows:

$$Q_s = Q_s' \frac{A_w}{A_w'}$$

where:  $Q_s$  = average discharge in runoff receiving stream (cfs)

8.4: PREDICTION OF LOADING IMPACTS OF HIGHWAY RUNOFF - CASE STUDY

$Q_s$  = average discharge in stream of record (cfs)

$A_w$  = runoff receiving stream watershed area (any area units)

$A_w$  = stream of record watershed area (any area units)

3. Determine the areas (in acres) in Central Business District, Other Commercial, Industrial, Single-Family Residential, Multiple-Family Residential, Cropland, Pasture, and Forested and Open Land used in the watershed draining to the highway runoff discharge point located farthest downstream. If it is projected by the planning agency for the location that development will modify land uses substantially in coming years, conduct the analysis for both present and ultimate land uses.
4. Determine annual area loading (lb/acre/yr) of each contaminant for each land use in the receiving water basin from local data, if they exist, or Table 8.4.1. (Note storm runoff pollutant loadings for specific land use categories.) Where a range is given, use the lower value if a conservative estimate of highway contribution to total loading is desired; otherwise, use the midpoint of the range. If pollutant loading rates are not available for a specific pollutant, then go to Step 7.
5. Approximate the proportion of each annual area loading delivered during the month or period in question according to:  
$$\text{lb/acre/mo (period)} = \left[ \frac{\text{hr ppt during month (period)}}{\text{hr ppt (lb/acre/yr)}} \right] \text{ or lb/acre/mo} = [ ]$$
6. Multiply loadings in lb/acre/mo by the respective acres to obtain loadings for the month (period) in question for each land use ( $L_{Li}$ ). Then sum over all land uses for each pollutant (summation  $L_{Li}$ ). Record results on Worksheet 8.4.a.
7. From Table 8.4.1a, determine the runoff coefficient for each land use in the watershed, above the discharge point for the project.
8. Multiply the runoff coefficient for each land use by the total seasonal rainfall for the site to obtain the runoff in inches.
9. Convert the runoff in inches to runoff volume by the following equation:

$$Q_{cf} = \frac{R \quad * \quad \text{acres}}{12 \quad * \quad 43,560}$$

8.4: PREDICTION OF LOADING IMPACTS OF HIGHWAY RUNOFF - CASE STUDY

R = runoff in inches

$Q_{cf}$  = runoff in cubic feet

10. Convert  $Q_{cf}$  to liters by multiplying by 28.31625.

$$R_L = Q_{cf} * 28.31625$$

$R_L$  = Runoff in liters

11. Determine total lbs. of pollutant by using the following equation and Table 8.4.2. Record results on Worksheet 8.4.b:

$$P_{pD} = R_L * P_{conc} * 2.2046 * 10^{-6}$$

where:  $P_{pD}$  = total pollutant loading  
 $R_L$  = runoff volume expressed as liters  
 $P_{conc}$  = pollutant concentration

12. If the receiving water is a stream, proceed to Step 13. If the receiving water is a lake or wetland, go to Step 15.

13. Estimate point source loadings ( $L_p$ ) of each pollutant as follows:

$$L_p \text{ (lb/mo)} = 1,965 Q_p C_p$$

where:  $Q_p$  and  $C_p$  are monthly quantities for the month in question

$Q_p$  = point source effluent flow rate (cfs) (average over year if not continuous). Obtain flow from discharge monitoring report as required by NPDES permit or develop industry typical flow.

$C_p$  = average point source effluent pollutant concentration (mg/l). Obtain from monitoring records or from industry typical discharge concentrations available from U.S. EPA Development Document Series for the specific point source category.

14. Estimate total stream loadings prior to highway presence as:

$$L_s = \text{summation } L_{L1} + L_p$$

Table 8.4.1. Storm runoff pollutant loadings for specific land use categories.

Land	Loading (lb/acre/yr)							
	TSS	OD COD	Pb	ZN	Cu	+NO 3 2	TKN	TP
Central Business District	964	955	6.3	2.7	1.9	4.0	13	2.5
Other Commercial	750	906	2.7	2.9	N/A	0.6	13	2.4
Industrial	50	56	1.8-6.3	3.1-11	0.3-1.0	0.4	2-13	0.8-3.6
Single-Family Residential	15	25	0.1	0.2	0.03	0.3	1-5	0.2-1.3
Multiple-Family Residential	390	297	0.6	0.3	0.3	3.4	3-4	1.2-1.4
Cropland	402	N/A	0.004-0.005	0.03-0.07	0.01-0.05	7.0	1.5	0.3
Pasture	306	N/A	0.003-0.013	0.02-0.15	0.02-0.04	0.3	0.6	0.06
Forested	76	N/A	0.01-0.03	0.01-0.03	0.02-0.03	0.5	2.6	0.08
Open	6	1.8	N/A	N/A	N/A	0.3	1.5	0.06

NOTES:

1. Means given where available; otherwise ranges are reported.
2. N/A -- Not available. (If specific pollutant loadings are not indicated here, then, determine loadings based on mean concentration values.)

SOURCE: Horner, R.R. et al., 1982.



8.4: PREDICTION OF LOADING IMPACTS OF HIGHWAY RUNOFF - CASE STUDY

Table 8.4.1a Values of runoff coefficients (C)  
for use in the runoff volume estimation.

Type of surface	Runoff coefficient  (C) <sup>a</sup>
<u>Rural Areas</u>	
Concrete or sheet asphalt pavement	0.8-0.9
Asphalt macadam pavement	0.6-0.8
Gravel roadways or shoulders	0.4-0.6
Bare earth	0.2-0.9
Steep grassed areas (2:1)	0.5-0.7
Turf meadows	0.1-0.4
Forested areas	0.1-0.3
Cultivated fields	0.2-0.4
<u>Urban Areas</u>	
Flat residential, with about 30 percent of area impervious	0.40
Flat residential, with about 60 percent of area impervious	0.55
Moderately steep residential, with about 50 percent of area impervious	0.65
Moderately steep built up area, with about 70 percent of area impervious	0.80
Flat commercial, with about 90 percent of area impervious	0.80

Source: Searcy, 1973.

<sup>a</sup> For flat slopes or permeable soil, use the lower values. For steep slopes or impermeable soil, use the higher values.

Table 8.4.2. Mean urban runoff concentrations by land use (NURP)  
(U.S. EPA, 1983)

<u>Pollutant</u>	<u>Units</u>	<u>Residential</u>	<u>Commercial</u>	<u>Industrial</u>	<u>Mixed</u>	<u>Open</u>
TSS	mg/l	206.0	160.0	143.0	297.0	218.0
BOD	mg/l	12.0	12.4	9.5	12.4	2.0
TN	mg/l	3.64	2.45	2.32	2.51	1.85
TP	mg/l	0.465	0.493	0.539	0.489	0.188
FCB (winter only)	cells/100 ml	7,099.0	7,099.0	7,099.0	7,099.0	7,099.0
S/S/F	cells/ 100 ml	31,995.0	31,995.0	31,995.0	31,995.0	31,995.0
O&G <sup>a</sup>	mg/l	3.89	13.13	7.1	6.23	.0
Fe	mg/l	2.73	2.73	2.73	2.73	2.73
As	ug/l	4.25	4.25	4.25	4.25	4.25
Cd	ug/l	1.58	1.58	1.58	1.58	1.58
Cr	ug/l	8.51	8.51	8.51	8.51	8.51
Cu	ug/l	19.7	19.7	19.7	19.7	19.7
Pb	ug/l	72.8	72.8	72.8	72.8	72.8
Hg	ug/l	0.5	0.5	0.5	0.5	0.5
Zn	ug/l	103.7	103.7	103.7	103.7	103.7
PCBs	ug/l	2.96	2.96	2.96	2.96	2.96
CHPs	ug/l	9.07	9.07	9.07	9.07	9.07

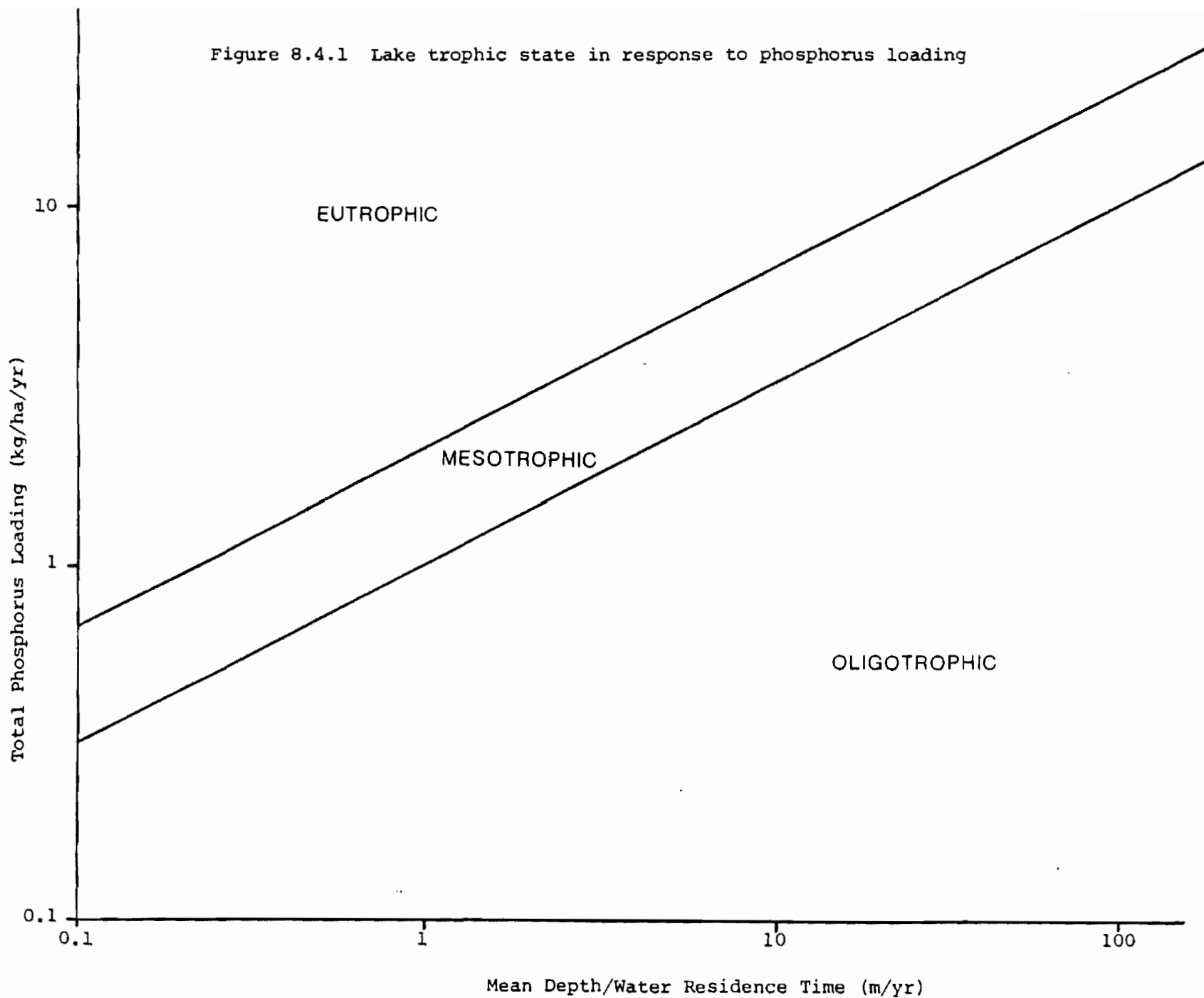
<sup>a</sup>Data taken from Stenstrom et al., 1984.

#### 8.4: PREDICTION OF LOADING IMPACTS OF HIGHWAY RUNOFF - CASE STUDY

15. Express the impact on stream pollutant loadings in terms of the estimated increase due to  $P_a$  highway runoff as a percentage of the original stream loadings ( $L_s$ ). If the estimated increase exceeds 10 percent for any pollutant, then mitigation may be required. If the stream eventually discharges to a lake or wetland, also evaluate the impact on the body of water according to the next Steps 16 and 17.
16. If the immediate or eventual receiving water is a lake or wetland, estimate total loadings for the month in question prior to the highway presence ( $L_{L,a}$ ) as equal to summation  $L_{L,1}$  plus any point source loading ( $1,965 Q_p C_p$ ).
17. If the immediate or eventual receiving water is a lake, conduct a special analysis to assess the potential impact of phosphorus loading on trophic state as follows:
  - a. Convert  $P_a$  and  $L_{L,a}$  to kg/mo by dividing by 2.2 lb/kg.
  - b. Estimate annual loadings from the monthly or seasonal loadings found previously by proportion (for both  $P_a$  and summation  $L_{L,1} + L_B$ ):
$$\text{kg/yr} = \frac{\text{annual hr precipitation}}{\text{hr precipitation during the month}} \text{ (kg/mo)}$$
  - c. Find the contributions of the highway and all other sources to the lake area total phosphorus (TP) loading (kg/ha/yr) by dividing  $L_H$  and  $L_{L,a}$ , respectively, by the lake surface area ( $A_{L,a}$ , ha). [Note: 1 hectare (ha) = 2.47 acres.]
  - d. Divide lake mean depth (m) by water residence time (yr), where water residence time = lake volume (any volume units)/outflow rate (any consistent volume/yr units).
  - e. Locate the lake on Figure 8.4.1, the trophic state graph (Vollenweider and Dillon, 1974), by using  $L_{L,a}/A_{L,a}$  as ordinate and the result of the previous step as abscissa.
18. If the highway loading addition does not move the status point near or into a higher trophic category, declare minimal impact on lake eutrophication and analyze impacts associated with maintenance or special problem areas. If a substantial impact on trophic state appears likely, mitigation should be further considered.

Figure 8.4.1 Lake trophic state in response to phosphorus loading

8-49



Source: Vollenweider and Dillon, 1974



**APPENDIX Y  
FINAL KARST REPORT (REDACTED)**

**TECHNICAL REPORT APPENDICES**

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<b>APPENDIX A</b>	<b>Memorandum of Understanding</b>
<b>APPENDIX B</b>	<b>Tabular results for activated carbon and water samples</b>
<b>APPENDIX C</b>	<b>Ozark Underground Laboratory Procedures and Criteria</b>
<b>APPENDIX D</b>	<b>Sampling Station Index and Karst Feature Index</b>
<b>APPENDIX E</b>	<b>Sampling Station and Select Feature Photographs</b>
<b>APPENDIX F</b>	<b>Individual Dye Trace Reports, Summary Table, and Figures</b>
<b>APPENDIX G</b>	<b>Documentation Graphs for All Analyzed Samples</b>
<b>APPENDIX H</b>	<b>Precipitation and Discharge Data from Illinois Central Spring</b>
<b>APPENDIX I</b>	<b>CONFIDENTIAL Data</b>
<b>APPENDIX J</b>	<b>Cave Fauna of the Section 5 Corridor of I-69</b>
<b>APPENDIX K</b>	<b>Indiana Bat Hibernacula Cave Reconnaissance</b>
<b>APPENDIX L</b>	<b>Pollutant Loading Estimate Tables and FHWA Methodology</b>
<b>APPENDIX M</b>	<b>IDNR Water Well Data</b>
<b>APPENDIX N</b>	<b>Detail Maps of Preferred Alternative and Resources</b>

REFNO	AQUELV	BAILERR	BEDROCK	PUMPRAT	BEDRO_1	SCREENL	STATIC	DEPTH	RNG	TWN	SEC	STRCOUNTY	STRTOPO	DATE
207379	0	0	0	1	0	0	37	150	1E	11N	18	MORGAN	MARTINSVILLE	9/26/1955
350554	0	0	0	80	0	3	8	63	1E	11N	18	MORGAN	MARTINSVILLE	1/15/2001
385127	0	0	0	15	0	4	8	60	1E	11N	18	MORGAN	MARTINSVILLE	8/30/2004
209574	0	0	50	0	565	0	45	77	1W	11N	26	MORGAN	HINDUSTAN	
209649	0	15	50	0	565	0	0	80	1W	11N	23	MORGAN	HINDUSTAN	9/26/1979
209604	0	12	27	0	593	0	0	75	1W	11N	26	MORGAN	HINDUSTAN	8/21/1977
209619	0	0	88	0	500	3	6	24	1W	11N	24	MORGAN	HINDUSTAN	6/28/1979
209629	0	30	28	0	572	0	0	52	1W	11N	24	MORGAN	HINDUSTAN	1/20/1965
207304	0	5	21	0	579	0	0	180	1E	11N	18	MORGAN	MARTINSVILLE	9/17/1959
207374	559	15	0	0	0	3	10	41	1E	11N	18	MORGAN	MARTINSVILLE	9/19/1971
269754	0	18	30	0	570	0	8	50	1W	11N	13	MORGAN	MARTINSVILLE	7/5/1975
269759	532	10	0	0	0	4	19	68	1W	11N	13	MORGAN	MARTINSVILLE	6/10/1966
403020	0	0	53	50	577	0	45	97	1W	11N	26	MORGAN	HINDUSTAN	7/25/2006
20888	0	0	0	60	0	60	0	145	1W	10N	28	MONROE	MODESTO	1/11/1988
213693	0	3	50	0	0	0	60	120	1W	8N	19	MONROE	CLEAR CREEK	7/20/1967
213698	0	3	70	0	0	0	31	105	1W	8N	19	MONROE	CLEAR CREEK	8/12/1971
221960	0	5	40	0	0	0	45	65	1W	9N	31	MONROE	BLOOMINGTON	10/3/1967
272239	0	0	0	0	0	0	0	0	1W	10N	33	MONROE	MODESTO	3/1/1994
310446	0	10	37	0	613	0	0	100	1W	9N	4	MONROE	MODESTO	4/26/1961
19798	0	0	12	0	718	0	0	0	1W	10N	28	MONROE	MODESTO	6/1/1991
19799	0	0	15	0	715	0	0	0	1W	10N	28	MONROE	MODESTO	7/1/1991
210630	0	2	6	0	704	0	41	160	1W	10N	33	MONROE	MODESTO	2/2/1962
213733	0	5	23	0	757	0	70	150	1W	8N	19	MONROE	CLEAR CREEK	11/5/1964
213703	0	2	7	0	753	0	41	105	1W	8N	19	MONROE	CLEAR CREEK	7/10/1964
213708	0	2	22	0	738	0	45	132	1W	8N	19	MONROE	CLEAR CREEK	4/21/1965
213713	0	5	16	0	769	0	70	140	1W	8N	19	MONROE	CLEAR CREEK	8/12/1964
213718	0	10	76	0	724	0	90	120	1W	8N	19	MONROE	CLEAR CREEK	4/23/1969
213723	0	4	27	0	763	0	75	170	1W	8N	19	MONROE	CLEAR CREEK	9/8/1964
221934	0	1	5	0	865	0	38	195	1W	9N	20	MONROE	BLOOMINGTON	7/31/1965
221939	0	4	11	0	799	0	55	120	1W	9N	20	MONROE	BLOOMINGTON	10/22/1973
222605	0	24	5	0	645	0	0	95	1W	9N	4	MONROE	BLOOMINGTON	9/10/1963
222015	0	0	0	0	0	0	0	150	1W	9N	29	MONROE	BLOOMINGTON	8/30/1960
222025	0	2	20	0	800	0	48	115	1W	9N	29	MONROE	BLOOMINGTON	10/27/1972
209578	0	0	0	0	0	405	139	410	1W	11N	35	MORGAN	HINDUSTAN	8/30/1986
338988	0	0	0	0	0	0	0	240	1W	10N	21	MONROE	MODESTO	8/21/1998
209573	0	20	40	0	730	0	0	100	1W	11N	35	MORGAN	HINDUSTAN	9/1/1960
209583	0	1	26	0	675	0	28	82	1W	11N	35	MORGAN	MODESTO	5/10/1963
209584	0	5	53	0	728	0	58	100	1W	11N	26	MORGAN	HINDUSTAN	9/6/1962
211755	0	8	14	0	786	0	110	222	1W	10N	21	MONROE	MODESTO	9/4/1962
211760	0	0	17	0	773	0	140	200	1W	10N	21	MONROE	MODESTO	10/22/1960
209608	0	2	40	0	682	0	70	212	1W	11N	34	MORGAN	MODESTO	10/8/1965
211785	0	10	16	0	804	0	40	90	1W	10N	15	MONROE	MODESTO	10/30/1959
211790	0	0	12	0	808	0	0	200	1W	10N	16	MONROE	MODESTO	6/10/1960

**Record of Water Well**

Indiana Department of Natural Resources

**Reference Number** *Driving directions to well* **Date completed**  
**213758**

**Owner-Contractor** **Name** **Address** **Telephone**  
 Owner  
 Driller  
 Operator

**Construction Details**  
**Well** *Use:* HOME *Drilling method:* Cable Tool *Pump type:*  
*Depth:* 100.0 *Pump setting depth:* *Water quality:*  
**Casing** *Length:* 30.0 *Material:* *Diameter:* 6.0  
**Screen** *Length:* *Material:* *Diameter:* Slot size:

**Well Capacity Test** *Type of test:* *Test rate:* gpm for hrs. *Bail Test rate:* 5.0 gpm for 1.0 hrs.  
*Drawdown:* ft. *Static water level:* 30.0 ft. *Bailer Drawdown:* 0.0 ft.

**Grouting Information** *Material:* *Depth:* from to  
*Installation Method:* *Number of bags used:*

**Well Abandonment** *Sealing material:* *Depth:* from to  
*Installation Method:* *Number of bags used:*

**Administrative** *County:* Monroe *Township:* 8N *Range:* 1W *Topo map:* Clear Creek  
*Section:* NE1/4 of the NE1/4 of the SW1/4 of Section 19  
*Grant Number:*  
*Field located by:* MT *on:* Jul 12, 1967  
*Courthouse location by:* *on:*  
*Location accepted w/o verification by:* *on:*  
*Subdivision name:* *Lot number:*  
*Ft W of EL:* 2200.0 *Ft N of SL:* 2300.0 *Ft E of WL:* *Ft S of NL:*  
*Ground elevation:* 750.0 *Depth to bedrock:* 8.0 *Bedrock elevation:* 742.0 *Aquifer elevation:*  
*UTM Easting:* 537586.0 *UTM Northing:* 4329259.0

*PADZF*

**Well Log**

Top	Bottom	Formation
0.0	8.0	YELLOW CLAY
8.0	12.0	STONE BLUE FLINT EXTRA HARD
12.0	18.0	STONE BUFF LS HARD
18.0	39.0	STONE GRAY LS SOFT
39.0	47.0	STONE BUFF LS HARD
47.0	61.0	STONE BROWNISH LS EXTRA HARD
61.0	65.0	STONE BROWNISH LS SOFTER
65.0	70.0	STONE GRAY LS HARD
70.0	76.0	STONE GRAY LS EXTRA HARD
76.0	82.0	STONE WHITE LS HARD
82.0	93.0	STONE WHITE LS SOFT
93.0	100.0	STONE WHITE LS HARD

*— = Bedrock*

**Comments** OWNER VERIFIED

**Record of Water Well**

Indiana Department of Natural Resources

**Reference Number** *Driving directions to well* **Date completed**  
**213668** Oct 09, 1971

**Owner-Contractor** **Name** **Address** **Telephone**  
 Owner  
 Driller  
 Operator

**Construction Details**

**Well** *Use:* HOME *Drilling method:* Cable Tool *Pump type:*  
*Depth:* 120.0 *Pump setting depth:* *Water quality:*  
**Casing** *Length:* 55.0 *Material:* *Diameter:* 6.0  
**Screen** *Length:* *Material:* *Diameter:* Slot size:

**Well Capacity Test** *Type of test:* *Test rate:* gpm for hrs. *BailTest rate:* 2.0 gpm for hrs.  
*Drawdown:* ft. *Static water level:* 60.0 ft. *Bailer Drawdown* 55.0 ft.

**Grouting Information** *Material:* *Depth:* from to  
*Installation Method:* *Number of bags used:*

**Well Abandonment** *Sealing material:* *Depth:* from to  
*Installation Method:* *Number of bags used:*

**Administrative** *County:* Monroe *Township:* 8N Range: 1W  
*Section:* SW 1/4 of the SW 1/4 of the NE 1/4 of Section 19 *Topo map:* Clear Creek  
*Grant Number:*  
*Field located by:* JRD *on:* Jul 26, 1978  
*Courthouse location by:* *on:*  
*Location accepted w/o verification by:* *on:*  
*Subdivision name:* *Lot number:*  
*Ft W of EL:* 2000.0 *Ft N of SL:* *Ft E of WL:* *Ft S of NL:* 2550.0  
*Ground elevation:* 770.0 *Depth to bedrock:* 50.0 *Bedrock elevation:* 720.0 *Aquifer elevation:*  
*UTM Easting:* 537904.0 *UTM Northing:* 4329392.0

**Well Log**

Top	Bottom	Formation
0.0	52.0	RED CLAY OPENINGS & LIMESTONE
50.0	100.0	SLIGHT BLUE LIMESTONE HARD
100.0	120.0	WHITE LIMESTONE

**Comments** MC 720; OWNER VERIFIED; 75 FT NORTH OF THAT RD.



Record of Water Well

Indiana Department of Natural Resources

Reference Number 213723 Driving directions to well Date completed Sep 08, 1964

Owner-Contractor Name Address Telephone Owner Driller Operator

Construction Details Well Use: HOME Depth: 170.0 Drilling method: Rotary Pump type: Pump setting depth: Water quality: Casing Length: 27.0 Material: Diameter: 6.5 Screen Length: Material: Diameter: Slot size:

Well Capacity Test Type of test: Drawdown: ft. Test rate: gpm for hrs. Static water level: 75.0 ft. BailTest rate: 4.0 gpm for hrs. Bailer Drawdown 164.0 ft.

Grouting Information Material: Installation Method: Depth: from to Number of bags used:

Well Abandonment Sealing material: Installation Method: Depth: from to Number of bags used:

Administrative County: Monroe Township: 8N Range: 1W Section: NW1/4 of the SE1/4 of the NW1/4 of Section 19 Topo map: Clear Creek Grant Number: Field located by: JRD on: Jul 26, 1978 Courthouse location by: on: Location accepted w/o verification by: on: Subdivision name: Lot number: Ft W of EL: Ft N of SL: Ft E of WL: 1700.0 Ft S of NL: 2000.0 Ground elevation: 790.0 Depth to bedrock: 27.0 Bedrock elevation: 763.0 Aquifer elevation: UTM Easting: 537399.0 UTM Northing: 4329577.0

Well Log table with columns: Top, Bottom, Formation. Rows show depths from 0.0 to 27.0 and formations: TOPSOIL, RED CLAY, CLAY W/ BROKEN LIME, LIMESTONE.

Comments MC 763; NEIGHBOR VERIFIED;

Record of Water Well

Indiana Department of Natural Resources

<b>Reference Number</b> 213713	<b>Driving directions to well</b>	<b>Date completed</b> Aug 12, 1964
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<b>Owner-Contractor</b>	<b>Name</b>	<b>Address</b>	<b>Telephone</b> ( )
Owner			
Driller			
Operator			

<b>Construction Details</b>	<b>Use:</b> HOME	<b>Drilling method:</b> Cable Tool	<b>Pump type:</b>
Well	<b>Depth:</b> 140.0	<b>Pump setting depth:</b>	<b>Water quality:</b>
Casing	<b>Length:</b> 20.0	<b>Material:</b>	<b>Diameter:</b> 6.0
Screen	<b>Length:</b>	<b>Material:</b>	<b>Diameter: Slot size:</b>

<b>Well Capacity Test</b>	<b>Type of test:</b>	<b>Test rate:</b> gpm for hrs.	<b>BailTest rate:</b> 4.5 gpm for 1.0 hrs.
	<b>Drawdown:</b> ft.	<b>Static water level:</b> 70.0 ft.	<b>Bailer Drawdown:</b> 5.0 ft.

<b>Grouting Information</b>	<b>Material:</b>	<b>Depth:</b> from to
	<b>Installation Method:</b>	<b>Number of bags used:</b>

<b>Well Abandonment</b>	<b>Sealing material:</b>	<b>Depth:</b> from to
	<b>Installation Method:</b>	<b>Number of bags used:</b>

<b>Administrative</b>	<b>County:</b> Monroe	<b>Township:</b> 8N Range: 1W	<b>Topo map:</b> Clear Creek
	<b>Section:</b> SE1/4 of the SW1/4of the NW1/4 of Section 19		
	<b>Grant Number:</b>		
	<b>Field located by:</b> JRD	<b>on:</b> Jnl 26, 1978	
	<b>Courthouse location by:</b>	<b>on:</b>	
	<b>Location accepted w/o verification by:</b>	<b>on:</b>	
	<b>Subdivision name:</b>	<b>Lot number:</b>	
	<b>Ft W of EL:</b>	<b>Ft N of SL:</b>	<b>Ft E of WL:</b> 1200.0 <b>Ft S of NL:</b> 2250.0
	<b>Ground elevation:</b> 785.0	<b>Depth to bedrock:</b> 16.0	<b>Bedrock elevation:</b> 769.0 <b>Aquifer elevation:</b>
	<b>UTM Easting:</b> 537234.0		<b>UTM Northing:</b> 4329492.0

<b>Well Log</b>	Top	Bottom	Formation
	0.0	6.0	YEL CLAY
	6.0	12.0	RED CLAY
	12.0	16.0	YEL CLAY
	16.0		

**Record of Water Well**

Indiana Department of Natural Resources

<b>Reference Number</b>	<b>Driving directions to well</b>		<b>Date completed</b>
<b>213708</b>			..pr
<b>Owner-Contractor</b>	<b>Name</b>	<b>Address</b>	
Owner			
Driller			
Operator			
<b>Construction Details</b>			
Well	<i>Use:</i> HOME	<i>Drilling method:</i> Rotary	<i>Pump type:</i>
	<i>Depth:</i> 132.0	<i>Pump setting depth:</i>	<i>Water quality:</i>
Casing	<i>Length:</i> 22.0	<i>Material:</i>	<i>Diameter:</i> 6.5
Screen	<i>Length:</i>	<i>Material:</i>	<i>Diameter: Slot size:</i>
<b>Well Capacity Test</b>	<i>Type of test:</i>	<i>Test rate:</i> gpm for hrs.	<i>Bail Test rate:</i> 2.0 gpm for hrs.
	<i>Drawdown:</i> ft.	<i>Static water level:</i> 45.0 ft.	<i>Bailer Drawdown:</i> 125.0 ft.
<b>Grouting Information</b>	<i>Material:</i>	<i>Depth:</i> from to	
	<i>Installation Method:</i>	<i>Number of bags used:</i>	
<b>Well Abandonment</b>	<i>Sealing material:</i>	<i>Depth:</i> from to	
	<i>Installation Method:</i>	<i>Number of bags used:</i>	
<b>Administrative</b>	<i>County:</i> Monroe		<i>Township:</i> 8N <i>Range:</i> 1W
	<i>Section:</i> SE1/4 of the SW1/4 of the NW1/4 of Section 19		<i>Topo map:</i> Clear Creek
	<i>Grant Number:</i>		
	<i>Field located by:</i> MT	<i>on:</i> Jul 12, 1967	
	<i>Courthouse location by:</i>	<i>on:</i>	
	<i>Location accepted w/o verification by:</i>	<i>on:</i>	
	<i>Subdivision name:</i>		
	<i>Fl W of EL:</i>	<i>Fl N of SL:</i>	<i>Fl E of WL:</i> 1000.0 <i>Fl S of NL:</i> 2400.0
	<i>Ground elevation:</i> 760.0	<i>Depth to bedrock:</i> 22.0	<i>Bedrock elevation:</i> 738.0 <i>Aquifer elevation:</i>
	<i>UTM Easting:</i> 537209.0		<i>UTM Northing:</i> 4329462.0
<b>Well Log</b>	<b>Top</b>	<b>Bottom</b>	<b>Formation</b>
	0.0	22.0	CLAY YELLOW
	22.0	132.0	LIMESTONE
<b>Comments</b>	MC; MAILBOX VERIFIED; WELL IN FRONT OF HOUSE APPROX. 25 FT.		

**Record of Water Well**

Indiana Department of Natural Resources

**Reference Number** *Driving directions to well* **Date completed**  
**213718**

**Owner-Contractor** **Name** **Address** **Telephone**  
 Owner () -  
 Driller () -  
 Operator () -

**Construction Details**  
**Well** *Use:* HOME *Drilling method:* Cable Tool *Pump type:*  
*Depth:* 120.0 *Pump setting depth:* *Water quality:*  
**Casing** *Length:* 77.0 *Material:* *Diameter:* 6.0  
**Screen** *Length:* *Material:* *Diameter: Slot size:*

**Well Capacity Test** *Type of test:* *Test rate:* gpm for hrs. *Bail Test rate:* 10.0 gpm for hrs.  
*Drawdown:* ft. *Static water level:* 90.0 ft. *Bailer Drawdown* 20.0 ft.

**Grouting Information** *Material:* *Depth:* from to  
*Installation Method:* *Number of bags used:*

**Well Abandonment** *Sealing material:* *Depth:* from to  
*Installation Method:* *Number of bags used:*

**Administrative** *County:* Monroe *Township:* 8N *Range:* 1W *Topo map:* Clear Creek  
*Section:* SE1/4 of the NE1/4 of the NW1/4 of Section 19  
*Grant Number:*  
*Field located by:* JRD *on:* Jul 27, 1978  
*Courthouse location by:* *on:*  
*Location accepted w/o verification by:* *on:*  
*Subdivision name:* *Lot number:*  
*Ft W of EL:* *Ft N of SL:* *Ft E of WL:* 2450.0 *Ft S of NL:* 1000.0  
*Ground elevation:* 800.0 *Depth to bedrock:* 76.0 *Bedrock elevation:* 724.0 *Aquifer elevation:*  
*UTM Easting:* 537625.0 *UTM Northing:* 4329875.0

<b>Well Log</b>	Top	Bottom	Formation
	0.0	60.0	LAYERS STONE & CLAY
	60.0	76.0	CAVE OR OPENING
	76.0	120.0	BROWN LIMESTONE

**Comments** MC 724; OWNER VERIFIED; JUST SOUTH OF HOUSE

**Record of Water Well**

Indiana Department of Natural Resources

**Reference Number** *Driving directions to well* **Date completed**  
**222015** Aug 30, 1960

<b>Owner-Contractor</b>	<b>Name</b>	<b>Address</b>	<b>Telephone</b>
Owner			() -
Driller			() -
Operator			() -

<b>Construction Details</b>			
Well	<i>Use:</i> HOME	<i>Drilling method:</i> Cable Tool	<i>Pump type:</i>
	<i>Depth:</i> 150.0	<i>Pump setting depth:</i>	<i>Water quality:</i>
Casing	<i>Length:</i>	<i>Material:</i>	<i>Diameter:</i>
Screen	<i>Length:</i>	<i>Material:</i>	<i>Diameter: Slot size:</i>

<b>Well Capacity Test</b>	<i>Type of test:</i>	<i>Test rate:</i> gpm for hrs.	<i>BailTest rate:</i> gpm for hrs.
	<i>Drawdown:</i> ft.	<i>Static water level:</i> ft.	<i>Bailer Drawdown</i> ft.

<b>Grouting Information</b>	<i>Material:</i>	<i>Depth:</i> from to
	<i>Installation Method:</i>	<i>Number of bags used:</i>

<b>Well Abandonment</b>	<i>Sealing material:</i>	<i>Depth:</i> from to
	<i>Installation Method:</i>	<i>Number of bags used:</i>

<b>Administrative</b>	<i>County:</i> Monroe	<i>Townshlp:</i> 9N Range: 1W	
	<i>Section:</i> NE1/4 of the NW1/4 of the SW1/4 of Section 29		<i>Topo map:</i> Bloomington
	<i>Grant Number:</i>		
	<i>Field located by:</i> JMH	<i>on:</i> Mar 28, 1961	
	<i>Courthouse location by:</i> JMH	<i>on:</i> Mar 28, 1961	
	<i>Location accepted w/o verification by:</i>	<i>on:</i>	
	<i>Subdivison name:</i>	<i>Lot number:</i>	
	<i>Ft W of EL:</i>	<i>Ft N of SL:</i> 1500.0	<i>Ft E of WL:</i> 1100.0 <i>Ft S of NL:</i>
	<i>Ground elevation:</i> 840.0	<i>Depth to bedrock:</i>	<i>Bedrock elevation:</i>

Record of Water Well

Indiana Department of Natural Resources

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**Reference Number** *Driving directions to well* **Date completed**  
**222025** Oct 27, 1972

**Owner-Contractor** *Name* *Address* *Telephone*  
 Owner () -  
 Driller () -  
 Operator () -

**Construction Details**  
 Well *Use:* HOME *Drilling method:* Cable Tool *Pump type:*  
*Depth:* 115.0 *Pump setting depth:* *Water quality:*  
 Casing *Length:* 22.0 *Material:* *Diameter:* 5.63  
 Screen *Length:* *Material:* *Diameter:* Slot size:

**Well Capacity Test** *Type of test:* *Test rate:* gpm for hrs. *Bail Test rate:* 1.5 gpm for hrs.  
*Drawdown:* ft. *Static water level:* 48.0 ft. *Bailer Drawdown:* ft.

**Grouting Information** *Material:* *Depth:* from to  
*Installation Method:* *Number of bags used:*

**Well Abandonment** *Sealing material:* *Depth:* from to  
*Installation Method:* *Number of bags used:*

**Administrative** *County:* Monroe *Township:* 9N *Range:* 1W *Topo map:* Bloomington  
*Section:* NE1/4 of the NW1/4 of the NW1/4 of Section 29  
*Grant Number:*  
*Field located by:* MK *on:* May 18, 1978  
*Courthouse location by:* *on:*  
*Location accepted w/o verification by:* *on:*  
*Subdivision name:* ARLINGTON *Lot number:*  
*Fl W of EL:* *Fl N of SL:* *Fl E of WL:* 1150.0 *Fl S of NL:* 300.0  
*Ground elevation:* 820.0 *Depth to bedrock:* 20.0 *Bedrock elevation:* 800.0 *Aquifer elevation:*  
*UTM Easting:* 538622.0 *UTM Northing:* 4338050.0

**Well Log**

Top	Bottom	Formation
0.0	20.0	TOPSOIL & LIMESTONE
20.0	115.0	WHITE LIMESTONE MED. HARD

**Comments** MC800; MC; DRY HOLE; OWNER VERIFIED - NO LONGER USED

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Record of Water Well

Indiana Department of Natural Resources

<b>Reference Number</b>	<b>Driving directions to well</b>		<b>Date completed</b>	
<b>221934</b>			Jul 31, 1965	
<b>Owner-Contractor</b>	<b>Name</b>	<b>Address</b>	<b>Telephone</b>	
Owner			()-	
Driller			()-	
Operator			()-	
<b>Construction Details</b>				
Well	<b>Use:</b> HOME	<b>Drilling method:</b> Cable Tool	<b>Pump type:</b>	
	<b>Depth:</b> 195.0	<b>Pump setting depth:</b>	<b>Water quality:</b>	
Casing	<b>Length:</b> 27.5	<b>Material:</b>	<b>Diameter:</b> 6.0	
Screen	<b>Length:</b>	<b>Material:</b>	<b>Diameter:</b> Slot size:	
<b>Well Capacity Test</b>				
	<b>Type of test:</b>	<b>Test rate:</b> gpm for hrs.	<b>Bail Test rate:</b> 0.67 gpm for 2.0 hrs.	
	<b>Drawdown:</b> ft.	<b>Static water level:</b> 38.0 ft.	<b>Bailer Drawdown:</b> 0.0 ft.	
<b>Grouting Information</b>				
	<b>Material:</b>	<b>Depth:</b> from to		
	<b>Installation Method:</b>	<b>Number of bags used:</b>		
<b>Well Abandonment</b>				
	<b>Sealing material:</b>	<b>Depth:</b> from to		
	<b>Installation Method:</b>	<b>Number of bags used:</b>		
<b>Administrative</b>				
	<b>County:</b> Monroe	<b>Township:</b> 9N Range: 1W		
	<b>Section:</b> SW 1/4 of the SW 1/4 of the SW 1/4 of Section 20			<b>Topo map:</b> Bloomington
	<b>Grant Number:</b>			
	<b>Field located by:</b> LES	<b>on:</b> Jul 01, 1966		
	<b>Courthouse location by:</b>	<b>on:</b>		
	<b>Location accepted w/o verification by:</b>	<b>on:</b>		
	<b>Subdivision name:</b>	<b>Lot number:</b>		
	<b>Ft W of EL:</b>	<b>Ft N of SL:</b> 300.0	<b>Ft E of WL:</b> 300.0	<b>Ft S of NL:</b>
	<b>Ground elevation:</b> 870.0	<b>Depth to bedrock:</b> 5.0	<b>Bedrock elevation:</b> 865.0	<b>Aquifer elevation:</b>
	<b>UTM Easting:</b> 538348.0	<b>UTM Northing:</b> 4338252.0		
<b>Well Log</b>				
	Top	Bottom	Formation	
	0.0	5.0	YEL CLAY	
	5.0	22.0	GRAY LS HARD	
	22.0	27.0	MUD SEAM	
	27.0	39.0	GRAY LS HARD	
	39.0	73.0	LT GRAY LS HARD	
	73.0	95.0	RUSTIC BUFF LS SOFTER	
	95.0	118.0	GRAY LS HARD	
	118.0	124.0	DARK GRAY LS EXTRA HARD	
	124.0	140.0	GRAY LS HARD	
	140.0	160.0	LT GRAY LS EXTR HARD	
	160.0	166.0	LT GRAY LS SOFTER	
	166.0	173.0	LT GRAY LS EXTRA HARD	
	173.0	180.0	LT GRAY LS LITTLE SOFTER	
	180.0	195.0	LT GRAY LS HARD	
<b>Comments</b>				
	MC 865			

Record of Water Well

Indiana Department of Natural Resources

**Reference Number** *Driving directions to well* **Date completed**  
**221939** ON L Oct 22, 1973

**Owner-Contractor** **Name** **Address** **Telephone**  
 Owner () -  
 Driller () -  
 Operator () -

**Construction Details**  
**Well** *Use:* HOME *Drilling method:* Other *Pump type:*  
*Depth:* 120.0 *Pump setting depth:* *Water quality:*  
**Casing** *Length:* 21.0 *Material:* *Diameter:* 6.25  
**Screen** *Length:* *Material:* *Diameter: Slot size:*

**Well Capacity Test** *Type of test:* *Test rate:* gpm for hrs. *Bail Test rate:* 4.0 gpm for 1.0 hrs.  
*Drawdown:* ft. *Static water level:* 55.0 ft. *Bailer Drawdown* 120.0 ft.

**Grouting Information** *Material:* *Depth:* from to  
*Installation Method:* *Number of bags used:*

**Well Abandonment** *Sealing material:* *Depth:* from to  
*Installation Method:* *Number of bags used:*

**Administrative** *County:* Monroe *Township:* 9N *Range:* 1W *Topo map:* Bloomington  
*Section:* SW 1/4 of the SW 1/4 of the SW 1/4 of Section 20  
*Grant Number:*  
*Field located by:* MBR *on:* May 18, 1978  
*Courthouse location by:* *on:*  
*Location accepted w/o verification by:* *on:*  
*Subdivision name:* *Lot number:*  
*Ft W of BL:* *Ft N of SL:* 500.0 *Ft E of WL:* 100.0 *Ft S of NL:*  
*Ground elevation:* 810.0 *Depth to bedrock:* 11.0 *Bedrock elevation:* 799.0 *Aquifer elevation:*  
*UTM Easting:* 538299.0 *UTM Northing:* 4338325.0

<b>Well Log</b>	Top	Bottom	Formation
	0.0	8.0	YEL CLAY
	8.0	11.0	RED CLAY
	11.0	24.0	GRAY KLS HARD
	24.0	36.0	GRAY LS EXTRA HARD
	36.0	42.0	BLUE LS EXTRA HARD
	42.0	65.0	GRAY LS HARD
	65.0	85.0	BUFF LS HARD
	85.0	100.0	GRAY LS HARD
	100.0	120.0	DARK GRAY LS HARD

**Comments** MC 799; OWNER VER; 18' S OF HSE



**Record of Water Well**

Indiana Department of Natural Resources

**Reference Number** *Driving directions to well* **Date completed**  
**222451** | Oct 26, 1971

**Owner-Contractor** **Name** **Address**  
 Owner  
 Driller  
 Operator ( ) -

**Construction Details**

**Well** *Use:* HOME *Drilling method:* Other *Pump type:*  
*Depth:* 195.0 *Pump setting depth:* *Water quality:*  
**Casing** *Length:* 20.0 *Material:* *Diameter:* 6.25  
**Screen** *Length:* *Material:* *Diameter:* Slot size:

**Well Capacity Test** *Type of test:* *Test rate:* gpm for hrs. *BailTest rate:* 7.5 gpm for hrs.  
*Drawdown:* ft. *Static water level:* 70.0 ft. *Bailer Drawdown:* 195.0 ft.

**Grouting Information** *Material:* *Depth:* from to  
*Installation Method:* *Number of bags used:*

**Well Abandonment** *Sealing material:* *Depth:* from to  
*Installation Method:* *Number of bags used:*

**Administrative** *County:* Monroe *Township:* 9N *Range:* 1W *Topo map:* Bloomington  
*Section:* SE1/4 of the SE1/4 of the SE1/4 of Section 18  
*Grant Number:*  
*Field located by:* BEB *on:* Mar 07, 1989  
*Courthouse location by:* *on:*  
*Location accepted w/o verification by:* *on:*  
*Subdivision name:* LANCASTER PARK *Lot number:*  
*Fl W of EL:* 150.0 *Fl N of SL:* 100.0 *Fl E of Wt.:* *Fl S of NL:*  
*Ground elevation:* 720.0 *Depth to bedrock:* 6.0 *Bedrock elevation:* 714.0 *Aquifer elevation:*  
*UTM Easting:* 538210.0 *UTM Northing:* 4339820.0

**Well Log**

Top	Bottom	Formation
0.0	2.0	YEL CLAY
2.0	6.0	RED CLAY
6.0	45.0	GRAY LS HARD
45.0	67.0	DARK GRAY LS HARD
67.0	130.0	GRAY LS HARD
130.0	146.0	WHITE LS HARD
146.0	170.0	GRAY LS HARD
170.0	195.0	BLUE SOAPSTONE HARD

**Comments** WELL LOCATED ON S SIDE OF HSE

**Record of Water Well**

Indiana Department of Natural Resources

**Reference Number** *Driving directions to well* **Date completed**  
**222610** May 02, 1963

**Owner-Contractor** **Name** **Address** **Telephone**  
 Owner ( ) -  
 Driller ( ) -

**Construction Details**  
**Well** *Use:* HOME *Drilling method:* Cable Tool *Pump type:*  
*Depth:* 110.0 *Pump setting depth:* *Water quality:*  
**Casing** *Length:* 21.5 *Material:* *Diameter:* 6.0  
**Screen** *Length:* *Material:* *Diameter:* Slot size:

**Well Capacity Test** *Type of test:* PUMPING *Test rate:* gpm for 1.0 hrs. *BailTest rate:* 1.0 gpm for hrs.  
*Drawdown:* ft. *Static water level:* 50.0 ft. *Bailer Drawdown:* 50.0 ft.

**Grouting Information** *Material:* *Depth:* from to  
*Installation Method:* *Number of bags used:*

**Well Abandonment** *Sealing material:* *Depth:* from to  
*Installation Method:* *Number of bags used:*

**Administrative** *County:* Monroe *Township:* 9N *Range:* 1W *Topo map:* Bloomington  
*Section:* SW 1/4 of the SW 1/4 of the NE 1/4 of Section 4  
*Grant Number:*  
*Field located by:* LES *on:* Jnl 01, 1966  
*Courthouse location by:* *on:*  
*Location accepted w/o verification by:* *on:*  
*Subdivision name:* *Lot number:*  
*Ft W of EL:* 2500.0 *Ft N of SL:* 3200.0 *Ft E of WL:* *Ft S of NL:*  
*Ground elevation:* 650.0 *Depth to bedrock:* 20.0 *Bedrock elevation:* 630.0 *Aquifer elevation:*  
*UTM Easting:* 540650.0 *UTM Northing:* 4343960.0

<b>Well Log</b>	Top	Bottom	Formation
	0.0	21.5	CLAY
	21.5	110.0	STONE & SH

**Comments** MC 630; VERY GOOD WELL

**Record of Water Well**

Indiana Department of Natural Resources

**Reference Number** *Driving directions to well* **Date completed**  
**222605** Sep 10, 1963

**Owner-Contractor** *Name* *Address* *Telephone*  
 Owner () -  
 Driller () -

**Construction Details**  
 Well *Use:* HOME *Drilling method:* Cable Tool *Pump type:*  
*Depth:* 95.0 *Pump setting depth:* *Water quality:*  
 Casing *Length:* 6.0 *Material:* *Diameter:* 6.0  
 Screen *Length:* *Material:* *Diameter:* Slot size:

**Well Capacity Test** *Type of test:* *Test rate:* gpm for hrs. *BailTest rate:* 24.0 gpm for hrs.  
*Drawdown:* ft. *Static water level:* ft. *Bailer Drawdown:* 0.0 ft.

**Grouting Information** *Material:* *Depth:* from to  
*Installation Method:* *Number of bags used:*

**Well Abandonment** *Sealing material:* *Depth:* from to  
*Installation Method:* *Number of bags used:*

**Administrative** *County:* Monroe *Township:* 9N Range: 1W *Topo map:* Bloomington  
*Section:* SE1/4 of the NE1/4of the NW1/4 of Section 4  
*Grant Number:*  
*Field located by:* LES *on:* Jul 01, 1966  
*Courthouse location by:* *on:*  
*Location accepted w/o verification by:* *on:*  
*Subdivision name:* *Lot number:*  
*Ft W of EL:* 2900.0 *Ft N of SL:* 3900.0 *Ft E of WL:* *Ft S of NL:*  
*Ground elevation:* 650.0 *Depth to bedrock:* 5.0 *Bedrock elevation:* 645.0 *Aquifer elevation:*  
*UTM Easting:* 540522.0 *UTM Northing:* 4344137.0

<b>Well Log</b>	Top	Bottom	Formation
	0.0	5.0	DIRT
	5.0	95.0	BLUE SH

**Comments** MC 645

**Record of Water Well**

Indiana Department of Natural Resources

**Reference Number** *Driving directions to well* **Date completed**  
**210630** Feb 02, 1962

**Owner-Contractor** **Name** **Address** **Telephone**  
 Owner () -  
 Driller () -  
 Operator () -

**Construction Details**  
**Well** *Use:* HOME *Drilling method:* Cable Tool *Pump type:*  
*Depth:* 160.0 *Pump setting depth:* *Water quality:*  
**Casing** *Length:* 18.5 *Material:* *Diameter:* 6.0  
**Screen** *Length:* *Material:* *Diameter:* Slot size:

**Well Capacity Test** *Type of test:* *Test rate:* gpm for hrs. *BailTest rate:* 1.6 gpm for 2.0 hrs.  
*Drawdown:* ft. *Static water level:* 41.0 ft. *Bailer Drawdown* ft.

**Grouting Information** *Material:* *Depth:* from to  
*Installation Method:* *Number of bags used:*

**Well Abandonment** *Sealing material:* *Depth:* from to  
*Installation Method:* *Number of bags used:*

**Administrative** *County:* Monroe *Township:* 10N *Range:* 1W *Topo map:* Modesto  
*Section:* SE1/4 of the SE1/4 of the SW1/4 of Section 33  
*Grant Number:*  
*Field located by:* CP *on:* Aug 01, 1967  
*Courthouse location by:* *on:*  
*Location accepted w/o verification by:* *on:*  
*Subdivision name:* *Lot number:*  
*Ft W of EL:* *Ft N of SL:* 50.0 *Ft E of WL:* 2400.0 *Ft S of NL:*  
*Ground elevation:* 710.0 *Depth to bedrock:* 6.0 *Bedrock elevation:* 704.0 *Aquifer elevation:*  
*UTM Easting:* 540701.0 *UTM Northing:* 4344615.0

<b>Well Log</b>	Top	Bottom	Formation
	0.0	6.0	DIRT
	6.0	14.0	HARD ROCK
	14.0	17.0	DIRT
	17.0	45.0	HARD ROCK
	45.0	55.0	SH
	55.0	65.0	HARD ROCK
	65.0	160.0	SH

**Comments** MC700; NEIGHBOR VERIFIED

**Record of Water Well**

Indiana Department of Natural Resources

**Reference Number** *Driving directions to well* ; **Date completed**  
**19798** Jun 01, 1991

**Owner-Contractor Name** *Address* *Telephone*  
 Owner () -  
 Company  
 Driller  
 Operator () -

**Construction Details**  
**Well** *Use:* OTHER *Drilling method:* Rotary *Pump type:*  
*Depth:* *Pump setting depth:* *Water quality:*  
**Casing** *Length:* *Material:* *Diameter:*  
**Screen** *Length:* *Material:* *Diameter:* *Slot size:*

**Well Capacity Test** *Type of test:* *Test rate:* gpm for hrs. *BailTest rate:* gpm for hrs.  
*Drawdown:* ft. *Static water level:* ft. *Bailer Drawdown:* ft.

**Grouting Information** *Material:* BENT *Depth:* from 4.0 to 150.0  
*Installation Method:* PUMP *Number of bags used:* 3.0

**Well Abandonment** *Sealing material:* *Depth:* from to  
*Installation Method:* *Number of bags used:*

**Administrative** *County:* Monroe *Township:* 10N *Range:* 1W *Topo map:* Modesto  
*Section:* NE1/4 of the NE1/4 of the NE1/4 of Section 28  
*Grant Number:*  
*Field located by:* JS *on:* Jul 22, 1993  
*Courthouse location by:* *on:*  
*Location accepted w/o verification by:* *on:*  
*Subdivision name:* WINDSOR PRIVATE *Lot number:* 25  
*Ft W of EL:* 600.0 *Ft N of SL:* *Ft E of WL:* *Ft S of NL:* 575.0  
*Ground elevation:* 730.0 *Depth to bedrock:* 12.0 *Bedrock elevation:* 718.0 *Aquifer elevation:*  
*UTM Easting:* 541385.0 *UTM Northing:* 4347625.0

<b>Well Log</b>	Top	Bottom	Formation
	0.0	12.0	CLAY
	12.0	150.0	STONE

**Comments** GEOTHERMAL WELL. ALL SIMILAR, VERIFIED BY ADDRESS

Record of Water Well

Indiana Department of Natural Resources

<b>Reference Number</b>	<b>Driving directions to well</b>		<b>Date completed</b>	
<b>19799</b>			Jul 01, 1991	
<b>Owner-Contractor</b>	<b>Name</b>	<b>Address</b>	<b>Telephone</b>	
Owner			()-	
Company			()-	
Driller				
Operator			()-	
<b>Construction Details</b>				
Well	<b>Use:</b> OTHER	<b>Drilling method:</b> Rotary	<b>Pump type:</b>	
	<b>Depth:</b>	<b>Pump setting depth:</b>	<b>Water quality:</b>	
Casing	<b>Length:</b>	<b>Material:</b>	<b>Diameter:</b>	
Screen	<b>Length:</b>	<b>Material:</b>	<b>Diameter: Slot size:</b>	
<b>Well Capacity Test</b>	<b>Type of test:</b>	<b>Test rate:</b> gpm for hrs.	<b>Bail/Test rate:</b> gpm for hrs.	
	<b>Drawdown:</b> ft.	<b>Static water level:</b> ft.	<b>Bailer Drawdown:</b> ft.	
<b>Grouting Information</b>	<b>Material:</b> BENT		<b>Depth:</b> from 4.0 to 150.0	
	<b>Installation Method:</b> PUMP		<b>Number of bags used:</b> 4.0	
<b>Well Abandonment</b>	<b>Sealing material:</b>		<b>Depth:</b> from to	
	<b>Installation Method:</b>		<b>Number of bags used:</b>	
<b>Administrative</b>	<b>County:</b> Monroe		<b>Township:</b> 10N <b>Range:</b> 1W	
	<b>Section:</b> NW1/4 of the NE1/4 of the NE1/4 of Section 28		<b>Topo map:</b> Modesto	
	<b>Grant Number:</b>			
	<b>Field located by:</b> JS		<b>on:</b> Jul 20, 1993	
	<b>Courthouse location by:</b>		<b>on:</b>	
	<b>Location accepted w/o verification by:</b>		<b>on:</b>	
	<b>Subdivision name:</b> WINDSOR PRIVATE		<b>Lot number:</b> 2	
	<b>Ft W of EL:</b> 790.0	<b>Ft N of SL:</b>	<b>Ft E of WL:</b>	<b>Ft S of NL:</b> 175.0
	<b>Ground elevation:</b> 730.0	<b>Depth to bedrock:</b> 15.0	<b>Bedrock elevation:</b> 715.0	<b>Aquifer elevation:</b>
	<b>UTM Easting:</b> 541325.0		<b>UTM Northing:</b> 4347750.0	
<b>Well Log</b>	<b>Top</b>	<b>Bottom</b>	<b>Formation</b>	
	0.0	15.0	CLAY	
	15.0	150.0	STONE	
<b>Comments</b>	GEOTHERMAL WELLS ALL SIMILAR, VERIFIED BY LOT 1			

Record of Water Well

Indiana Department of Natural Resources

**Reference Number** *Driving directions to well* **Date completed**  
**211760** . Oct 22, 1960

**Owner-Contractor** **Name** **Address** **Telephone**  
 Owner () -  
 Driller () -  
 Operator () -

**Construction Details**  
**Well** *Use:* HOME *Drilling method:* Cable Tool *Pump type:*  
*Depth:* 200.0 *Pump setting depth:* *Water quality:*  
**Casing** *Length:* 19.0 *Material:* *Diameter:* 6.0  
**Screen** *Length:* *Material:* *Diameter:* Slot size:

**Well Capacity Test** *Type of test:* *Test rate:* gpm for hrs. *Bail Test rate:* gpm for 6.67 hrs.  
*Drawdown:* ft. *Static water level:* 140.0 ft. *Bailer Drawdown* ft.

**Grouting Information** *Material:* *Depth:* from to  
*Installation Method:* *Number of bags used:*

**Well Abandonment** *Sealing material:* *Depth:* from to  
*Installation Method:* *Number of bags used:*

**Administrative** *County:* Monroe *Township:* 10N Range: 1W  
*Section:* SW1/4 of the SE1/4of the SE1/4 of Section 21 *Topo map:* Modesto  
*Grant Number:*  
*Field located by:* JMH *on:* Mar 27, 1961  
*Courthouse location by:* *on:*  
*Location accepted w/o verification by:* *on:*  
*Subdivision name:* *Lot number:*  
*Ft W of EL:* 1200.0 *Ft N of SL:* 600.0 *Ft E of WL:* *Ft S of NL:*  
*Ground elevation:* 790.0 *Depth to bedrock:* 17.0 *Bedrock elevation:* 773.0 *Aquifer elevation:*  
*UTM Easting:* 541176.0 *UTM Northing:* 4347973.0

<b>Well Log</b>	Top	Bottom	Formation
	0.0	17.0	DIRT & CLAY
	17.0	36.0	WH LS
	36.0	68.0	BLUE SHALE L WATER
	68.0	167.0	BLUE SHALE
	167.0	170.0	SOFT SHALE & WATER
	170.0	200.0	BLUE SHALE

**Comments** MC 775:

Record of Water Well

Indiana Department of Natural Resources

**Reference Number** *Driving directions to well* **Date completed**  
**211790** Jun 10, 1960

**Owner-Contractor** **Name** **Address** **Telephone**  
 Owner () -  
 Driller () -  
 Operator () -

**Construction Details**  
**Well** *Use:* HOME *Drilling method:* *Pump type:*  
*Depth:* 200.0 *Pump setting depth:* *Water quality:*  
**Casing** *Length:* *Material:* *Diameter:*  
**Screen** *Length:* *Material:* *Diameter:* Slot size:

**Well Capacity Test** *Type of test:* *Test rate:* gpm for hrs. *BailTest rate:* gpm for hrs.  
*Drawdown:* ft. *Static water level:* ft. *Bailer Drawdown:* ft.

**Grouting Information** *Material:* *Depth:* from to  
*Installation Method:* *Number of bags used:*

**Well Abandonment** *Sealing material:* *Depth:* from to  
*Installation Method:* *Number of bags used:*

**Administrative** *County:* Monroe *Township:* 10N Range: 1W *Topo map:* Modesto  
*Section:* SE1/4 of the SE1/4 of the SE1/4 of Section 16  
*Grant Number:*  
*Field located by:* JMH *on:* Mar 27, 1961  
*Courthouse location by:* *on:*  
*Location accepted w/o verification by:* *on:*  
*Subdivision name:* *Lot number:*  
*Ft W of El:* 400.0 *Ft N of SL:* 600.0 *Ft E of WL:* *Ft S of NL:*  
*Ground elevation:* 820.0 *Depth to bedrock:* 12.0 *Bedrock elevation:* 808.0 *Aquifer elevation:*  
*UTM Easting:* 541422.0 *UTM Northing:* 4349600.0

<b>Well Log</b>	Top	Bottom	Formation
	0.0	12.0	CLAY
	12.0	27.0	WH LS
	27.0	154.0	BLUE SHELL
	154.0	200.0	KNOB STONE

**Comments** MC810; NO WATER - DRY



Record of Water Well

Indiana Department of Natural Resources

**Reference Number** *Driving directions to well* **Date completed**  
**211785**

**Owner-Contractor** **Name** **Address** **Telephone**  
 Owner ( ) -  
 Driller ( ) -  
 Operator ( ) -

**Construction Details**  
**Well** *Use:* HOME *Drilling method:* *Pump type:*  
*Depth:* 90.0 *Pump setting depth:* *Water quality:*  
**Casing** *Length:* 20.0 *Material:* *Diameter:* 6.0  
**Screen** *Length:* *Material:* *Diameter: Slot size:*

**Well Capacity Test** *Type of test:* *Test rate:* gpm for hrs. *Ball Test rate:* 10.0 gpm for 2.0 hrs.  
*Drawdown:* ft. *Static water level:* 40.0 ft. *Bailer Drawdown:* ft.

**Grouting Information** *Material:* *Depth:* from to  
*Installation Method:* *Number of bags used:*

**Well Abandonment** *Sealing material:* *Depth:* from to  
*Installation Method:* *Number of bags used:*

**Administrative** *County:* Monroe *Township:* 10N *Range:* 1W *Topo map:* Modesto  
*Section:* NE1/4 of the SW1/4 of the NW1/4 of Section 15  
*Grant Number:*  
*Field located by:* JMH *on:* Mar 27, 1961  
*Courthouse location by:* JMH *on:* Mar 28, 1961  
*Location accepted w/o verification by:* *on:*  
*Subdivision name:* *Lot number:*  
*Fl W of EL:* *Fl N of SL:* *Fl E of WL:* 800.0 *Fl S of NL:* 1500.0  
*Ground elevation:* 820.0 *Depth to bedrock:* 16.0 *Bedrock elevation:* 804.0 *Aquifer elevation:*  
*UTM Easting:* 541784.0 *UTM Northing:* 4350581.0

Well Log	Top	Bottom	Formation
	0.0	16.0	DIRT
	16.0	74.0	SHALE
	74.0	90.0	BLUE SHALE

**Comments** MC 805:

Record of Water Well

Indiana Department of Natural Resources

<b>Reference Number</b>	<b>Driving directions to well</b>		<b>Date completed</b>
<b>209608</b>			Oct 08, 1965
<b>Owner-Contractor</b>	<b>Name</b>	<b>Address</b>	<b>Telephone</b>
Owner			() -
Driller			() -
Operator			() -
<b>Construction Details</b>			
Well	<b>Use:</b> HOME	<b>Drilling method:</b> Rotary	<b>Pump type:</b>
	<b>Depth:</b> 212.0	<b>Pump setting depth:</b>	<b>Water quality:</b>
Casing	<b>Length:</b> 47.0	<b>Material:</b>	<b>Diameter:</b> 6.5
Screen	<b>Length:</b>	<b>Material:</b>	<b>Diameter: Slot size:</b>
<b>Well Capacity Test</b>	<b>Type of test:</b>	<b>Test rate:</b> gpm for hrs.	<b>BailTest rate:</b> 2.0 gpm for hrs.
	<b>Drawdown:</b> ft.	<b>Static water level:</b> 70.0 ft.	<b>Bailer Drawdown</b> 125.0 ft.
<b>Grouting Information</b>	<b>Material:</b>	<b>Depth:</b> from to	
	<b>Installation Method:</b>	<b>Number of bags used:</b>	
<b>Well Abandonment</b>	<b>Sealing material:</b>	<b>Depth:</b> from to	
	<b>Installation Method:</b>	<b>Number of bags used:</b>	
<b>Administrative</b>	<b>County:</b> Morgan	<b>Township:</b> 11N Range: 1W	
	<b>Section:</b> SW 1/4 of the SE 1/4 of the NE 1/4 of Section 34		<b>Topo map:</b> Modesto
	<b>Grant Number:</b>		
	<b>Field located by:</b> WG	<b>on:</b> Jun 15, 1976	
	<b>Courthouse location by:</b>	<b>on:</b>	
	<b>Location accepted w/o verification by:</b>	<b>on:</b>	
	<b>Subdivision name:</b>	<b>Lot number:</b>	
	<b>Ft W of EL:</b> 950.0	<b>Ft N of SL:</b>	<b>Ft E of WL:</b>
	<b>Ground elevation:</b> 722.0	<b>Depth to bedrock:</b> 40.0	<b>Bedrock elevation:</b> 682.0
	<b>UTM Easting:</b> 542505.0		<b>Aquifer elevation:</b>
			<b>UTM Northing:</b> 4355121.0
<b>Well Log</b>	<b>Top</b>	<b>Bottom</b>	<b>Formation</b>
	0.0	40.0	CLAY YELLOW
	40.0	212.0	SHALE BLUE
<b>Comments</b>	MC 680; TALKED TO OWNER; WELL 75 FT NE OF NORTH END OF HOME; RED BRICK HOUSE ON WEST SIDE OF RD WITH BLACK & WHITE TRIM		

Record of Water Well

Indiana Department of Natural Resources

<b>Reference Number</b>	<b>Driving directions to well</b>		<b>Date completed</b>
<b>209583</b>			May 10, 1963
<b>Owner-Contractor</b>	<b>Name</b>	<b>Address</b>	<b>Telephone</b>
Owner			() -
Driller			() -
Operator			() -
<b>Construction Details</b>			
Well	<i>Use:</i> HOME	<i>Drilling method:</i> Cable Tool	<i>Pump type:</i>
	<i>Depth:</i> 82.0	<i>Pump setting depth:</i>	<i>Water quality:</i>
Casing	<i>Length:</i> 28.0	<i>Material:</i>	<i>Diameter:</i> 5.625
Screen	<i>Length:</i>	<i>Material:</i>	<i>Diameter:</i> Slot size:
<b>Well Capacity Test</b>	<i>Type of test:</i>	<i>Test rate:</i> gpm for hrs.	<i>Bail Test rate:</i> 0.5 gpm for 3.0 hrs.
	<i>Drawdown:</i> ft.	<i>Static water level:</i> 28.0 ft.	<i>Bailer Drawdown:</i> ft.
<b>Grouting Information</b>	<i>Material:</i>	<i>Depth:</i> from to	
	<i>Installation Method:</i>	<i>Number of bags used:</i>	
<b>Well Abandonment</b>	<i>Sealing material:</i>	<i>Depth:</i> from to	
	<i>Installation Method:</i>	<i>Number of bags used:</i>	
<b>Administrative</b>	<i>County:</i> Morgan	<i>Township:</i> 11N Range: 1W	
	<i>Section:</i> NW1/4 of the SW1/4 of the NW1/4 of Section 35		<i>Topo map:</i> Modesto
	<i>Grant Number:</i>		
	<i>Field located by:</i> U	<i>on:</i> Apr 01, 1964	
	<i>Courthouse location by:</i>	<i>on:</i>	
	<i>Location accepted w/o verification by:</i>	<i>on:</i>	
	<i>Subdivision name:</i>	<i>Lot number:</i>	
	<i>Ft W of EL:</i>	<i>Ft N of SL:</i>	<i>Ft E of WL:</i> 700.0
	<i>Ground elevation:</i> 701.0	<i>Depth to bedrock:</i> 26.0	<i>Bedrock elevation:</i> 675.0
	<i>UTM Easting:</i> 543072.0		<i>Aquifer elevation:</i>
			<i>UTM Northing:</i> 4355305.0
<b>Well Log</b>	<b>Top</b>	<b>Bottom</b>	<b>Formation</b>
	0.0	26.0	SOIL & BR CLAY
	26.0	35.0	BR SHALE
	35.0	82.0	BLUE SHALE
<b>Comments</b>	FC ONLY; MAILBOX; WATER @ 75, APPROX. 30 GAL/HR		

**Record of Water Well**

Indiana Department of Natural Resources

**Reference Number** *Driving directions to well* *Date completed*  
**209584** Sep 06, 1962

**Owner-Contractor** *Name* *Address* *Telephone*  
 Owner () -  
 Driller () -  
 Operator () -

**Construction Details**  
 Well *Use:* HOME *Drilling method:* Cable Tool *Pump type:*  
*Depth:* 100.0 *Pump setting depth:* *Water quality:*  
 Casing *Length:* 57.0 *Material:* *Diameter:* 6.0  
 Screen *Length:* *Material:* *Diameter:* Slot size:

**Well Capacity Test** *Type of test:* *Test rate:* gpm for hrs. *Bail Test rate:* 5.0 gpm for 2.0 hrs.  
*Drawdown:* ft. *Static water level:* 58.0 ft. *Bailer Drawdown:* ft.

**Grouting Information** *Material:* *Depth:* from to  
*Installation Method:* *Number of bags used:*

**Well Abandonment** *Sealing material:* *Depth:* from to  
*Installation Method:* *Number of bags used:*

**Administrative** *County:* Morgan *Township:* 11N *Range:* 1W *Topo map:* Hindustan  
*Section:* NE1/4 of the SW1/4 of the SW1/4 of Section 26  
*Grant Number:*  
*Field located by:* WG *on:* Jun 18, 1976  
*Courthouse location by:* *on:*  
*Location accepted w/o verification by:* *on:*  
*Subdivision name:* *Lot number:*  
*Ft W of EL:* *Ft N of SL:* *Ft E of WL:* *Ft S of NL:*  
*Ground elevation:* 781.0 *Depth to bedrock:* 53.0 *Bedrock elevation:* 728.0 *Aquifer elevation:*  
*UTM Easting:* 543293.0 *UTM Northing:* 4356190.0

**Well Log**

Top	Bottom	Formation
0.0	39.0	YELLOW CLAY
39.0	53.0	BLUE CLAY
53.0	100.0	SHALE & WATER

**Comments** MC 730; MC; DAUGHTER VERIFIED; WELL LOCATED UNDER CONCRETE SLAB - 10 FT EAST OF HOME

**Record of Water Well**

Indiana Department of Natural Resources

**Reference Number** *Driving directions to well* **Date completed**  
**209574**

**Owner-Contractor** **Name** **Address** **Telephone**  
 Owner () -  
 Driller () -

**Construction Details**  
**Well** *Use:* HOME *Drilling method:* Cable Tool *Pump type:*  
*Depth:* 77.0 *Pump setting depth:* *Water quality:*  
**Casing** *Length:* 53.9 *Material:* *Diameter:* 5.625  
**Screen** *Length:* *Material:* *Diameter:* Slot size:

**Well Capacity Test** *Type of test:* *Test rate:* gpm for hrs. *BailTest rate:* gpm for hrs.  
*Drawdown:* ft. *Static water level:* 45.0 ft. *Bailer Drawdown:* ft.

**Grouting Information** *Material:* *Depth:* from to  
*Installation Method:* *Number of bags used:*

**Well Abandonment** *Sealing material:* *Depth:* from to  
*Installation Method:* *Number of bags used:*

**Administrative** *County:* Morgan *Township:* 11N *Range:* 1W *Topo map:* Hindustan  
*Section:* NE1/4 of the NW 1/4 of the SE 1/4 of Section 26  
*Grant Number:*  
*Field located by:* U *on:* Apr 01, 1964  
*Courthouse location by:* *on:*  
*Location accepted w/o verification by:* *on:*  
*Subdivision name:* *Lot number:*  
*Fl W of EL:* 1300.0 *Fl N of SL:* *Fl E of WL:* *Fl S of NL:* 2600.0  
*Ground elevation:* 615.0 *Depth to bedrock:* 50.0 *Bedrock elevation:* 565.0 *Aquifer elevation:*  
*UTM Easting:* 544053.0 *UTM Northing:* 4356646.0

**Well Log**

Top	Bottom	Formation
0.0	40.0	CLAY
40.0	45.0	MUD, GRAV, QCKSD, GRAV, SH, GRAV
45.0	50.0	WATERBEARING
50.0	77.0	SHALE

**Comments**

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Record of Water Well

Indiana Department of Natural Resources

<b>Reference Number</b>	<b>Driving directions to well</b>		<b>Date completed</b>	
<b>209604</b>			Aug 21, 1977	
<b>Owner-Contractor</b>	<b>Name</b>	<b>Address</b>	<b>Telephone</b>	
Owner			()-	
Driller			()-	
<b>Construction Details</b>				
Well	<b>Use:</b> HOME	<b>Drilling method:</b> Cable Tool	<b>Pump type:</b>	
	<b>Depth:</b> 75.0	<b>Pump setting depth:</b>	<b>Water quality:</b>	
Casing	<b>Length:</b> 27.0	<b>Material:</b>	<b>Diameter:</b> 4.0	
Screen	<b>Length:</b>	<b>Material:</b>	<b>Diameter: Slot size:</b>	
<b>Well Capacity Test</b>	<b>Type of test:</b>	<b>Test rate:</b> gpm for hrs.	<b>BailTest rate:</b> 12.0 gpm for 2.0 hrs.	
	<b>Drawdown:</b> ft.	<b>Static water level:</b> ft.	<b>Bailer Drawdown</b> 75.0 ft.	
<b>Grouting Information</b>	<b>Material:</b>	<b>Depth:</b> from to		
	<b>Installation Method:</b>	<b>Number of bags used:</b>		
<b>Well Abandonment</b>	<b>Sealing material:</b>	<b>Depth:</b> from to		
	<b>Installation Method:</b>	<b>Number of bags used:</b>		
<b>Administrative</b>	<b>County:</b> Morgan	<b>Township:</b> 11N Range: 1W		
	<b>Section:</b> NW1/4 of the NE1/4 of the NE1/4 of Section 26			<b>Topo map:</b> Hindustan
	<b>Grant Number:</b>			
	<b>Field located by:</b> ECM	<b>on:</b> Jun 05, 1987		
	<b>Courthouse location by:</b>	<b>on:</b>		
	<b>Location accepted w/o verification by:</b>	<b>on:</b>		
	<b>Subdivision name:</b>	<b>Lot number:</b>		
	<b>Ft W of EL:</b> 1100.0	<b>Ft N of SL:</b>	<b>Ft E of WL:</b>	<b>Ft S of NL:</b> 600.0
	<b>Ground elevation:</b> 620.0	<b>Depth to bedrock:</b> 27.0	<b>Bedrock elevation:</b> 593.0	<b>Aquifer elevation:</b>
	<b>UTM Easting:</b> 544171.0		<b>UTM Northing:</b> 4357305.0	
<b>Well Log</b>	<b>Top</b>	<b>Bottom</b>	<b>Formation</b>	
	0.0	0.5	TOP SOIL	
	0.5	9.0	BROWN HARDPAN	
	9.0	12.0	BROWN GRAVE HARDPAN	
	12.0	27.0	GREY HARDPAN	
	27.0	75.0	BLUE SHALE	
<b>Comments</b>	MC 593; NEIGHBOR VERIFICATION; WELL NOW LOCATED ON NEW CHURCH PROPERTY.			

**Record of Water Well**

Indiana Department of Natural Resources

**Reference Number** *Driving directions to well* **Date completed**  
**209649** Sep 26, 1979

**Owner-Contractor** *Name* *Address* *Telephone*  
 Owner () -  
 Company () -  
 Driller () -  
 Operator () -

**Construction Details**  
 Well *Use:* HOME *Drilling method:* Cable Tool *Pump type:*  
*Depth:* 80.0 *Pump setting depth:* *Water quality:*  
 Casing *Length:* 50.0 *Material:* *Diameter:* 4.0  
 Screen *Length:* *Material:* *Diameter:* Slot size:

**Well Capacity Test** *Type of test:* *Test rate:* gpm for hrs. *BailTest rate:* 15.0 gpm for 2.0 hrs.  
*Drawdown:* ft. *Static water level:* ft. *Bailer Drawdown:* 5.0 ft.

**Grouting Information** *Material:* *Depth:* from to  
*Installation Method:* *Number of bags used:*

**Well Abandonment** *Sealing material:* *Depth:* from to  
*Installation Method:* *Number of bags used:*

**Administrative** *County:* Morgan *Township:* 11N *Range:* 1W *Topo map:* Hindustan  
*Section:* SW 1/4 of the SE1/4 of the SE1/4 of Section 23  
*Grant Number:*  
*Field located by:* PES *on:* Jun 18, 1980  
*Courthouse location by:* *on:*  
*Location accepted w/o verification by:* *on:*  
*Subdivision name:* *Lot number:*  
*Ft W of EL:* 950.0 *Ft N of SL:* 200.0 *Ft E of WL:* *Ft S of NL:*  
*Ground elevation:* 615.0 *Depth to bedrock:* 50.0 *Bedrock elevation:* 565.0 *Aquifer elevation:*  
*UTM Easting:* 544212.0 *UTM Northing:* 4357518.0

<b>Well Log</b>	Top	Bottom	Formation
	0.0	0.6	TOP SOIL
	0.6	10.0	BROWN HARDPAN
	10.0	50.0	BLUEISH GREY MUD
	50.0	80.0	GREY SHALE

**Comments** MC 565; VERIFIED BY NEIGHBOR; MC

Record of Water Well

Indiana Department of Natural Resources

**Reference Number** *Driving directions to well* **Date completed**  
**209619**

**Owner-Contractor Name Address Telephone**  
 Driller ( ) -  
 Operator ( ) -

**Construction Details**  
 Well *Use:* OTHER *Drilling method:* Cable Tool *Pump type:*  
*Depth:* 24.0 *Pump setting depth:* *Water quality:*  
 Casing *Length:* 21.0 *Material:* *Diameter:* 2.0  
 Screen *Length:* 3.0 *Material:* *Diameter:* 1.25 Slot size:

**Well Capacity Test** *Type of test:* *Test rate:* gpm for hrs. *BailTest rate:* gpm for hrs.  
*Drawdown:* ft. *Static water level:* 6.01 ft. *Bailer Drawdown:* ft.

**Grouting Information** *Material:* *Depth:* from to  
*Installation Method:* *Number of bags used:*

**Well Abandonment** *Sealing material:* *Depth:* from to  
*Installation Method:* *Number of bags used:*

**Administrative** *County:* Morgan *Township:* 11N Range: 1W *Topo map:* Hindustan  
*Section:* NE1/4 of the NW1/4 of the SW1/4 of Section 24  
*Grant Number:*  
*Field located by:* USGS *on:*  
*Courthouse location by:* *on:*  
*Location accepted w/o verification by:* *on:*  
*Subdivision name:* *Lot number:*  
*Ft W of EL:* *Ft N of SL:* *Ft E of WL:* 2550.0 *Ft S of NL:* 1000.0  
*Ground elevation:* 587.48 *Depth to bedrock:* 88.0 *Bedrock elevation:* 500.0 *Aquifer elevation:*  
*UTM Easting:* 544806.0 *UTM Northing:* 4358223.0

<b>Well Log</b>	Top	Bottom	Formation
	0.0	3.0	ROAD FILL BRN CLAY S&G
	3.0	8.0	BRM C;AU & SILT W/ TRACE SAND
	8.0	10.0	BRN GRAY SAND & CLAY MOIST
	10.0	15.0	SAND & GRAVEL WET W/ CLAY
	15.0	70.0	GREY WET SAND W/ TR CLAY
	70.0	88.0	MED GRAVEL & SAND
	88.0		BEDROCK

**Comments** MC 500; MC; CHEM TEST



**Record of Water Well**

Indiana Department of Natural Resources

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<b>Reference Number</b>	<b>Driving directions to well</b>		<b>Date completed</b>
<b>209629</b>			Jan 20, 1965

<b>Owner-Contractor</b>	<b>Name</b>	<b>Address</b>	<b>Telephone</b>
Owner	:		() -
Driller			() -

<b>Construction Details</b>	<b>Use:</b>	<b>Drilling method:</b> Cable Tool	<b>Pump type:</b>
Well	<b>Depth:</b> 52.0	<b>Pump setting depth:</b>	<b>Water quality:</b>
Casing	<b>Length:</b> 28.0	<b>Material:</b>	<b>Diameter:</b> 6.0
Screen	<b>Length:</b>	<b>Material:</b>	<b>Diameter:</b> Slot size:

<b>Well Capacity Test</b>	<b>Type of test:</b>	<b>Test rate:</b> gpm for hrs.	<b>Bail Test rate:</b> 30.0 gpm for 0.5 hrs.
	<b>Drawdown:</b> ft.	<b>Static water level:</b> ft.	<b>Bailer Drawdown:</b> ft.

<b>Grouting Information</b>	<b>Material:</b>	<b>Depth:</b> from to
	<b>Installation Method:</b>	<b>Number of bags used:</b>

<b>Well Abandonment</b>	<b>Sealing material:</b>	<b>Depth:</b> from to
	<b>Installation Method:</b>	<b>Number of bags used:</b>

<b>Administrative</b>	<b>County:</b> Morgan	<b>Township:</b> 11N Range: 1W	<b>Topo map:</b> Hindustan
	<b>Section:</b> SE1/4 of the SE1/4 of the NW1/4 of Section 24		
	<b>Grant Number:</b>		
	<b>Field located by:</b> CD	<b>on:</b>	
	<b>Courthouse location by:</b>	<b>on:</b>	
	<b>Location accepted w/o verification by:</b>	<b>on:</b>	
	<b>Subdivision name:</b>	<b>Lot number:</b>	
	<b>Ft W of EL:</b>	<b>Ft N of SL:</b> 2650.0	<b>Ft E of WL:</b> 2150.0
	<b>Ground elevation:</b> 600.0	<b>Depth to bedrock:</b> 28.0	<b>Bedrock elevation:</b> 572.0
	<b>UTM Easting:</b> 545159.0		<b>Ft S of NL:</b>
			<b>Aquifer elevation:</b>
			<b>UTM Northing:</b> 4358267.0

<b>Well Log</b>	<b>Top</b>	<b>Bottom</b>	<b>Formation</b>
	0.0	28.0	SOIL & CLAY
	28.0	52.0	BORDEN SHALE

<b>Comments</b>	MC 572; OWNER VERIFIED; MC
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Record of Water Well

Indiana Department of Natural Resources

**Reference Number** **Driving directions to well** **Date completed**  
**269754** **I** **Jul 05, 1975**

**Owner-Contractor** **Name** **Address** **Telephone**  
 Owner () -  
 Driller () -  
 Operator () -

**Construction Details**  
**Well** **Use:** HOME **Drilling method:** Cable Tool **Pump type:**  
**Depth:** 50.0 **Pump setting depth:** **Water quality:**  
**Casing** **Length:** 31.0 **Material:** **Diameter:** 4.0  
**Screen** **Length:** **Material:** **Diameter:** Slot size:

**Well Capacity Test** **Type of test:** **Test rate:** gpm for hrs. **BailTest rate:** 18.0 gpm for 2.0 hrs.  
**Drawdown:** ft. **Static water level:** 8.0 ft. **Bailer Drawdown** 20.0 ft.

**Grouting Information** **Material:** **Depth:** from to  
**Installation Method:** **Number of bags used:**

**Well Abandonment** **Sealing material:** **Depth:** from to  
**Installation Method:** **Number of bags used:**

**Administrative** **County:** Morgan **Township:** 11N **Range:** 1W **Topo map:** Martinsville  
**Section:** SE1/4 of the SW1/4 of the SE1/4 of Section 13  
**Grant Number:**  
**Field located by:** WDH **on:** Jun 25, 1976  
**Courthouse location by:** **on:**  
**Location accepted w/o verification by:** **on:**  
**Subdivision name:** **Lot number:**  
**Ft W of EL:** 1650.0 **Ft N of SL:** 150.0 **Ft E of WL:** **Ft S of NL:**  
**Ground elevation:** 600.0 **Depth to bedrock:** 30.0 **Bedrock elevation:** 570.0 **Aquifer elevation:**  
**UTM Easting:** 545588.0 **UTM Northing:** 4359123.0

<b>Well Log</b>	<b>Top</b>	<b>Bottom</b>	<b>Formation</b>
	0.0	10.0	BR CLAY & GRAV
	10.0	30.0	RED SHALE (WATER)
	30.0	50.0	SHALE (WATER)

**Comments** MC 570: O.V. 30' S. OF RED BARN

Record of Water Well

Indiana Department of Natural Resources

<b>Reference Number</b>	<b>Driving directions to well</b>		<b>Date completed</b>
<b>269759</b>			Jun 10, 1966
<b>Owner-Contractor</b>	<b>Name</b>	<b>Address</b>	<b>Telephone</b>
Owner			() -
Driller			() -
Operator			() -
<b>Construction Details</b>			
Well	<b>Use:</b> HOME	<b>Drilling method:</b> Cable Tool	<b>Pump type:</b>
	<b>Depth:</b> 68.0	<b>Pump setting depth:</b>	<b>Water quality:</b>
Casing	<b>Length:</b> 65.0	<b>Material:</b>	<b>Diameter:</b> 4.0
Screen	<b>Length:</b> 4.0	<b>Material:</b>	<b>Diameter:</b> 3.5 <b>Slot size:</b> 6
<b>Well Capacity Test</b>	<b>Type of test:</b>	<b>Test rate:</b> gpm for hrs.	<b>Bail Test rate:</b> 10.0 gpm for hrs.
	<b>Drawdown:</b> ft.	<b>Static water level:</b> 19.0 ft.	<b>Bailer Drawdown:</b> 0.0 ft.
<b>Grouting Information</b>	<b>Material:</b>	<b>Depth:</b> from to	
	<b>Installation Method:</b>	<b>Number of bags used:</b>	
<b>Well Abandonment</b>	<b>Sealing material:</b>	<b>Depth:</b> from to	
	<b>Installation Method:</b>	<b>Number of bags used:</b>	
<b>Administrative</b>	<b>County:</b> Morgan	<b>Township:</b> 11N <b>Range:</b> 1W	
	<b>Section:</b> NE1/4 of the NE1/4 of the SE1/4 of Section 13	<b>Topo map:</b> Hindustan	
	<b>Grant Number:</b>		
	<b>Field located by:</b> CD	<b>on:</b> Aug 01, 1967	
	<b>Courthouse location by:</b>	<b>on:</b>	
	<b>Location accepted w/o verification by:</b>	<b>on:</b>	
	<b>Subdivision name:</b>	<b>Lot number:</b>	
	<b>Ft W of EL:</b> 150.0	<b>Ft N of SL:</b> 2500.0	<b>Ft E of WL:</b> <b>Ft S of NL:</b>
	<b>Ground elevation:</b> 600.0	<b>Depth to bedrock:</b>	<b>Bedrock elevation:</b> <b>Aquifer elevation:</b> 532.0
	<b>UTM Easting:</b> 546025.0		<b>UTM Northing:</b> 4359838.0
<b>Well Log</b>	<b>Top</b>	<b>Bottom</b>	<b>Formation</b>
	0.0	2.0	TOPSOIL
	2.0	19.0	DRY SAND
	19.0	54.0	FINE SAND
	54.0	61.0	YEL SAND & GRAV
	61.0	62.0	BR CLAY
	62.0	68.0	S&G
<b>Comments</b>	MC 530		

Record of Water Well

Indiana Department of Natural Resources

**Reference Number** *Driving directions to well* **Date completed**  
**207374** Sep 19, 1971

**Owner-Contractor** *Name* *Address* *Telephone*  
 Owner 0 -  
 Driller 0 -  
 Operator 0 -

**Construction Details**  
 Well *Use:* HOME *Drilling method:* Cable Tool *Pump type:*  
*Depth:* 41.0 *Pump setting depth:* *Water quality:*  
 Casing *Length:* 39.0 *Material:* *Diameter:* 4.0  
 Screen *Length:* 3.0 *Material:* *Diameter:* 3.0 *Slot size:* 6

**Well Capacity Test** *Type of test:* *Test rate:* gpm for hrs. *Bail/est rate:* 15.0 gpm for 1.0 hrs.  
*Drawdown:* ft. *Static water level:* 10.0 ft. *Bailer Drawdown:* 5.0 ft.

**Grouting Information** *Material:* *Depth:* from to  
*Installation Method:* *Number of bags used:*

**Well Abandonment** *Sealing material:* *Depth:* from to  
*Installation Method:* *Number of bags used:*

**Administrative** *County:* Morgan *Township:* 11N *Range:* 1E  
*Section:* NW1/4 of the SW1/4 of the NW1/4 of Section 18 *Topo map:* Martinsville  
*Grant Number:*  
*Field located by:* TMB *on:* Aug 28, 1973  
*Courthouse location by:* *on:*  
*Location accepted w/o verification by:* *on:*  
*Subdivision name:* *Lot number:*  
*Ft W of EL:* *Ft N of SL:* *Ft E of WL:* 500.0 *Ft S of NL:* 1850.0  
*Ground elevation:* 600.0 *Depth to bedrock:* *Bedrock elevation:* *Aquifer elevation:* 559.0  
*UTM Easting:* 546248.0 *UTM Northing:* 4360205.0

<b>Well Log</b>	Top	Bottom	Formation
	0.0	1.5	TOP SOIL
	1.5	8.0	BROWN HARDPAN
	8.0	20.0	BROWN GRAVEL HARDPAN
	20.0	39.0	BLUE GRAVEL HARDPAN
	39.0	41.0	GREY GRAVEL

**Comments** MC560; OWNER VERIFIED LOCATION;

Record of Water Well

Indiana Department of Natural Resources

<b>Reference Number</b>	<b>Driving directions to well</b>		<b>Date completed</b>
<b>213733</b>			06-03-1964
<b>Owner-Contractor</b>	<b>Name</b>	<b>Address</b>	<b>Telephone</b>
Owner Driller Operator			
<b>Construction Details</b>			
Well	<b>Use:</b> HOME	<b>Drilling method:</b> Cable Tool	<b>Pump type:</b>
	<b>Depth:</b> 150.0	<b>Pump setting depth:</b>	<b>Water quality:</b>
Casing	<b>Length:</b> 27.0	<b>Material:</b>	<b>Diameter:</b> 6.0
Screen	<b>Length:</b>	<b>Material:</b>	<b>Diameter: Slot size:</b>
<b>Well Capacity Test</b>	<b>Type of test:</b>	<b>Test rate:</b> gpm for hrs.	<b>Bail Test rate:</b> 5.0 gpm for 1.0 hrs.
	<b>Drawdown:</b> ft.	<b>Static water level:</b> 70.0 ft.	<b>Baller Drawdown:</b> 0.0 ft.
<b>Grouting Information</b>	<b>Material:</b>	<b>Depth:</b> from to	
	<b>Installation Method:</b>	<b>Number of bags used:</b>	
<b>Well Abandonment</b>	<b>Sealing material:</b>	<b>Depth:</b> from to	
	<b>Installation Method:</b>	<b>Number of bags used:</b>	
<b>Administrative</b>	<b>County:</b> Monroe	<b>Township:</b> 8N Range: 1W	
	<b>Section:</b> SE of the SW of the NW of Section 19		<b>Topo map:</b> Clear Creek
	<b>Grant Number:</b>		
	<b>Field located by:</b> MT	<b>on:</b> Jul 12, 1967	
	<b>Courthouse location by:</b>	<b>on:</b>	
	<b>Location accepted w/o verification by:</b>	<b>on:</b>	
	<b>Subdivision name:</b>	<b>Lot number:</b>	
	<b>Ft W of EL:</b>	<b>Ft N of SL:</b>	<b>Ft E of WL:</b> 1300.0 <b>Ft S of NL:</b> 2500.0
	<b>Ground elevation:</b> 780.0	<b>Depth to bedrock:</b> 23.0	<b>Bedrock elevation:</b> 757.0 <b>Aquifer elevation:</b>
	<b>UTM Easting:</b> 537282.0		<b>UTM Northing:</b> 4329425.0
<b>Well Log</b>	<b>Top</b>	<b>Bottom</b>	<b>Formation</b>
	0.0	12.0	YELLOW CLAY
	12.0	23.0	RED CLAY
	23.0	38.0	STONE GRAY LIMESTONE HARD
	38.0	40.0	STONE BLUE SHALE SOFT
	40.0	44.0	STONE DARK GRAY LS HARD
	44.0	50.0	STONE GRAY LS HARD
	50.0	71.0	STONE GRAY LS EXTRA HARD
	71.0	98.0	STONE BUFF LS SOFT
	98.0	117.0	STONE GRAY LS HARD
	117.0	126.0	STONE WHITE OR GRAY LS HARD
	126.0	150.0	STONE GRAY LS HARD
<b>Comments</b>	OWNER VERIFIED		

Record of Water Well

Indiana Department of Natural Resources

**Reference Number** *Drilling directions to well* **Date completed**  
**213683** Apr 21, 1962

**Owner-Contractor** **Name** **Address** **Telephone**  
 Owner  
 Driller  
 Operator

**Construction Details**  
**Well** *Use:* HOME *Drilling method:* Cable Tool *Pump type:*  
*Depth:* 130.0 *Pump setting depth:* *Water quality:*  
**Casing** *Length:* 7.0 *Material:* *Diameter:*  
**Screen** *Length:* *Material:* *Diameter:* Slot size:

**Well Capacity Test** *Type of test:* *Test rate:* gpm for hrs. *Bail/*Test rate: 1.0 gpm for hrs.  
*Drawdown:* ft. *Static water level:* 54.0 ft. *Bailer Drawdown* 70.0 ft.

**Grouting Information** *Material:* *Depth:* from to  
*Installation Method:* *Number of bags used:*

**Well Abandonment** *Sealing material:* *Depth:* from to  
*Installation Method:* *Number of bags used:*

**Administrative** *County:* Monroe *Township:* 8N *Range:* 1W  
*Section:* NE of the NE of the NW of Section 19 *Topo map:* Clear Creek  
*Grant Number:*  
*Field located by:* U-S *on:* Jul 01, 1963  
*Courthouse location by:* *on:*  
*Location accepted w/o verification by:* *on:*  
*Subdivision name:* *Lot number:*  
*Ft W of EL:* *Ft N of SL:* *Ft E of WL:* 2200.0 *Ft S of NL:* 100.0  
*Ground elevation:* 775.0 *Depth to bedrock:* 7.0 *Bedrock elevation:* 768.0 *Aquifer elevation:*  
*UTM Easting:* 537559.0 *UTM Northing:* 4330161.0

**Well Log**

Top	Bottom	Formation
0.0	7.0	CLAY
7.0	100.0	WHITE LIME
100.0	130.0	BLUE LIME

**Comments**

## Record of Water Well

Indiana Department of Natural Resources

<b>Reference Number</b> <b>213688</b>	<b>Driving directions to well</b>	<b>Date completed</b> Oct 22, 1987	
<b>Owner-Contractor Name</b> Owner Driller	<b>Address</b>	<b>Telephone</b>	
<b>Construction Details</b>	<b>Use:</b> HOME <b>Depth:</b> 145.0 <b>Length:</b> 21.0 <b>Length:</b>	<b>Drilling method:</b> Rotary <b>Pump setting depth:</b> <b>Material:</b> <b>Material:</b>	
Well Casing Screen		<b>Pump type:</b> <b>Water quality:</b> CLEAR <b>Diameter:</b> 6.63 <b>Diameter: Slot size:</b>	
<b>Well Capacity Test</b>	<b>Type of test:</b> <b>Drawdown:</b> 145.0 ft.	<b>Test rate:</b> 3.0 gpm for 2.0 hrs. <b>Static water level:</b> 38.0 ft. <b>Ball Test rate:</b> gpm for hrs. <b>Baller Drawdown:</b> ft.	
<b>Grouting Information</b>	<b>Material:</b> <b>Installation Method:</b>	<b>Depth:</b> from to <b>Number of bags used:</b>	
<b>Well Abandonment</b>	<b>Sealing material:</b> <b>Installation Method:</b>	<b>Depth:</b> from to <b>Number of bags used:</b>	
<b>Administrative</b>	<b>County:</b> Monroe <b>Section:</b> NE of the NE of the NW of Section 19 <b>Grant Number:</b> <b>Field located by:</b> JLL <b>Courthouse location by:</b> <b>Location accepted w/o verification by:</b> <b>Subdivision name:</b> <b>Ft W of EL:</b> <b>Ground elevation:</b> 770.0 <b>UTM Easting:</b> 537650.0	<b>Township:</b> 8N <b>Range:</b> 1W <b>Topo map:</b> Clear Creek <b>on:</b> Nov 10, 1988 <b>on:</b> <b>on:</b> <b>Lot number:</b> <b>Ft E of WL:</b> 2550.0 <b>Bedrock elevation:</b> 761.0 <b>UTM Northing:</b> 4330050.0 <b>Ft S of NL:</b> 450.0 <b>Aquifer elevation:</b>	
<b>Well Log</b>	<b>Top</b>	<b>Bottom</b>	<b>Formation</b>
	0.0	5.0	YEL CLAY
	5.0	9.0	RED CLAY
	9.0	13.0	GRAY LS HARD
	13.0	15.0	YEL SH SOFT
	15.0	30.0	GRAY LS H.
	30.0	36.0	BLUE LS H.
	36.0	52.0	GRAY LS H.
	52.0	76.0	BUFF LS H.
	76.0	84.0	BLUE LS H.
	84.0	106.0	GRAY LS H.
	106.0	120.0	WHITE LS H.
	120.0	132.0	GRAY LS H.
	132.0	145.0	DARK GRAY LS H.
<b>Comments</b>	MAILBOX VERIFIED WELL OFF SW CORNER OF HOUSE VISABLE FROM RD., WELL 1550' NE OF HWY 37 ON N. SIDE ROCKPORT RD.		

## Record of Water Well

Indiana Department of Natural Resources

<b>Reference Number</b> <b>213658</b>	<b>Driving directions to well</b>		<b>Date completed</b> Sep 18, 1972	
<b>Owner-Contractor</b> Owner Driller Operator	<b>Name</b>	<b>Address</b>	<b>Telephone</b>	
<b>Construction Details</b>	<b>Use:</b> HOME		<b>Drilling method:</b> Cable Tool	
Well	<b>Depth:</b> 140.0		<b>Pump setting depth:</b>	
Casing	<b>Length:</b> 12.0		<b>Material:</b>	
Screen	<b>Length:</b>		<b>Material:</b>	
			<b>Pump type:</b>	
			<b>Water quality:</b>	
			<b>Diameter:</b> 5.63	
			<b>Diameter Slot size:</b>	
<b>Well Capacity Test</b>	<b>Type of test:</b>	<b>Test rate:</b> gpm for hrs.		<b>Ball Test rate:</b> 3.5 gpm for hrs.
	<b>Drawdown:</b> ft.	<b>Static water level:</b> 51.0 ft.		<b>Bailer Drawdown:</b> ft.
<b>Grouting Information</b>	<b>Material:</b>		<b>Depth:</b> from to	
	<b>Installation Method:</b>		<b>Number of bags used:</b>	
<b>Well Abandonment</b>	<b>Sealing material:</b>		<b>Depth:</b> from to	
	<b>Installation Method:</b>		<b>Number of bags used:</b>	
<b>Administrative</b>	<b>County:</b> Monroe		<b>Township:</b> 8N Range: 1W	
	<b>Section:</b> NW of the NW of the NE of Section 19		<b>Topo map:</b> Clear Creek	
	<b>Grant Number:</b>			
	<b>Field located by:</b> JRD		<b>on:</b> Jul 26, 1978	
	<b>Courthouse location by:</b>		<b>on:</b>	
	<b>Location accepted w/o verification by:</b>		<b>on:</b>	
	<b>Subdivision name:</b>		<b>Lot number:</b>	
	<b>Ft W of EL:</b> 2200.0	<b>Ft N of SL:</b>	<b>Ft E of WL:</b>	<b>Ft S of NL:</b> 250.0
	<b>Ground elevation:</b> 770.0	<b>Depth to bedrock:</b> 10.0	<b>Bedrock elevation:</b> 760.0	<b>Aquifer elevation:</b>
	<b>UTM Easting:</b> 537827.0		<b>UTM Northing:</b> 4330099.0	
<b>Well Log</b>	Top	Bottom	Formation	
	0.0	10.0	TOP SOIL	
	10.0	140.0	MEDIUM HARD WHITE LIMESTONE	
<b>Comments</b>	MC 760; NEIGHBOR VERIFIED; EAST OF HOUSE; DRY HOLE			



**Record of Water Well**

Indiana Department of Natural Resources

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<b>Reference Number</b> <b>213728</b>	<b>Driving directions to well</b>	<b>Date completed</b> Nov 24, 1965
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<b>Owner-Contractor</b> Owner Driller Operator	<b>Name</b>	<b>Address</b>	<b>Telephone</b>
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<b>Construction Details</b>	<b>Use:</b> HOME	<b>Drilling method:</b> Cable Tool	<b>Pump type:</b>
Well	<b>Depth:</b> 100.0	<b>Pump setting depth:</b>	<b>Water quality:</b>
Casing	<b>Length:</b> 17.5	<b>Material:</b>	<b>Diameter:</b> 6.0
Screen	<b>Length:</b>	<b>Material:</b>	<b>Diameter: Slot size:</b>

<b>Well Capacity Test</b>	<b>Type of test:</b>	<b>Test rate:</b> gpm for hrs.	<b>Ball Test rate:</b> 5.0 gpm for hrs.
	<b>Drawdown:</b> ft.	<b>Static water level:</b> ft.	<b>Baller Drawdown:</b> 65.0 ft.

<b>Grouting Information</b>	<b>Material:</b>	<b>Depth:</b> from to
	<b>Installation Method:</b>	<b>Number of bags used:</b>

<b>Well Abandonment</b>	<b>Sealing material:</b>	<b>Depth:</b> from to
	<b>Installation Method:</b>	<b>Number of bags used:</b>

<b>Administrative</b>	<b>County:</b> Monroe	<b>Township:</b> 8N Range: 1W	<b>Topo map:</b> Clear Creek
	<b>Section:</b> NE of the NE of the NW of Section 19		
	<b>Grant Number:</b>		
	<b>Field located by:</b> CES	<b>on:</b> Jul 01, 1966	
	<b>Courthouse location by:</b>	<b>on:</b>	
	<b>Location accepted w/o verification by:</b>	<b>on:</b>	
	<b>Subdivision name:</b>	<b>Lot number:</b>	
	<b>Ft W of EL:</b>	<b>Ft N of SL:</b>	<b>Ft E of WL:</b> 2600.0 <b>Ft S of NL:</b> 100.0
	<b>Ground elevation:</b> 740.0	<b>Depth to bedrock:</b> 15.0	<b>Bedrock elevation:</b> 725.0 <b>Aquifer elevation:</b>
	<b>UTM Easting:</b> 537694.0		<b>UTM Northing:</b> 4330161.0

<b>Well Log</b>	<b>Top</b>	<b>Bottom</b>	<b>Formation</b>
	0.0	16.0	RED CLAY
	16.0	30.0	WHITE SOFT LIMESTONE
	30.0	95.0	WHITE MEDIUM HARD LIMESTONE
	95.0	100.0	BLUE LIMESTONE HARD

**Comments**      MC 725

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Record of Water Well

Indiana Department of Natural Resources

**Reference Number** *Drilling directions to well* **Date completed**  
**222742** Mar 28, 1962

**Owner-Contractor Name Address Telephone**  
 Owner  
 Driller  
 Operator

**Construction Details**  
 Well *Use:* HOME *Drilling method:* Cable Tool *Pump type:*  
*Depth:* 140.0 *Pump setting depth:* *Water quality:*  
 Casing *Length:* 25.0 *Material:* *Diameter:* 6.0  
 Screen *Length:* *Material:* *Diameter:* Slot size:

**Well Capacity Test** *Type of test:* *Test rate:* gpm for hrs. *Ball Test rate:* 12.0 gpm for hrs.  
*Drawdown:* ft. *Static water level:* 90.0 ft. *Baller Drawdown:* 40.0 ft.

**Grouting Information** *Material:* *Depth:* from to  
*Installation Method:* *Number of bags used:*

**Well Abandonment** *Sealing material:* *Depth:* from to  
*Installation Method:* *Number of bags used:*

**Administrative** *County:* Monroe *Township:* 8N *Range:* 2W  
*Section:* NE of the SE of the NE of Section 24 *Topo map:* Clear Creek  
*Grant Number:*  
*Field located by:* JRD *on:* Jul 27, 1978  
*Courthouse location by:* *on:*  
*Location accepted w/o verification by:* *on:*  
*Subdivision name:* *Lot number:*  
*ft W of EL:* 100.0 *ft N of SL:* *ft E of WL:* *ft S of NL:* 1350.0  
*Ground elevation:* 785.0 *Depth to bedrock:* 25.0 *Bedrock elevation:* 760.0 *Aquifer elevation:*  
*UTM Easting:* 536848.0 *UTM Northing:* 4329779.0

**Well Log**

Top	Bottom	Formation
0.0	25.0	YELLOW DIRT
25.0	127.0	GREY LIMESTONE
127.0	132.0	BUFF COLOR LIMESTONE
132.0	140.0	GREY LIMESTONE

**Comments** MC 60; OWNER VERIFIED / JUST WEST OF HOUSE; COULDN'T LOCATE, NEE SPECIFIC DISTANCE



## I-69 EVANSVILLE TO INDIANAPOLIS TIER 2 STUDIES

### Section 5—Final Environmental Impact Statement

# APPENDIX Y FINAL KARST REPORT (REDACTED)

## TECHNICAL REPORT APPENDICES

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APPENDIX A	Memorandum of Understanding
APPENDIX B	Tabular results for activated carbon and water samples
APPENDIX C	Ozark Underground Laboratory Procedures and Criteria
APPENDIX D	Sampling Station Index and Karst Feature Index
APPENDIX E	Sampling Station and Select Feature Photographs
APPENDIX F	Individual Dye Trace Reports, Summary Table, and Figures
APPENDIX G	Documentation Graphs for All Analyzed Samples
APPENDIX H	Precipitation and Discharge Data from Illinois Central Spring
APPENDIX I	CONFIDENTIAL Data
APPENDIX J	Cave Fauna of the Section 5 Corridor of I-69
APPENDIX K	Indiana Bat Hibernacula Cave Reconnaissance
APPENDIX L	Pollutant Loading Estimate Tables and FHWA Methodology
APPENDIX M	IDNR Water Well Data
<b>APPENDIX N</b>	<b>Detail Maps of Preferred Alternative and Resources</b>

# **Appendix N**

Karst Mapping

Redacted for reasons related to karst.