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Problem Descriptions for the

Decision Support Software Demonstration

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Introduction

This demonstration is focused on evaluating the utility of decision support software in addressing environmental problems. Three endpoints have been selected for evaluation: a) Visualization, b) Sample Optimization, and c) Cost/Benefit Analysis. The definitions for these three areas in this program follow.

Visualization:

Visualization software will be evaluated in terms of the ability to integrate site and contamination data in a coherent and accurate fashion which aids in understanding the contamination problem. Tools used in visualization can range from data display in graphical or contour form to integrating site maps and aerial photos into the results. Visualization can be used on all problems.

Sample Optimization:

Sample optimization software will be evaluated for soil and groundwater contamination problems in terms of predicting the minimum number and location of samples needed to define a contaminated region with a specified level of confidence. The confidence level is defined as the probability with which the contaminant concentration exceeds the specified level in a region with a known area in the horizontal plane (e.g., radius of 50 feet) and a fixed vertical resolution (e.g., 10 feet). For example, at the 100 ppb level, the 75% confidence level is the region in which there is greater than a 75% chance that the contaminant exceeds 100 ppb with a grid resolution of a 30 foot radius in the horizontal plane and 10 foot thickness in the vertical plane.

Cost/Benefit Analysis:

Cost/Benefit analysis software will be evaluated on soil and groundwater contamination problems. In general, cost/benefit analysis will be defined as the cost optimization relative to a benefit. In cost/benefit analysis problems the Developers will be given the data and asked to answer one of the three following questions.

- Where and how large is the region in which the contamination concentration exceeds a threshold value? This cost/benefit analysis is defined as a Type 1 analysis. This analysis can be accomplished by interpolation, statistical, or geostatistical approaches.
- Where and how large is the region in which the contamination concentration exceeds a set of threshold values with one or more confidence levels? Guidance will be given on the criteria for selecting a cleanup level and a confidence level which will be used to support the cleanup decision. This is defined as a Type 2 cost/benefit analysis.
- What is the estimate of human health risk as a function of contamination levels for a specified confidence? Exposure pathways will be specified as part of the problem

definition. Based on the analysis, the Developer will be asked to estimate the human health risk for specified exposure pathways at specified times. This is defined as a type 3 cost/benefit analysis.

Ten problems are being developed for the demonstration. Sites A, N, S, and T have two independent problems, one for sample optimization and one for cost/benefit analysis. Sites B and D have a sample optimization problem which can be completed with the addition of cost/benefit analysis. These problems and their associated data are summarized in the following table. Although a problem is listed as a three-dimensional problem, it may be analyzed in two-dimensions using vertical slices or other techniques. The following sections provide information on the test problems and the type of questions that will be posed as part of the demonstration. The output suggestions are the minimum requirements of the analysis. Additional output may be supplied. This is particularly true in situations in which the additional output has aided in the understanding and analysis of the problem. Examples of additional output are providing contours at levels not requested or using different algorithms to analyze the problem and then showing the results and comparing the algorithms.

Summary of available problems.

	Site A Sample Opt and Cost/ Ben	Site B	Site D	Site N Sample Opt and Cost/ Ben	Site S GW Sample Opt	Site S: GW Cost/Ben	Site T Sample Opt and Cost/Ben
Contaminants	TCE, PCE, DCA, DCE,	Tc-99, TCE, VC,	TCE, PCE, DCA, DCE,	As, Cd, Cr	Carbon Tetra-chloride	Chlordane	EDB, DCP, DBCP, CT
Problem Type	3-D GW	2-D GW	3-D GW	2-D Soil	3-D GW	3-D GW	3-D soil and 3-D GW
Sample Locations	X	X	X	X	X	X	X
Samp Elevations	X		X		X	X	X
Samp ID	X		X	X	X	X	X
Media	GW	GW	GW	Soil	GW	GW	Soil/GW
Geology	X	X	X		X	X	X
Time-dependent	X (water levels only)	X extra data set with 10 years data	X extra data set with 10 years data				X (contaminants in GW) 2 years.
Surface Elevation	X	X	X		X	X	X
Hydraulic Head	X	X	X		X	X	X
HYD Cond	X	X	X		X	X	X
Aerial Photos (jpg or tif files)		X					
Visualization	X	X	X	X	X	X	X
Sample Opt	X (source area, GW)	X	X	X (Soils)	X		X (SOILS)
Cost Ben 1 and 2	X (regional GW)	X (after sample opt)	X (after sample opt)	X	X	X	X (GW)
Cost Ben 3	X	X		X		X	X

Groundwater Cost/Benefit Problem: Site A

Problem:

A three-dimensional groundwater cost/benefit problem for two contaminants (PCE and TCA). The importance of this aquifer to the region has lead to a detailed sampling of the plume. Based on the supplied data define the region of the plume at PCE contamination levels of 100 and 500 ppb and TCA levels of 5 and 50 ppb. For type 2 analysis, estimate the plume boundaries for the 10, 50, and 90% confidence levels. For health risk cost/benefit analysis calculate the risks associated with drinking 2 l/day from the aquifer at two defined points over the next five years. One point is in the central region of the plume and one is at the outer edge. Assume that the well is screened over a 10 foot thickness and is located in the highest contamination region at that location.

Problem Objective:

This test problem is to be used as a method for analyzing the accuracy with which the software predicts plume boundaries to define the extent of a 3-dimensional groundwater contamination problem on a large scale (the problem domain is approximately 1 square mile) This set contains detailed geologic data which can be used to assist in understanding the problem. The following information describes the test problem and output requirements.

Site Description:

Site A has been in operation since the late 1940's. It is an industrial machine plant which uses solvents and degreasing agents. It overlies an important aquifer which supplies more than 2.7 million gallons of water per day for industrial, commercial, and residential use. A large region of the aquifer has been contaminated due to releases of VOC's from the machine plant. Source control is considered an important remediation objective to prevent further contamination.

Site A is located in the northeastern US and in 1983 it was discovered that soil and groundwater was contaminated with VOCs (tetracholorethylene, tricholoethylene and vinyl chloride) and some heavy metals (chromium, nickel, and lead). Site characterization and monitoring activities were initiated and it was determined that agricultural and industrial activities from nearby industries were identified as sources of contamination. The industrial plant was shut down in 1985. The primary concern is VOC contamination in the aquifer and the potential migration to public water supplies.

Hydraulic and Transport Parameters:

The aquifer in the area consists primarily of stratified sand and gravel with some basal

till and is overlain in places by alluvium. Hydraulic conductivities in the aquifer range from 5 to 500 ft per day but throughout most of its extent range from 50 to 250 feet per day. The zones of highest hydraulic conductivity coincide with sediments deposited by glacial meltwaters originating from drainage channels to the north and northwest near a river. The maximum saturated thickness of the aquifer exceeds 100 feet near its eastern extent but generally ranges from 0 to 60 feet. Laterally, the aquifer is bounded by till-covered bedrock uplands. The river located to the north and northwest is gently sloping and the aquifer is drained by the river and its tributaries.

Hydraulic gradients in the region generally range from 0.001 - 0.005 ft/ft. The effective porosity of the aquifer is 0.3. Dispersion values are not known, however, the plume has undergone substantial lateral spreading due to changes in pumping conditions over the past thirty years.

There is a small fraction of organic matter in aquifer which sorbs the VOC's. For this problem, assume that the retardation factor for PCE is 1.1 and for TCA 1.2. Also assume that there are no degradation mechanisms.

Input:

Three data base files. One data base file (dbf) file providing initial sample locations, surface elevations, sample elevations, and measured concentrations. Sampling has been performed on a five-foot vertical scale. The second data base file contains information on hydraulic head data at three different times and location of the surface, till, and bedrock layers. The third data base file contains the location of the receptors for use in the human health risk analysis. Shape, tif and dxf files will be provided for surface structures which include buildings and surface water bodies.

Data Files:

AGEOL.DBF	Site Wide Geology and Water Level Information
ARECEPTORS.DBF	Location of receptors for human health risk analysis
ACBWELLS.DBF	Contaminant concentration data

Visualization Files (shape, dxf, tif):

Buildings	Site wide buildings
Pools	Surface water
Water	Surface water

Output:

Plume volume definition cost/benefit:

a) Map with sample locations.
b) Contour map at each concentration level (four total).
c) Estimates of the volume (area) and mass contained in the regions above the specified concentration levels. Estimates of the cost of remediation.
d) For type -II analysis: Plume maps at the three specified confidence levels at each concentration level (total of 12).
e) Provide a list of files and their description generated in the analysis.
f) Provide documentation of the approach used in the analysis, types of models used, and rationale for assumptions. This should include model parameters for statistical and contouring algorithms.
g) Provide files containing location (x,y, z) and concentration for the files used to visualize the plume. This is needed to check the accuracy of the analysis.

Health Risk:

a) Map with sample locations.
b) Contour map of the plume at years 1 and 5.
c) Estimated health risk for each contaminant at the two specified locations for the resident scenario at years 1 and 5.
d) Provide a list of files and their description generated in the analysis. This includes files with the average concentration at the receptor point and the estimated risk. Provide a list of conceptual model and data assumptions. Justification for all assumptions must be provided as part of the analysis.
e) Provide files containing location (x,y, z) and concentration for the files used to visualize the plume. This is needed to check the accuracy of the analysis.

All maps must have scales, axis titles and legends.

Groundwater Sample Optimization Problem: Site A

Problem:

Three-dimensional groundwater sample optimization problem for two contaminants (TCE and cis-DCE). At this site, hydraulic control of the source region is being considered as a remediation option. To achieve this, the region of contamination must be defined for the contaminants of concern. The objective of this problem is to define the source region of the plume at contamination levels above 10 and 100 ppb with confidence level of 10, 50, and 90%. The confidence level is defined as the probability with which the contaminant concentration exceeds the specified level in a region with a 50 foot radius in the horizontal plane and a 10 foot vertical resolution. Evaluation will be based on the accuracy of locating the plume and the required number of additional samples.

Problem Objective:

This test problem is to be used as a method for analyzing the accuracy with which the software predicts sample locations to define the extent of a 3-dimensional groundwater contamination problem. This set contains detailed geologic data which can be used to assist in understanding the problem. The following information describes the test problem and output requirements

Site Description:

Site A has been in operation since the late 1940's. It is an industrial machine plant which uses solvents and degreasing agents. It overlies an important aquifer which supplies more than 2.7 million gallons of water per day for industrial, commercial, and residential use. A large region of the aquifer has been contaminated due to releases of VOC's from the machine plant. Source control is considered an important remediation objective to prevent further contamination.

Site A is located in the northeastern US and in 1983 it was discovered that soil and groundwater was contaminated with VOCs (tetracholorethylene, tricholoethylene and vinyl chloride) and some heavy metals (chromium, nickel, and lead). Site characterization and monitoring activities were initiated and it was determined that agricultural and industrial activities from nearby industries were identified as sources of contamination. The industrial plant was shut down in 1985. The primary concern is VOC contamination in the aquifer and the potential migration to public water supplies.

Hydraulic and Transport Parameters:

The aquifer in the area consists primarily of stratified sand and gravel with some basal till and is overlain in places by alluvium. Hydraulic conductivities in the aquifer range from

5 to 500 ft per day but throughout most of its extent range from 50 to 250 feet per day. The zones of highest hydraulic conductivity coincide with sediments deposited by glacial meltwaters originating from drainage channels to the north and northwest near a river. The maximum saturated thickness of the aquifer exceeds 100 feet near its eastern extent but generally ranges from 0 to 60 feet. Laterally, the aquifer is bounded by till-covered bedrock uplands. The river located to the north and northwest is gently sloping and the aquifer is drained by the river and its tributaries.

Hydraulic gradients in the region generally range from 0.001 - 0.005 ft/ft. The effective porosity of the aquifer is 0.3. Dispersion values are not known, however, the plume has undergone substantial lateral spreading due to changes in pumping conditions over the past thirty years.

There is a small fraction of organic matter in aquifer which sorbs the VOC's. For this problem, assume that the retardation factor for DCE and TCE is 1.1. Also assume that there are no degradation mechanisms.

Input:

Two data base files. One data base file (dbf) file providing initial sample locations, surface elevations, sample elevations, and measured concentrations. Sampling has been performed on a five-foot vertical scale. The second data base file contains information on hydraulic head data and location of the till layer and confining bedrock. Shape, tif and dxf files of surface features will be provided.

Data Files:

AGEOL.DBF	Geology and water level information for the entire region.
ASOWELLS.DBF	Initial data from seven vertical profile wells in the source region.

Visualization Files:

Buildings	Buildings in the source region.
River	Surface water in the source region.

Output:

a) Map with initial well locations.
b) Map with recommended well locations and sample elevations.
c) Plume map at each concentration level for each contaminant and one confidence level (total of 8). Plume maps may be two or three-dimensional.
d) Provide a list of files and their description generated in the analysis.
e) Include a file with all additional well locations.
f) Provide documentation of the approach used in the analysis, types of models used,

and rationale for assumptions. This should include model parameters for contouring algorithms.

g) Provide files containing location (x,y, z) and concentration for the files used to visualize the plume. This is needed to check the accuracy of the analysis.

All maps must have scales, axis titles and legends.

Groundwater Contamination Sample Optimization and Cost Benefit Problem: Site B

Problem:

Groundwater contamination is limited to a thin water bearing unit at this site. This provides a two-dimensional sample optimization problem for three contaminants (trichloroethene (TCE), vinyl chloride (VC), and technetium-99). Initial sampling attempted to define the central region of the plume has been conducted for one year. Develop a sampling strategy to define the region in which the groundwater contamination exceeds the values given in the table 5 with a confidence level of 10% and 90% for a scale on the order of 500 foot in radius. The confidence level is defined as the probability with which the contaminant concentration exceeds the specified level in a region with a 150 foot radius in the horizontal plane. Evaluation will be based on the accuracy of locating the groundwater contamination and the required number of additional samples.

After using the sample optimization procedure and collecting additional data a cost/benefit analysis can be performed to estimate the location, mass and volume of the plume for each contaminant at the concentration thresholds in table 5, estimate the volume and mass in the plume. For type 2 cost/benefit analysis, provide the plume size based on 50, 75, and 90% confidence levels. For type 3 cost/benefit analysis, evaluate the health risks to a receptor (location and well screen depth specified) over the next ten years assuming an exposure scenario of consumption of 2 l/day of groundwater and removal of further sources to the groundwater over the next five years.

Table 5: Site B: Groundwater contamination problem threshold levels

Contaminant	Threshold Level
TCE	50, 500 (μg/l)
VC	50, 250 (μg/l)
Tc-99	10000, 40000 (pCi/l)

Problem Objective:

This test problem is to be used as a method for analyzing the accuracy with which the software predicts sample locations to define the extent of contamination. This problem focuses on the use of sample optimization on large-scale problem. The following information describes the test problem and output requirements

Site Description:

Site B is located in a sparsely populated area of the southern United States on a 547-ha (1,350 acre) site about 4.8 km (3 mi) south of a large river. Site B is typical of many metal fabrication or industrial facilities because it has numerous potential sources of contamination (e.g., material storage areas, process activity areas, service facilities, and waste management areas). As with any manufacturing facility, laboratory activities and cleaning operations can introduce solvents and other organic chemicals into the environment. Industrial operations include feed and withdrawal of material from the primary process, treatment of water for both potable and cooling purposes, steam generation for heating purposes, decontamination of equipment removed from the plant for maintenance or replacement, recovery of heavy metals from various waste materials, and treatment of industrial wastes. As a result of these activities, soil, groundwater and surface waters are contaminated. Of primary concern is migration off-site of groundwater contaminated with organic compounds and radionuclides.

Site B is about 5 km (3 mi) south of a major river and approximately 16 km (10 mi) west of a city of more than 25,000 people. Approximately 90% of the area within an 8-km (5-mi) radius of the site is agricultural or forested land.

Site B covers about 540 hectares (ha). The main plant area covers, 300 ha. The remaining 240 ha are maintained as a buffer zone surrounding the site. Active waste-management areas within the buffer zone include a raw-water treatment plant, a residential landfill, an inert landfill, and two industrial treatment lagoons. In addition, various inactive units, including a former sanitary landfill and several concrete rubble piles, are located outside the main plant area. Approximately 850 ha (2,100 acres) of land beyond the buffer zone area are leased by the state.

Site B is situated in an area characterized by a relatively flat terrain. Elevations vary from about 300 to 450 ft above mean sea level (msl) on the site property, with the ground surface sloping at a rate of approximately 5.1 m/km (27 ft/mi) toward the river north of the site. Two main topographic features dominate the landscape in the surrounding area: (1) the loess-covered plains, at an average elevation of 118.9 m (390 ft), and (2) the floodplain zone of the river (north of the site), dominated by alluvial sediments, at an average elevation of 96.1 m (315 ft) above mean sea level. The terrain of the site is slightly modified by the dendritic drainage systems associated with the two principal streams in the area. These northerly flowing streams have eroded small valleys that are approximately 6.1 m (20 ft) below the adjacent plain.

The geologic framework in the region consists of Mississippian carbonate bedrock overlain by unconsolidated Cretaceous, Tertiary, and Quartenary sediments. The oldest unconsolidated sediments beneath the site are the weathered Mississippian rubble zone and

the Upper Cretaceous Tuscaloosa Formation, which together are approximately 6.1 m (20 ft) thick. Unconformably overlying these formations are the Upper Cretaceous McNairy Formation and Paleocene Clayton Formation, which consist of interbedded and interlensing sands, silts, and clays. Totaling 68.6 m (225 ft) thick, these two formations have been grouped together and termed the McNairy Formation. In the southern portion of the site, the Paleocene Porters Creek Clay and the Eocene deposits of sand and silt overlie the McNairy.

The continental deposits can be subdivided into two components: a lower gravel or sandy gravel unit that varies in thickness form 0 to 105 ft and an upper clay-sand unit with a comparable range of thickness. The top of the gravel facies unit occurs at a depth of approximately 40 to 65 ft in the vicinity of Site B. The clay facies of the continental deposits are believed to consist of discontinuous, fine sand lenses enclosed by the dominant clay.

The surficial deposit at the site is a 1.5-7.6-m (5-25 ft) thick clayey silt of aeolian origin known as loess. The youngest sediments consist of recent alluvial floodplain material or fill. The soils that formed in the loess and alluvial floodplain are mainly silt loams and clay loams. Loess, which consists of clayey, sandy silt, and silty clay, outcrops at the surface over a majority of the area encompassed by Site B. Thickness of the unit varies from 0 m in the small creek valleys to 10.6 m (35 ft) immediately northeast of the site.

The Upper Late Deposits occur at a depth of up to 10.6 m (35 ft) below ground surface (bgs) and outcrop along the banks of a small stream northeast of the site. The thickness ranges from 6.1 m (20 ft) south of the Creek Terrace to 18.3 m (60 ft) north of it. Sand, silt, and clay with some gravel compose the Upper Late Deposits immediately northwest of the Creek Terrace.

For transport calculations assume that all contaminants move at the groundwater flow velocity. Dispersion is not known, but it is expected to be low due to the homogeneous nature of the aquifer. For these calculations assume that no decay mechanisms take place.

Input:

Shape, tif and dxf files containing maps of surface structures (roads, surface waters, and buildings). One data base file (dbf) file providing initial sample locations, and measured concentrations. One data base file containing information on geological structure and water levels. The final data base file contains receptor locations for human health risk analysis.

Data Files:
BGEOL.DBF
BWELLS2.DBF
BRECEPTOR.DBF

Visualization Files (shape, dxf, tif):

BLDGS
LAKE
RIVER
STREETS
RR
2.5meter.JPG Aerial photo on a 2.5 meter grid
5meter.JPG Aerial photo on a 5.0 meter grid

The above files are needed to complete the problem described. In addition, if it is desired to follow the plume for multiple years, the data file BVIS.DBF may be downloaded. Instructions on how to find this file will be provided after completion of the problem described above or after a decision has been made not o perform the problem. The BVIS.DBF file contains ten years of data including some of the data used in the test problem. The test problem data and the BVIS.DBF data do not conform on all aspects. Test problem data was modified to obtain better plume definition.

Output:

Sample optimization:

a) Map with initial sample locations.
b) Map with recommended sample locations.
c) Groundwater contamination map at each concentration level and confidence level (total of twelve).
d) Provide a list of files and their description generated in the analysis.
e) Include a file with all additional sample locations needed for each confidence level.
f) Provide documentation of the approach used in the analysis, types of models used, and rationale for assumptions. This should include model parameters for statistical and contouring algorithms.
g) Provide files containing location (x,y, z) and concentration for the files used to visualize the plume. This is needed to check the accuracy of the analysis.

Plume volume definition cost/benefit:

a) Map with sample locations.
b) Contour map at each concentration level (four total).
c) Estimates of the volume (area) and mass contained in the regions above the specified concentration levels.
d) For type -II analysis: Plume maps at the three specified confidence levels at each concentration level (total of twelve).
e) Provide a list of files and their description generated in the analysis.
f) Provide documentation of the approach used in the analysis, types of models used, and rationale for assumptions. This should include model parameters for statistical

and contouring algorithms.

g) Provide files containing location (x,y, z) and concentration for the files used to visualize the plume. This is needed to check the accuracy of the analysis.

Health Risk:

a) Map with sample locations.

b) Contour map of the plume at years 1 and 5.

c) Estimated health risk for each contaminant at the specified locations for the resident scenario at years 1 and 5.

d) Provide a list of files and their description generated in the analysis. This includes files with the average concentration at the receptor point and the estimated risk. Provide a list of conceptual model and data assumptions. Justification for all assumptions must be provided as part of the analysis.

e) Provide files containing location (x,y, z) and concentration for the files used to visualize the plume. This is needed to check the accuracy of the analysis.

All maps must have scales, axis titles and legends.

Groundwater Sample Optimization and Cost/Benefit Problem: Site D

Problem:

Three-dimensional groundwater sample optimization problem for four VOC contaminants (PCE, DCE, TCE, and DCA). For each contaminant define the region of the plume at contamination levels exceeding the levels specified in the table below with confidence levels of 10, 50, and 90%. For example, at the 100 ppb level, the 50 % confidence level is the region in which there is greater than a 50% chance that the contaminant exceeds 100 ppb with a grid resolution of a 200 foot radius in the horizontal plane and 30 foot thickness in the vertical plane.

Contaminant	Levels (μg/l)
TCE	50, 100, 500
DCE	5,50
DCA	5,50
PCE	5,25

After using the sample optimization procedure and collecting additional data a cost/benefit analysis can be performed to estimate the location, mass and volume of the plume for each contaminant at concentration thresholds listed above. For type 2 cost/benefit analysis, provide the plume size based on 10, 50 and 90% confidence levels.

Problem Objective:

This test problem is to be used as a method for analyzing the accuracy with which the software predicts sample locations to define the extent of contamination and then extending the analysis to perform a cost/benefit analysis. The following information describes the test problem and output requirements.

Site Description:

Site D is located in the western United States and consists of about 3,000 acres of land bounded by municipal areas on the west and southwest and unincorporated areas on northwest and east. Site D has been an active industrial facility since its initial operations in 1936. Operations have included maintenance and repair of aircraft and recently the maintenance and repair of communications equipment and electronics.

Site D has engaged in a wide variety of operations involving the use, storage, and disposal of hazardous materials. These operations included aircraft storage, aircraft

maintenance using racks, hangars, machine shops and washracks, aircraft painting, wastewater treatment, fuel/oil storage, electronics testing and repair, generator dismantling, aircraft painting, firing range, ammunition storage and fire training. Materials used include industrial solvents, caustic cleaners, electroplating chemicals, heavy metals, polychlorinated biphenyls (PCB), low-level radioactive wastes, and a variety of fuel oils and lubricants. Accidental spills and releases of these materials have resulted in contaminated soil, groundwater and surface water. Of primary concern are VOC contaminated soil and groundwater as well as soils contaminated with metals.

Surface features at Site D include open grassland, creeks and drainage, and vernal pools, as well as industrial and residential areas. The land surface is a relatively flat plain that slopes gently to the west. Surface elevations range from about 75 feet above mean sea level (msl) on the eastern side to about 50 feet msl on the western side.

Soil in the vadose zone, or the unsaturated zone between the surface and the groundwater table, is composed of interbedded layers of sands, silts, and clays. This zone is currently approximately 90 to 105 feet thick. Clays and hardpan layers slow, but do not halt, infiltration of liquids.

Groundwater is encountered at about 90 to 105 feet bgs, and flows generally south-southwest. However, the water table was at one time much higher; water levels have declined continuously for about 50 years because of overdrafting by irrigation, supply, and extraction wells. In areas of groundwater contamination, changes in flow direction and the declining water table have produced a contaminant "smear zone." As groundwater levels declined, some of the groundwater contaminants remained in the newly exposed portion of the vadose zone. These contaminants have remained as gases in soil pore spaces or as liquid films.

Input:

One data base file (dbf) file providing initial sample locations, surface elevations, sample elevations, and measured concentrations. Sampling has been conducted at various elevations during the study to define the nature and extent of contamination. The second data base file contains information on hydraulic head data. Shape, tif and dxf files are provided which contain surface structures (roads, buildings, surface water, etc.). Contaminant data will be provided at four times.

Data Files:

DWATER.DBF	Water Levels
DGEO.DBF	Geology from monitoring wells
DWELLS.DBF	Contaminant Concentrations for selected species.

Visualization Files:

BLDG	Buildings on site.
CREEKS	Creeks on site
ROADS	Roads on site
RUNWAY	Runway location.

The above files are needed to complete the problem described. In addition, if it is desired to follow the plume for multiple years, the data file DVIS.DBF may be downloaded. Instructions on how to find this file will be provided after completion of the problem described above or after a decision has been made not o perform the problem. The DVIS.DBF file contains ten years of data including some of the data used in the test problem. The test problem data and the DVIS.DBF data do not conform exactly to one another. Modifications were made to the test problem to better define the plume.

Output:

a) Map with initial well locations.
b) Map with recommended well locations.
c) Plume map at each concentration level and each confidence level (total of six). Plume maps may be two or three-dimensional.
d) Provide a list of files and their description generated in the analysis.
e) Include a file with all additional well locations needed for each confidence level.
f) Provide documentation of the approach used in the analysis, types of models used, and rationale for assumptions. This should include model parameters for contouring algorithms.
g) Provide files containing location (x,y, z) and concentration for the files used to visualize the plume. This is needed to check the accuracy of the analysis.

Plume volume definition cost/benefit:

a) Map with sample locations.
b) Contour map at each concentration level (four total).
c) Estimates of the volume (area) and mass contained in the regions above the specified concentration levels. Estimates of the cost of remediation.
d) For type -II analysis: Plume maps at the three specified confidence levels at each concentration level (total of twelve).
e) Provide a list of files and their description generated in the analysis.
f) Provide documentation of the approach used in the analysis, types of models used, and rationale for assumptions. This should include model parameters for statistical and contouring algorithms.
g) Provide files containing location (x,y, z) and concentration for the files used to visualize the plume. This is needed to check the accuracy of the analysis.

All maps must have scales, axis titles and legends.

Soil Contamination Sample Optimization Problem: Site N

Problem:

Surface soil contamination (two-dimensional) sample optimization problem for a three contaminants (Arsenic (As), Cadmium(Cd), and Chromium (Cr)). Initial sampling indicated a contaminated region on the site. Develop a sampling strategy to define all locations on the site in which the soil contamination exceeds the values given in the table 1 with confidence levels of 10, 50% and 90% on a 50 foot radius. Budgetary restraints limit the total expenditure on sampling to $96,000. Sample costs are $1200 per sample which includes collection and analyzing the surface soil sample (all four contaminants). Therefore, the number of additional samples should be less than 80. If this is insufficient to characterize the entire region, use the software to select the regions with the highest probability of defining the contaminated regions. Evaluation will be based on the accuracy of locating the soil contamination and the requested number of additional samples.

Table 1: Soil contamination sample optimization problem threshold levels

Contaminant	Threshold Levels (mg/kg)
Arsenic	125, 500
Cadmium	70, 700
Chromium	370, 3700

Problem Objective:

This test problem is to be used as a method for analyzing the accuracy with which the software predicts sample locations to define the extent of contamination. This set contains the most extensive and reliable data set for evaluating the accuracy of the analysis for a soil contamination problem. To focus only on the accuracy of the soil sample optimization analysis, the problem has been simplified greatly by removing information regarding groundwater contamination at this site and it has been limited to three contaminants. The following information describes the test problem and output requirements.

Site Description:

Site N is located in a sparsely populated area of the southern United States. Site N is typical of many metal fabrication or industrial facilities because it has numerous potential sources of contamination (e.g., material storage areas, process activity areas, service facilities, and waste management areas). As with any manufacturing facility, laboratory activities and cleaning operations can introduce solvents and other organic chemicals into the

environment. Industrial operations include feed and withdrawal of material from the primary process, recovery of heavy metals from various waste materials, and treatment of industrial wastes. Of primary concern is contamination of the surface soils by heavy metals.

Input:

Shape, tif and dxf files containing maps of surface structures (roads, surface waters, and buildings). One data base file (dbf) file providing initial sample locations, and measured concentrations.

Data Files:

NSOILSO.DBF	Soil contamination levels at selected locations.

Visualization Files:

ROADS	Roads
WATER	Surface water
CREEKS	Creeks

Output:

a) Map with initial sample locations.
b) Map with recommended sample locations.
c) Soil contamination map at each concentration level and each confidence level (total of six).
d) Provide a list of files and their description generated in the analysis.
e) Include a file with all additional sample locations needed for each confidence level.
f) Provide documentation of the approach used in the analysis, types of models used, and rationale for assumptions. This should include model parameters for statistical and contouring algorithms.
g) Provide files containing location (x,y, z) and concentration for the files used to visualize the plume. This is needed to check the accuracy of the analysis.

All maps must have scales, axis titles and legends.

Soil Contamination Cost/Benefit Problem: Site N

Problem:

Surface soil contamination (two-dimensional) cost/benefit problem for a three contaminants (Arsenic (As), Cadmium(Cd), and Chromium (Cr)). Detailed sampling indicated a contaminated region on the site. Develop a cost/benefit analysis to evaluate the cost or remediation to the clean-up levels specified in Table 2. Assume that the soil will be excavated to a depth of one foot and treated at a cost of $20 per cubic foot. The minimum remediation area is 10 feet by 10 feet. For type 2 analysis, estimate the regions above the threshold limit with a 90% and 50% confidence level. For health risk cost/benefit analysis, two scenarios are considered, an on-site worker during excavation and a resident. The on-site worker will be assumed to consume 500 mg/d of soil for one year during excavation. The worker will cover all areas of the site during the excavation process. The resident will be assumed to live on a 200 by 100 foot area and consume 100 mg/d of soil for 30 years.

Table 2: Soil contamination sample optimization problem threshold levels

Contaminant	Minimum Threshold Limit (mg/kg)	Maximum Threshold Limit (mg/kg)
Arsenic	75	500
Cadmium	70	700
Chromium	370	3700

Problem Objective:

This test problem is to be used as a method for analyzing the accuracy with which the software predicts sample locations to define the extent of contamination. This set contains the most extensive and reliable data set for evaluating the accuracy of the analysis for a soil contamination problem. To focus only on the accuracy of the soil cost/benefit analysis, the problem has been simplified greatly by removing information regarding groundwater contamination at this site and it has been limited to three contaminants. The following information describes the test problem and output requirements.

Site Description:

Site N is located in a sparsely populated area of the southern United States. Site N is typical of many metal fabrication or industrial facilities because it has numerous potential sources of contamination (e.g., material storage areas, process activity areas, service facilities, and waste management areas). As with any manufacturing facility, laboratory activities and cleaning operations can introduce solvents and other organic chemicals into the

environment. Industrial operations include feed and withdrawal of material from the primary process, recovery of heavy metals from various waste materials, and treatment of industrial wastes. Of primary concern is contamination of the surface soils by heavy metals.

Input:

Shape, tif and dxf files containing maps of surface structures (roads and surface waters). One data base file (dbf) file providing initial sample locations, and measured concentrations. One data base file containing receptor locations.

Data files:

NSOILCB.DBF	Soil concentration data
NRECEPTOR.DBF	Receptor Locations

Visualization Files (shape, dxf, and tif):

Roads	Roads
Water	Surface water locations

Output:

Economic cost/benefit:

a) Map with sample locations.
b) Contour map at each concentration level (six total).
c) Estimates of the volume (area) and mass contained in the regions above the specified concentration levels. Estimates of the cost of remediation.
d) For type -II analysis: Plume maps at the two specified confidence levels and the two concentration levels (total of 13).
e) Provide a list of files and their description generated in the analysis.
f) Provide documentation of the approach used in the analysis, types of models used, and rationale for assumptions. This should include model parameters for contouring algorithms.
g) Provide files containing location (x,y, z) and concentration for the files used to visualize the plume. This is needed to check the accuracy of the analysis.

Health Risk:

a) Map with sample locations.
b) Estimated health risk for each contaminant for on-site worker scenario.
c) Estimated health risk for each contaminant for resident scenario.
d) Provide a list of files and their description generated in the analysis. This includes files with the average concentration at the receptor point and the estimated risk.
Provide a list of conceptual model and data assumptions. Justification for all

assumptions must be provided as part of the analysis.

e) Provide files containing location (x,y, z) and concentration for the files used to visualize the plume. This is needed to check the accuracy of the analysis.

All maps must have scales, axis titles and legends.

Groundwater Sample Optimization Problem: Site S

Problem:

Three-dimensional groundwater sample optimization problem for a single contaminant (carbon tetrachloride). Define the region of the plume at contamination levels of 5 and 500 ppb with confidence levels of 10, 50, and 90%. Evaluation will be based on the accuracy of locating the plume and the required number of additional samples.

Problem Objective:

This test problem is to be used as a method for analyzing the accuracy with which the software predicts sample locations to define the extent of contamination. This set contains the most extensive and reliable data set for evaluating the accuracy of the analysis. To focus only on the accuracy of the analysis, the problem has been simplified greatly by removing information regarding surface structures (e.g., buildings and roads) and we have selected only one contaminant for the problem. The following information describes the test problem and output requirements.

Site Description:

Site S has been in operation since 1966. It is an industrial fertilizer plant producing pesticides, fertilizer, and using industrial solvents such as carbon tetrachloride and trichlorethene (TCE). Recently, it was determined that routine process operations were causing a release of carbon tetrachloride into the ground. Measurements of the carbon tetrachloride concentration in groundwater have been as high as 80 ppm a few hundred feet downgradient from the well. The site boundary is approximately 5000 feet from the facility where the release occurs. Sentinel wells at the boundary do not detect carbon tetrachloride.

The unsaturated zone is composed of a coarse sandy soil with minimal presence of silt or clay. Unsaturated zone hydraulic characteristics have not been measured for the site.

The regional groundwater system is characterized by a layered sequence of Pleistocene and Cretaceous gravel, sand, silt and clay deposits. The aquifer system has been designated by EPA as a sole source aquifer system. The stratigraphic sequence contains three major aquifers and two confining units in ascending order:

- Lawrence aquifer
- Jones clay confining unit
- Monahan aquifer
- Smiths clay confining unit
- Glacial aquifer

Near the site, the groundwater divide is north of the site and flow is generally toward the south. Contamination originating from the site is in the Glacial aquifer which is between 250 and 300 feet thick. This is an unconfined water table aquifer and is an important source of water for public and private wells in the area. The outwash deposits of sand and gravel are highly permeable and hydraulic conductivities generally range from 100 - 300 ft/day. The general flow direction is to the south at approximately 1 ft/day in the horizontal direction and 10 ft/yr (0.036 ft/d) in the vertical direction. Vertical flow changes in the vicinity of the Smiths confining layer.

Input:

Two data base files. One data base file (dbf) file providing initial sample locations, surface elevations, sample elevations, and measured concentrations. Sampling has been performed on a five-foot vertical scale. The second data base file contains information on hydraulic head data and geologic stratigraphy.

Data Files:

SSOWELL.DBF	Contaminant data and sample locations
SSOGEO.DBF	Geology and water level data

Output:

a) Map with initial well locations.
b) Map with recommended well locations.
c) Plume map at each concentration level and each confidence level (total of six) Plume maps may be two or three-dimensional.
d) Provide a list of files and their description generated in the analysis.
e) Include a file with all additional well locations needed for each confidence level.
f) Provide documentation of the approach used in the analysis, types of models used, and rationale for assumptions. This should include model parameters for contouring algorithms.
g) Provide files containing location (x,y, z) and concentration for the files used to visualize the plume. This is needed to check the accuracy of the analysis.

All maps must have scales, axis titles and legends.

Groundwater Cost/Benefit Problem: Site S

Problem:

Three-dimensional groundwater sample optimization problem for a single contaminant (chlordane). For type 1 cost/benefit analysis, define the region, mass, and volume of the plume at contamination levels of 5 and 500 ppb. For type 2 cost/benefit

analysis, extend the analysis to define the plume volumes as a function of three confidence levels, 10, 50, and 90% . For type 3 cost/benefit analysis, evaluate the health risk at the three wells near the site boundary (MW-252, MW-254, and MW-255 exact location is specified in the data base files) assuming a resident drinks 2 l/day from a well screened over a ten foot interval across the maximum concentration of the plume. Assume source control prevents further release to the aquifer in the health risk analysis.

Problem Objective:

This test problem is to be used as a method for analyzing the accuracy with which the software defines the extent of a groundwater contamination plume. This set contains the most extensive and reliable data set for evaluating the accuracy of the analysis. To focus only on the accuracy of the analysis, the problem has been simplified greatly by removing information regarding surface structures (e.g., buildings and roads) and we have selected only one contaminant for the problem. The following information describes the test problem and output requirements.

Site Description:

Site S has been in operation since 1966. It is an industrial fertilizer plant producing pesticides, fertilizer, and using industrial solvents such as carbon tetrachloride and trichlorethelyene (TCE). Recently, it was determined that a storage tank containing chlordane had a small leak. Measurements of the chlordane concentration in groundwater have been near 1 ppm at several locations on site. The site boundary is approximately 5000 feet from the facility where the release occurs. Sentinel wells at the boundary do not detect chlordane. In addition, there are several regions on the site with soil contamination by heavy metals.

The leaking seal is located about thirty feet above the water table and five feet below grade. The unsaturated zone is composed of a coarse sandy soil with minimal presence of silt or clay. Unsaturated zone hydraulic characteristics have not been measured for the site.

The regional groundwater system is characterized by a layered sequence of Pleistocene and Cretaceous gravel, sand, silt and clay deposits. The aquifer system has been designated by EPA as a sole source aquifer system. The stratigraphic sequence contains three major aquifers and two confining units in ascending order:

- Lawrence aquifer
- Jones clay confining unit
- Monahan aquifer
- Smiths clay confining unit
- Glacial aquifer

Near the site, the groundwater divide is north of the site and flow is generally toward the south. Contamination originating from the site is in the Glacial aquifer which is between 150 and 250 feet thick in this region. This is an unconfined water table aquifer and is an important source of water for public and private wells in the area. The outwash deposits of sand and gravel are highly permeable and hydraulic conductivities generally range from 100 - 300 ft/day. The general flow direction is to the south at approximately 1 ft/day in the horizontal direction and 7 - 15 ft/yr in the vertical direction. Vertical flow changes in the vicinity of the Smiths confining layer.

For transport calculations assume that all contaminants move at the groundwater flow velocity. Dispersion is not known, but it is expected to be low due to the homogeneous nature of the sandy aquifers. For these calculations assume that no decay mechanisms take place.

Input:

Two data base files. One data base file (dbf) file providing initial sample locations, surface elevations, sample elevations, and measured concentrations. Sampling has been performed on a five-foot vertical scale. The second data base file contains information on hydraulic head data and geologic stratigraphy.

Data Files:

SCBWELL.DBF	contaminant concentration data and sample locations
SCBGEO.DBF	geology data and water levels.

Output:

Plume volume definition cost/benefit:

a) Map with sample locations.
b) Contour map at each concentration level (two total).
c) Estimates of the volume (area) and mass contained in the regions above the specified concentration levels. Estimates of the cost of remediation.
d) For type -II analysis: Plume maps at the three specified confidence levels at each concentration level.
e) Provide a list of files and their description generated in the analysis.
f) Provide documentation of the approach used in the analysis, types of models used, and rationale for assumptions. This should include model parameters for statistical and contouring algorithms.
g) Provide files containing location (x,y, z) and concentration for the files used to visualize the plume. This is needed to check the accuracy of the analysis.

Health Risk:

a) Map with sample locations.
b) Contour map of the plume at years 1, 5, and 10.
c) Estimated health risk for each contaminant for resident scenario at years 1, 5, and 10.
d) Provide a list of files and their description generated in the analysis. This includes files with the average concentration at the receptor point and the estimated risk.
Provide a list of conceptual model and data assumptions. Justification for all assumptions must be provided as part of the analysis.
g) Provide files containing location (x,y, z) and concentration for the files used to visualize the plume. This is needed to check the accuracy of the analysis.

All maps must have scales, axis titles and legends.

Soil Contamination Sample Optimization Problem: Site T

Problem:

Soil contamination sample optimization problem for four contaminants (EDB, DCP, DBCP, Carbon Tetrachloride). Initial sampling indicated a contaminated region on the site. This problem has two phases. In the first phase develop a sampling strategy to define all surface locations on the site in which the soil contamination exceeds the values given in the table 3 with confidence level of 10, 50 and 90% on a 50 by 50 foot grid. After defining the region of surface contamination define subsurface contamination in the regions found to be above the 90% confidence limit. In this phase, suggest subsurface sampling locations on a ten foot vertical scale to fully characterize the soil contamination level at depths from 0 to 30 feet below ground surface (approximate location of the aquifer). The confidence level is defined as the probability with which the contaminant concentration exceeds the specified level in a 50 by 50 foot region in the horizontal plane. Evaluation will be based on the accuracy of locating the soil contamination and the required number of additional samples.

Table 3: Site T soil contamination threshold levels

Contaminant	Threshold Level (μg/kg)
Ethylene Dibromide (EDB)	21
Dichloropropane (DCP)	500
Dibromochloropropane (DBCP)	50
Carbon Tetrachloride	5

Problem Objective:

This test problem is to be used as a method for analyzing the accuracy with which the software predicts sample locations to define the extent of contamination. This problem is focused on generating a three-dimensional characterization of the soil contamination. The following information describes the test problem and output requirements.

Site Description:

Site T was developed in the 1950's as an area to store agricultural equipment as well as fertilizers, pesticides, herbicides and insecticides. Mixing operations (fertilizers and pesticides or herbicides and insecticides) were discontinued or replaced in the 1980's when levels of pesticides and herbicides in soil and wastewater were determined to be of concern.

Site T consists of 18 acres located in an undeveloped area of the western US with the nearest residence being approximately 0.5 miles north of the site.

The site is situated in a valley which has a very minor relief. Surface elevations vary on the order of 5 feet over a distance of several thousand feet. Creeks and drainage are cut into the land surface by several feet with relatively steep banks. Regional topography shows surface drainage flows from west to east, but most overland flow is focused to creek beds and ditches.

Site T is underlain by alluvial deposits of silt, clay, sand and gravel. The sand and gravel occur as thin, discontinuous lenses in the vadose zone and upper saturated zone. These lenses have saturated hydraulic conductivity ranging from 5 - 50 ft/day. A laterally continuous regional aquifer underlies the surface at approximately 105 feet bgs. The aquifer conductivity is 490 - 630 ft/day.

The source of soil and groundwater contamination is primarily an earthen, unlined disposal basin which was used during the pesticide handling and mixing operations for disposal of rinsates, residual chemicals and various storage containers. 1,2-dibromoethane (Ethylene dibromide, EDB), 1,2-dicholoropropane (DCP), 1,2-dibromo-3-chloropropance (DBCP) and carbon tetrachloride are the contaminants of concern in soil and groundwater.

Input:

Shape, tif and dxf files containing maps of surface structures (roads, surface waters, and buildings). One data base file (dbf) file providing initial sample locations, and measured concentrations.

Data Files:

TSOILSO	Soil contamination data and locations.

Visualization Files:

BLDGS	Buildings on site
OUTLINE	Outline of the site and nearby residential areas

Output:

a) Map with initial sample locations.
b) Map with recommended sample locations in the horizontal plane and vertical profiling sample locations.
c) Soil contamination map for each contaminant at each confidence level (total of eight). Maps may be two or three-dimensional representations of the contamination.
d) Provide a list of files and their description generated in the analysis.
e) Include a file with all additional sample locations.

f) Provide documentation of the approach used in the analysis, types of models used, and rationale for assumptions. This should include model parameters for statistical and contouring algorithms.

g) Provide files containing location (x,y, z) and concentration for the files used to visualize the plume. This is needed to check the accuracy of the analysis.

All maps must have scales, axis titles and legends.

Groundwater Cost/Benefit Problem: Site T

Problem:

A groundwater cost/benefit problem for four contaminants (EDB, DCP, DBCP, Carbon Tetrachloride). Sampling indicates a contaminated region on the site with the potential for reaching a residential neighborhood. Definition of the plume is needed to plan remedial strategies. Use the supplied data to estimate the volume, mass, and location of the contaminant plumes at the levels specified in Table 4. For type 2 cost/benefit analysis, estimate the 50, and 90% confidence level plumes at the specified concentrations. For type 3 cost/benefit analysis, evaluate the health risks to a residential receptor (location and well screen depth specified) and an on-site receptor over the next ten years. For the residential receptor consumption of 2 l/day of groundwater is the exposure pathway. For the on-site receptor assume 1 l/day consumption. In both cases, assume removal of further sources to the groundwater.

Table 4: Site T groundwater contamination threshold levels

Contaminant	Threshold Levels (μg/kg)
Ethylene Dibromide (EDB)	5, 100, 1000
Dichloropropane (DCP)	5, 100, 1000
Dibromochloropropane (DBCP)	0.2, 5
Carbon Tetrachloride	5, 25

Problem Objective:

This test problem is to be used as a method for analyzing the accuracy with which the software predicts plume boundaries to define the extent of a 3-dimensional groundwater contamination problem in a complicated flow field. This set contains detailed geologic data which can be used to assist in understanding the problem. The following information describes the test problem and output requirements.

Site Description:

Site T was developed in the 1950's as an area to store agricultural equipment as well as fertilizers, pesticides, herbicides and insecticides. Mixing operations (fertilizers and pesticides or herbicides and insecticides) were discontinued or replaced in the 1980's when levels of pesticides and herbicides in soil and wastewater were determined to be of concern. Site T consists of 18 acres located in an undeveloped area of the western US with the nearest

residence being approximately 0.5 miles north of the site.

The site is situated in a valley which has a very minor relief. Surface elevations vary on the order of 5 feet over a distance of several thousand feet. Creeks and drainage are cut into the land surface by several feet with relatively steep banks. Regional topography shows surface drainage flows from west to east, but most overland flow is focused to creek beds and ditches.

Site T is underlain by alluvial deposits of silt, clay, sand and gravel. The sand and gravel occur as thin, discontinuous lenses in the vadose zone and upper saturated zone. These lenses have saturated hydraulic conductivity ranging from 5 - 50 ft/day. A laterally continuous regional aquifer underlies the surface at approximately 105 feet bgs. The aquifer conductivity is 490 - 630 ft/day.

For transport calculations assume that all contaminants move at the groundwater flow velocity. Dispersion is not known, but it is expected to be high due to the heterogeneous nature of the geology. For these calculations assume that no decay mechanisms take place.

The source of soil and groundwater contamination is primarily an earthen, unlined disposal basin which was used during the pesticide handling and mixing operations for disposal of rinsates, residual chemicals and various storage containers. 1,2-dibromoethane (Ethylene dibromide, EDB), 1,2-dicholoropropane (DCP) and 1,2-dibromo-3-chloropropance (DBCP) are the contaminants of concern in soil and groundwater.

Input:

Shape, tif and dxf files containing maps of surface structures (roads, surface waters, and buildings). One data base file (dbf) file providing initial sample locations, and measured concentrations.

Data Files:

TWELLSCB	Ground water contamination data and locations.
TGEOCB	Geology data for the site
TWATERCB	Water level data for two time periods.
TCBRECEPTOR	Receptor locations.

Visualization Files:

BLDGS	Buildings on site
OUTLINE	Outline of the site and nearby residential areas

Output:

Plume volume definition cost/benefit:

a) Map with sample locations.
b) Contour map at each concentration level (total of ten).
c) Estimates of the volume and mass contained in the regions above the specified concentration levels.
d) For type -II analysis: Plume maps at the two specified confidence levels at each concentration level (total of twenty).
e) Provide a list of files and their description generated in the analysis.
f) Provide documentation of the approach used in the analysis, types of models used, and rationale for assumptions. This should include model parameters for statistical and contouring algorithms.
g) Provide files containing location (x,y, z) and concentration for the files used to visualize the plume. This is needed to check the accuracy of the analysis.

Health Risk:

a) Map with sample locations.
b) Contour map of the plume at years 1 and 5 and 10 years.
c) Estimated health risk for each contaminant at the specified locations for the resident scenario at years 1, 5 and 10.
d) Provide a list of files and their description generated in the analysis. This includes files with the average concentration at the receptor point and the estimated risk. Provide a list of conceptual model and data assumptions. Justification for all assumptions must be provided as part of the analysis.
e) Provide files containing location (x,y, z) and concentration for the files used to visualize the plume. This is needed to check the accuracy of the analysis.

All maps must have scales, axis titles and legends.