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**Conversion of Hanford Site Well Locations
to Washington Coordinate System of 1983,
South Zone 1991 (WCS83S)**

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Summary

Past construction and survey practices have resulted in the use of multiple local coordinate systems for measuring and reporting the horizontal position of wells and other facilities and locations on the Hanford Site. Regulatory reporting requirements mandated by the Tri-Party Agreement and the increasing use of spatial data analysis in support of environmental studies have significantly increased the need to provide horizontal location data in a single coordinate system that is applicable across the entire Site.

This report describes the development of a coordinate transformation process and algorithm and its application to the conversion of the horizontal coordinates of Hanford Site wells from the various local coordinate systems and datums to a single standard coordinate system, the Washington Coordinate System of 1983, South Zone 1991 (WCS83S). This work was undertaken as an interim measure to supplement ongoing resurveying efforts so that the best currently available well location information can be reported and made accessible in WCS83S coordinates as required by Washington State law.

The coordinate transformation algorithm, implemented as a computer program called CTRANS, uses standard two-dimensional translation, rotation, and scaling transformation equations and can be applied to any set of horizontal point locations. For each point to be transformed, the coefficients of the transformation equations are calculated locally, using the coordinates of the three nearest registration points (points with known locations in both coordinate systems).

The report contains a discussion of efforts to verify and validate both the software and the well location data, a description of the methods used to estimate transformation and registration point accuracy, instructions for using the computer program, and a summary of the Hanford well conversion results for each local coordinate system and datum. Also included are the results of using recent U.S. Army Corps of Engineers survey data to obtain estimated measures of location errors in wells for which the local coordinate data source is undocumented, unverified, and therefore of unknown accuracy. The estimated average error in the local coordinate data of these wells was about 14 meters for wells in the 100-F and 600 areas, about 150 meters in the 100-KE/KW area, and 2 meters or less in all other Hanford areas. Because of the large errors in the local coordinates of the 100-KE/KW wells, a complete resurvey of these wells is recommended.

An important side benefit of this well conversion effort has been the development of the CTRANS coordinate conversion program and the associated registration point files for the different local coordinate systems on the Hanford Site. CTRANS runs on UNIX workstations and on personal computers with a Windows interface. CTRANS has been and continues to be used extensively to convert local coordinates of waste sites and other points of special interest.

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1.0 Introduction

The Tri-Party Agreement significantly increased the need to report the horizontal locations of wells and other Hanford Site features in a single coordinate system that is both applicable across the entire site and accessible to and understood by all interested parties, including the regulators and the public. Past construction and survey practices on the site have promoted the development of multiple local coordinate systems. The diversity of these systems makes it difficult to spatially relate data from multiple areas or to report the data to the regulators as required by Washington State law.

This report describes a coordinate transformation algorithm and process that has been developed and applied to the conversion of the horizontal locations of wells within or near the Hanford site boundaries from the various local coordinate systems to the Washington Coordinate System of 1983, South Zone 1991 (WCS83S), the required coordinate system for reporting horizontal locations of wells and other facilities at the Hanford Site. Upon completion of verification and validation of the data sources and transformations, the resulting WCS83S coordinates will be stored in electronic databases and geographic information systems. They can then be used to facilitate the reporting visual presentation, and spatial analysis of complex environmental data at the Hanford Site within a single consistent coordinate system.

The Pacific Northwest Laboratory (PNL) performed this work for the Westinghouse Hanford Company (WHC) as part of the Hanford Environmental Information System (HEIS) project. HEIS is jointly coordinated by WHC and PNL for the U.S. Department of Energy.

The remaining sections and appendices of this report include the following information:

- a brief history of Hanford Site wells and the coordinate systems used at the site
- an overview of the methods used to obtain, prepare, and transform well location data
- descriptions of the coordinate transformation method implemented in a computer program called CTRANS (Coordinate TRANSformation)
- the preparation of well location data needed to support the transformation algorithm and computer program
- methods and results of verifying and validating both the computer program and the well location coordinate data and transformations
- comments on site issues of well accounting and nomenclature
- Appendix A: Summary of well coordinate conversion results
- Appendix B: Well location source discrepancies and probable errors (resolved and unresolved); piezometer wells; wells with missing location data

- **Appendix C:** Description of the algorithms used in the coordinate transformation software; program input/output specifications; user instructions; software test plan; software testing report; peer review comments on the algorithms; program listing
- **Appendix D:** Verification and validation plan for well location data; instructions and participants in a visual verification of well locations.

2.0 Hanford Well History and Site Coordinate Systems

There have been approximately 5000 wells constructed within or near the current boundaries of the Hanford Site, more than 200 of which existed before the establishment of the site. Most pre-Hanford wells were hand-dug farm wells, many of which have since been backfilled or are no longer usable. Wells on the Hanford Site have fulfilled various purposes. Some wells were originally constructed to provide sanitary water for outlying installations such as U.S. Army facilities. Many deep wells were drilled by the Basalt Waste Isolation Project (BWIP) to assess the feasibility of using the deep basalts beneath the Hanford Site for permanent disposal of nuclear wastes. Most of the remaining wells have been and continue to be used to monitor the vadose zone and groundwater beneath the Hanford Site for purposes of environmental surveillance, analysis, and restoration.

With the exception of some wells that have been abandoned for many years, each well has a unique name assigned to it by which it is identified and referenced on survey sheets and in electronic databases. Different well naming conventions are used for wells in different areas of the site. A well's name may have several variations, and its name may have changed one or more times over the course of its history. All Hanford wells are identified in the HEIS database with a unique "HEIS well name." Therefore, the wells in this report are identified primarily by their HEIS names. The older names have also been used in the process of searching for information on well identification and location coordinates.

A number of coordinate systems have been and continue to be used to reference the horizontal locations of wells and other facilities on the Hanford Site. Most of these coordinate systems were developed to support localized construction projects. They typically use a local origin and grid that is site dependent for meridian orientation. In addition to these local coordinate systems, many Hanford wells and other site features have been surveyed in universally recognized coordinate systems such as latitude/longitude and Washington State Plane coordinates, using either the North American Datum of 1927 (NAD27) or the North American Datum of 1983 (NAD83). The following coordinate systems have been used on the Hanford Site.

- **Washington Coordinate System of 1983, South Zone 1991 (WCS83S)**—the official coordinate system for the Hanford Site as defined by the Revised Code of Washington (RCW). Various referred to as "Washington State Plane," "Lambert NAD83," and "WCS83S," this coordinate system is actually a projection of the earth's surface using the Lambert Conformal Conic projection of the GRS80 Spheroid.
- **Plant Coordinates**—the most extensively used local coordinate system, used for locations across the entire Site.
- **Richland Coordinates**—an extension of the original coordinate system for the City of Richland.
- **100-K Local Grid**—a rotated coordinate system used within and near the 100-KE and 100-KW areas.

- **100-N Local Grid**— a rotated coordinate system used within and near the 100-N area. This coordinate system was originally a northerly extension of the 100-K grid.
- **White Bluffs and Hanford Townsite (Historical).** The White Bluffs coordinate system was a limited-use coordinate system covering the old townsite of White Bluffs. The Hanford Townsite coordinate system was a limited-use coordinate system covering the old Hanford construction camp. Neither system was ever tied to the Plant coordinate system, no monuments remain, and no Hanford Site location data is maintained in either of these systems.

Table 1 lists details about the origin, coordinate values, and use of each of the coordinate systems. Figure 1 is a map of the Hanford Site that identifies the designated "areas" of the site and shows the origins and orientations of the local coordinate systems that are still in use.

Table 1. Coordinate Systems Used on the Hanford Site^(a)

<u>Coordinate System</u>	<u>Origin, Orientation</u>	<u>Coordinate Values, units</u>	<u>Site Areas Covered</u>
WCS83S	Southwest corner of bounding latitude/longitude lines encompassing the State of Washington (Lambert Conformal Conic projection)	Northings & Eastings, meters	most locational data since 1989 (entire site)
Plant Coordinates	near 400 area, rotated 0.1472° counterclockwise relative to WCS83S ^(b)	Northings/Southings & Eastings/Westings, feet	600 area (entire site); 200-East; 200-West; 100-B/C; 100-D/DR; 100-F; 100-H; 400; some locations in 100-KE/KW, 100-N, 300, and 1100 areas
Richland Coordinates	southwest of Richland, rotated 0.8255° counterclockwise from WCS83S	Northings & Eastings, feet	in and near 300, 1100, and 3000 areas
100-K Local Grid	U.S. Coast and Geodetic Survey Benchmark "Cleveland," rotated 27.3136° counterclockwise from WCS83S (parallel to the Columbia river)	Northings & Eastings, feet	100-K East 100-K West
100-N Local Grid	U.S. Coast and Geodetic Survey Benchmark "Joe," rotated 22.8527° clockwise from WCS83S (parallel to the Columbia river)	Northings & Eastings, feet	100-N area
White Bluffs and Hanford Townsite	randomly set point, rotated substantially from North	Southings & Westings	old townsite of White Bluffs and old Hanford construction camp

(a) Most of the information about the Hanford coordinate systems are extracted from unpublished algorithms, reports, and the recollections of local experts. The accuracy of this report's transformations depends on the relative accuracy of the measurements within each grid and not on the accuracy of the location of the grids' origins or orientations.

(b) Survey control baseline (N:50,000) for Plant coordinates is immediately North of the North boundary of the 200-East Area.

Hanford

Figure 1. Origins and Orientations of Hanford Area Local Coordinate Systems

3.0 General Approach for Preparing and Transforming Well Location Data

Because horizontal coordinate data for many wells on the Hanford site are available in a local coordinate system only, it was necessary to apply a computational transformation to derive the WCS83S coordinates for those wells. A transformation algorithm using two-dimensional translation, rotation, and scaling equations was developed and implemented as a FORTRAN-77 computer program called CTRANS (Coordinate TRANSformation). For each point to be transformed, the coefficients of the transformation equations for that point are calculated locally, based on the coordinates of the three nearest points selected from a list of candidate registration points (points with known locations in both coordinate systems).

CTTRANS was designed to achieve the following objectives: 1) automate the transformation process; 2) obtain the best transformation accuracy possible with the available data; 3) use a consistent methodology for all site coordinate systems and datums; and 4) record a log of the transformation parameters, registration points, and other lineage and accuracy information associated with each well.

The major steps taken in the preparation for and performance of the well coordinate transformations are summarized below:

1. **Data sources evaluated.** Sources of well coordinates, including survey reports and electronic (computer) databases, in all available coordinate systems were identified and evaluated for content, accuracy, and reliability.
 - a) **Well location data discrepancies identified.** Comparisons were made among multiple sources of well locations reported in the same coordinate system to identify wells for which there were discrepancies of more than one foot (0.3 meters) in the reported coordinates. If a discrepancy could not be easily and quickly resolved, one of the conflicting values was selected, based on estimated relative accuracy and reliability among the conflicting data sources, for input to the transformation process, and the discrepancy was added to an annotated list of coordinate anomalies to be resolved.
 - b) **Wells with only WCS83S coordinates identified.** Wells for which WCS83S coordinate values were the only available coordinates were set aside for validation and eventual direct entry into the electronic databases.
 - c) **Wells with only local-system coordinates identified.** Wells for which local coordinate values constituted the only available locational information were added to a list of wells requiring transformation. This list was separated into sublists for each local coordinate system.
 - d) **Wells with both WCS83S and local-system coordinates identified.** For each local coordinate system, wells with sources of coordinate data in both WCS83S and the local system were used to develop two lists: 1) a list of wells, survey monuments, and other

points for which data from survey sheets were available in both coordinate systems, to be evaluated as candidate registration points for the transformations; and 2) a list of wells for which survey data sheets were unavailable in either or both coordinate systems. The latter list would be used to help validate the candidate registration points (see Step 3 below).

2. **Candidate registration points screened for coverage and spacing.** For each local coordinate system/datum, the candidate registration points developed in Step 1d, Item 1 were plotted on a base map of the Hanford Site or the area covered by the local coordinate system. The wells to be converted were also plotted on the same map. The spatial distribution of candidate registration points was visually examined for coverage of the area containing the wells to be converted. Clusters of two or more candidate registration points that were in close proximity to one another relative to the overall spatial distribution of points were also visually identified, and all but one of the candidate points from each cluster were removed from the list of potential registration points. This was done to prevent numerical errors resulting from the use of pairs of registration points that are closely spaced relative to their distances from the point to be converted.
3. **Registration points evaluated and validated.** For each local coordinate system/datum, the registration points selected in Step 2 were evaluated for accuracy of registration relative to one another by using the CTRANS program to perform transformations of each candidate point's local coordinates using other candidate points as registration points. The transformed WCS83S coordinates were then compared to the surveyed coordinates of that candidate point. Differences on the order of one-half meter or less were generally considered acceptable. In some parts of the 600 area where there were few available candidate registration points, differences of one meter or less in the transformed and surveyed locations were accepted. Candidate registration points that were identified as being unacceptably out of registration with the other points were removed from the list. The list of wells assembled in Step 1d, Item 2 (those having "known" locations in both coordinate systems but from sources other than survey sheets) were then transformed by CTRANS for self-validation and to help validate marginal candidate registration points.
4. **Final registration points used as CTRANS input data.** The final sets of registration points resulting from Step 3 were then assembled as the sets of reference points to be used by CTRANS to perform the coordinate transformations of the list of wells developed in Step 1c for each local coordinate system/datum. The resulting sets of registration points can be used to calculate WCS83S coordinates for any Hanford Site point location for which the location is known in one of the local coordinate systems. Appendix A shows, for each local coordinate system/datum, the number of registration points used and two measures (average and root-mean-square error) of the accuracy of the registration point set as determined by the validation process described in Step 3 above.

Additional details of this general approach are presented in Section 5, "Preparation and Evaluation of Location Data to Support the Transformation Algorithm," and Section 6, "Verification and Validation of the CTRANS Program and the Well Location Data."

4.0 Coordinate Transformation Method and CTRANS Program Outputs

The CTRANS (Coordinate TRANSformation) computer program was developed, tested, and applied to the conversion of the coordinates of Hanford Site wells from the various local coordinate systems to WCS83S. The program's transformation algorithm is based on the use of registration points (points for which the location is known in both the source and destination coordinate systems) from which transformation coefficients are calculated and applied to the source coordinates of the points to be transformed. CTRANS performs a localized transformation for each target point to be converted by selecting an appropriate subset of "nearest-neighbor" registration points from among the set of available registration points. CTRANS performs both a three-point (affine) and a two-point (uniform scaling) transformation for verification and comparison. The affine transformation results are selected for output if the spatial relationships among the three points meet specific criteria (e.g., non-colinearity) designed to ensure the accuracy of the transformation. If those criteria are not met, the results of the two-point transformation are selected for output. Appendix C contains detailed descriptions of the transformation equations and result selection criteria used by CTRANS (C1), descriptions of the input and output file formats (C2), instructions for operating the program (C3), the software test plan and test results (C4, C5), comments from a peer review of the transformation algorithm (C6), and a FORTRAN source listing of the Unix workstation version of the program (C7).

CTTRANS needs to be run only once to transform a set of point locations from the same source coordinate system/datum. The program creates three output files:

- **Log File of Transformation Information:** This automatically created log file records information relevant to the transformations, such as the registration points selected and used to transform each target point, and the results of both the three-point and two-point transformations.
- **Well Names and Coordinates:** CTRANS also creates a summary file of well names and corresponding WCS83S coordinates that can be used to build a Geographic Information System (GIS) map file.
- **Database Loader Input File:** CTRANS creates a specially formatted file that can be used by a database loader program to load the well coordinates into the appropriate fields of the HEIS database tables. CTRANS also writes to the loader file a numeric code to indicate the data source of the loaded coordinates for each well or point location.

5.0 Preparation and Evaluation of Location Data to Support the Transformation Algorithm

This chapter describes the process used to evaluate source data and select registration point locations needed as input to the coordinate transformation algorithm.

5.1 Sources of Well Coordinates and Identification of Probable Errors

Multiple sources of information exist on the location of Hanford Site wells. Historical survey data sheets, where available, are generally a reliable source of coordinates for site wells. Some of the well surveys were performed in only one coordinate system, while others were done in two or more coordinate systems. Electronic (computer) databases are another source of well location information. However, these databases generally contain no supporting location reference or verification information such as a survey sheet number and date or other indication of the source and estimated accuracy of the stored coordinate values.

The two major on-site databases that contain well location information are HEIS and WELLDON. The Hanford Environmental Information System (HEIS) is a large relational database that maintains and provides access to comprehensive information on Hanford Site environmental monitoring activities and laboratory analysis results (Westinghouse Hanford Company 1990). WELLDON is a generic name used to refer to a collection of data tables stored in the Paradox database system on the Hanford personal computer network (WELLDON is a noncertified well construction database maintained by the WHC Environmental Field Services group). WELLDON contains well maintenance and survey information and a host of other miscellaneous information on Hanford Site wells. In both databases, the majority of well locations are given in only one coordinate system. Some are given in two systems, usually WCS83S and Plant coordinates or one of the other local coordinate systems. Many Hanford wells have locational data stored in both HEIS and WELLDON.

Systematic comparisons of entries by well name in the two databases and comparisons with available survey data sheets resulted in the identification of discrepancies in the locations of some wells. In addition, a number of probable errors in coordinate data values were identified during the transformation process. Some of the discrepancies have been resolved, while others require further investigation and in some cases may require re-surveying the wells in question. Appendix B includes three lists of well location anomalies: B1, a list of wells for which database discrepancies or indicated errors have been resolved; B2, a list of wells for which resolution of discrepancies or probable errors is still in progress as of the date of this report; and B3, a list of wells for which the WCS83S coordinates obtained from a recent U.S. Army Corps of Engineers (USACE) survey exhibited significant differences (5 meters or more) from the WCS83S coordinates obtained from the CTRANS transformation of the local coordinates. It is assumed that the local system coordinate data values are inaccurate for these latter wells.

5.2 Selection of Registration Points

For each local coordinate system and datum on the Hanford Site, the set of candidate registration points included all point locations of any type (wells, survey monuments, etc.) for which reliable locational data sources (i.e., survey sheets) were available in both local and WCS83S coordinate systems. Because there was a lack of available 600 Area (site-wide) Plant-to-WCS83S candidate registration points in some remote areas of the site, reported results from a number of older (1984-85) surveys that used the NAD27 datum were included in the set of candidate registration points after applying the NADCON conversion algorithm (Environmental Systems Research Institute 1991) to convert NAD27 feet to NAD83 meters. The use of the NAD27 datum and NADCON conversion algorithm was observed to result in a non-uniform shift of the coordinates of these points of up to approximately 0.5 meters relative to the registration points that were surveyed directly in WCS83S (NAD83) coordinates. This shift then introduces a proportional error in the transformation of points that use one or more of these NAD27 surveyed wells as registration points.

There were three general criteria or methods used to screen potential registration points. The first method involved the creation, plotting, and visual inspection of a map of the potential registration points. The wells to be converted were also plotted on the map by using an approximate local-to-WCS83S conversion algorithm. By overlaying the registration point coverage and the preliminary well coverage map onto the Hanford base maps, the spatial distribution of registration points in relation to that of the wells to be converted was visually evaluated to insure that the reference points provided adequate coverage of the area containing the wells. These maps also provided a means to easily identify groups of two or more registration points that were in close proximity to one another, relative to the spatial distribution of the set of points as a whole. All but one of the points within each of these clusters were then removed by applying the second selection criteria: indicated precision and accuracy of the reported survey results. Where distinguishable, the surveyed point with the best accuracy or precision was retained from each cluster. If there was no obvious "best" point, then the selection of the registration point to retain was made arbitrarily.

The final screening method involved an algorithmic verification of the candidate registration points with respect to one another. The CTRANS program was run using the set of potential registration points as both the reference set and the conversion set. Each registration point thus had its local coordinates transformed to WCS83S using the nearest registration points (not including itself). These transformed coordinates were compared to the surveyed WCS83S coordinates of each point. Any significant discrepancies, presumably due to inaccuracy, imprecision, and/or registration to different datums, could be attributable to either the target point and/or to one or more of the "nearest neighbor" registration points. By examining the various combinations of these cross-registrations, it was usually possible to isolate the source of the discrepancies to one or more surveyed points. These questionable points were then removed from the list of registration points and added to a list of wells or other surveyed points requiring further verification. This self-transformation process was then repeated until all remaining points registered acceptably well (generally within one meter).

6.0 Verification and Validation of the CTRANS Program and the Well Location Data

The following definitions of verification and validation are assumed for this report.

- *Software verification* is a process used to determine that the software accurately performs the functions described in its documentation. *Software validation* is a process used to determine that the results produced by the software constitute an acceptably true representation of the real world.
- *Data verification* is the process used to determine that data stored in the computer or presented to the user are identical or equivalent (within acceptable precision) to the data obtained from the data source. *Data validation* is the process used to determine that the data collection instruments and processes have provided data which are an acceptably true representation or measurement of the real world.

Given these definitions and the purpose of the current input data and software—which is to transform local coordinates of generally unknown accuracy to WCS83S—it is impossible to ascertain the validity of the transformation results. In other words, it is impossible to determine the accuracy of the output data when the accuracy of the input data is unknown. What can be estimated, however, are the additional errors introduced by the transformation process itself. We can also compute estimated measures of the location errors of wells in a given area by comparing the transformed local coordinates to the WCS83S coordinates obtained from the most accurate survey data available for surveyed wells in that area.

The estimated well coordinate accuracy measures will be stored along with the WCS83S well coordinates in the HEIS database. Lineage information for the well coordinate transformations will also be entered into HEIS, including a reference to this report.

The following sections describe the verification and validation of the CTRANS software program and the verification and validation of the Hanford well location data.

6.1 Software Verification and Validation

A software test plan was written for the CTRANS coordinate transformation program. This test plan (Appendix C4) was used by an independent tester to test the operation of CTRANS. The CTRANS program and algorithms were verified by running the program against a test registration set. This was done by plotting a set of points on a coordinate grid and then performing a known translation, rotation, and scaling of the points by hand calculations to obtain transformed coordinates in a new coordinate system. The original and manually transformed coordinates were then input to CTRANS as both the registration set and the conversion set. Each point was transformed by CTRANS using the other points as registration points. The coordinates calculated by CTRANS were then compared to the translated, rotated, and scaled coordinates obtained by hand calculation. The

tester's report is included as Appendix C5. The report indicates that the tested CTRANS algorithm is free of errors and that the program performs as documented in the CTRANS user manual (Appendix C3).

The CTRANS algorithm has been submitted to a PNL internal peer review. The reviewers' comments are summarized in Appendix C6. The reviewers recognized the difficulty of calculating a reliable set of WCS83S coordinates for the Hanford wells, given the lack of adequate information on the accuracy and reliability of the local coordinate data for many of the wells. The reviewers found the CTRANS algorithm to be mathematically correct. The application of the algorithm to the conversion of Hanford well coordinates was deemed to be appropriate for the purpose of supplying the best available WCS83S coordinate values, provided that information regarding the quality of the input data is included with the reported results.

6.2 Data Verification, Validation, and Error Estimation

This section discusses the verification and validation of the Hanford well location data, including WCS83S coordinates derived from mathematical transformations as well as WCS83S data obtained directly from surveys and other sources. The purpose of the verification and validation effort is to provide people who use the data with information on the accuracy of the Hanford well coordinates. The verification and validation plan for site well location data is supplied in Appendix D1.

Unless there is a survey sheet with closure information, there is no way to directly estimate the accuracy of a well location. The best one can hope to do is to estimate the average error for a group of wells within the same locality or area, and use the average error as an estimate for the local coordinate error of each well in the area.

The errors in a surveyed well's local coordinates were estimated by comparing the values of the transformed (local to WCS83S) coordinates to the surveyed WCS83S values. Historical surveys performed by Kaiser Engineers Hanford (KEH) were used for the initial accuracy estimations. Most of the KEH surveys were done in both the local coordinate system and WCS83S. More recently, the United States Army Corps of Engineers (USACE) has begun resurveying a large number of wells on the Hanford site using high-precision Global Positioning System (GPS) equipment. These surveys produce WCS83S coordinates only, using the NAD83/1991 adjusted datum. Phases I and II of these surveys were completed in early 1993. The results of these initial USACE surveys were used to verify existing WCS83S well coordinate data and to provide accuracy estimates for wells that previously had only undocumented and unverified local coordinate data.

In the following sections, the transformed coordinates are compared to the KEH and USACE surveys described above to produce arithmetic average and root-mean-square (RMS) distance error measures. The final section of this data verification and validation discussion describes a visual verification effort by PNL and WHC personnel who are familiar with onsite well locations.

6.2.1 Comparison of Transformed Coordinates to KEH Surveys

Table 2 shows, for each of the Hanford areas and datums, the arithmetic average transformation error and the RMS transformation error calculated for the set of wells for which KEH survey data were available in both local and WCS83S coordinate systems. These error measures were computed from the differences between the transformed local coordinates and the surveyed WCS83S coordinates for each well. For 600 area wells surveyed in Plant coordinates, the average error was 0.631 meters and the RMS error was 1.255 meters. For all other areas and datums, the average error ranged between 0.016 and 0.256 meters, and the RMS error ranged between 0.017 and 0.533 meters. These error measures provide an indication of the consistency and adequacy of the registration points used in the coordinate transformations for each area/datum. The transformation errors were higher for the 600 area wells because they are distributed across the entire Hanford site and many of them are located some distance (e.g. several miles) from the nearest available registration points.

It should be noted that the small errors identified with the registration sets (see Appendix A) are somewhat misleading because wells that exhibited large deviations in the transformed versus surveyed WCS83S coordinates were considered to be "problem" wells and were excluded from the registration set. This was done because the primary purpose of the registration set is to produce reliable transformations. Lists of wells for which probable coordinate errors or other problems were identified are included in Appendix B.

6.2.2 Comparison of Transformed Coordinates to USACE Surveys

In May 1993 the United States Army Corps of Engineers (USACE) made available the results of recent surveys of selected Hanford wells. The USACE survey results (WCS83S coordinates only) are well documented and have closure information that indicate survey accuracies to within a centimeter.

**Table 2. Measures of Transformation Errors by Area/Datum
(Comparison with KEH Survey Data)**

<u>Area/Datum</u>	<u>Average error, meters</u>	<u>RMS error, meters</u>	<u>Number of wells in set</u>
100-B/C/Plant Coord. Datum	0.024	0.031	24
100-D/DR/Plant Coord. Datum	0.230	0.413	40
100-F/Plant Coord. Datum	0.183	0.273	19
100-H/100-H Coord. Datum	0.161	0.273	15
100-K/100-K Coord. Datum	0.256	0.533	10
100-N/100-N Coord. Datum	0.016	0.017	16
200-E/Plant Coord. Datum	0.121	0.222	118
200-W/Plant Coord. Datum	0.115	0.147	106
300/1100/Richland Coord. Datum	0.115	0.339	34
600/Plant Coord. Datum	0.631	1.255	113

For each of the Hanford areas, we selected a random sample of USACE surveyed wells for which we previously had only local coordinate data. We compared the USACE results to the WCS83S coordinates transformed from the original Hanford coordinates using CTRANS and the registration sets for each of the Hanford area/datum combinations. The average and RMS errors from this comparison are listed in Table 3. These errors were on the order of 1 to 2 meters or less for all areas except the 100-F, 100-K, and 600 areas. High average and RMS errors combined with a relatively high ratio of RMS to average error (on the order of 1.5 or more) indicate that most of the error is contributed by a few wells with poorly estimated local coordinates. In the case of the 100-K area, all eight included wells appear to have poorly estimated Plant coordinates.

- For wells in the 100-F area, the error measures were 14.3 meters (average) and 30.9 meters (RMS), almost entirely contributed by two of the nine wells.
- For the eight wells with Plant coordinates in the 100-K area, the corresponding error measures were 148 meters and 237 meters. There were no wells in the 100-K area that had only 100-K grid coordinates.
- For the "local-coordinates-only" wells in the 600 area, the average error and RMS error measures were 14.3 and 34.8 meters respectively, as computed from a random sample of the USACE-surveyed 600 area wells. Again, the error measures are primarily contributed by inaccuracies in the local (plant) coordinates for a small number of wells. Four of the fifteen wells in the 600 Area sample set have errors greater than 10 meters.

If it is assumed that the sample sets used were reasonably representative, the error measures listed in Table 3 can be used as a rough measure of the accuracy of all "local-coordinates-only" wells in the respective areas for the indicated local coordinate system/datum.

**Table 3. Measures of Local Coordinate Data Errors by Area/Datum
(Comparison with USACE Survey Data)**

<u>Area/Datum</u>	<u>Average error, meters</u>	<u>RMS error, meters</u>	<u>Number of wells in set</u>
100-B/C/Plant Coord. Datum	0.299	0.300	11
100-D/DR/Plant Coord. Datum	0.740	0.948	4
100-F/Plant Coord. Datum	14.266	30.936	9
100-H/100-H coord. Datum	0.407	0.631	27
100-K/Plant Coord. Datum	147.976	237.301	8
100-N/100-N Coord. Datum	0.339	0.364	54
100-N/Plant Coord. Datum	2.082	2.131	17
200-E/Plant Coord. Datum	0.520	0.612	15
200-W/Plant Coord. Datum	1.700	2.865	15
300/1100/Richland Coord. Datum	0.391	0.445	52
600/Plant Coord. Datum	14.295	34.825	15

6.2.3 Visual Verification of Well Locations

In an effort to obtain additional verification information, the well location data points were plotted on base maps of buildings, roads, fences, and other recognizable features at various scales for each of the Hanford areas. The appropriate maps were then given to PNL and WHC personnel who are familiar with the locations of wells in a particular region of the Hanford Site, and these people were asked to examine the maps and determine if the wells with which they are familiar appeared to be plotted in the correct location relative to the base map features. For wells that appeared to be improperly located, each verifier was asked to mark the corrected location on the map. The list of persons that responded in this verification exercise and the information requested from them are listed in Appendix D2. Table 4 summarizes the results of the visual verification effort.

The large number of "improperly located wells" in the 600 area is most probably due to the low accuracy of the 600 area base maps. The maps used were derived from USGS maps digitized by Austin-McDaniels. The same maps are currently reproduced from USGS DLG files. However, USGS makes no warranties as to the accuracy of these DLG data.

The improperly located wells were added to the lists of wells with discrepancies included in Appendix B. The improperly named wells and the wells with changed names are listed in Table 5. The additional wells identified by the verifiers were added to the list of wells for which we have not been able to find coordinate data (Appendix B5).

Table 4. Well Location Visual Verification Summary

	<u>100-B/C</u>	<u>100-D/DR</u>	<u>100-F</u>	<u>100-H</u>	<u>100-K</u>	<u>100-N</u>	<u>200-E</u>	<u>200-W</u>	<u>300/1100</u>	<u>600</u>	<u>Total</u>
Improperly located wells (est. error > 10 meters)	3	0	1	1	2	1	3	2	0	29 ^(a)	42
Improperly named wells	2	0	1	0	0	0	1	0	0	8	12
Name change (verifier looked for well under another name)	0	6	0	0	4	6	1	0	0	0	17
Additional wells identified (not included in current list/coverage)	0	0	0	1	0	1	0	0	0	3	5

(a) May be attributed to base map errors for some wells. These wells will be re-verified with corrected base maps.

Table 5. Wells with Improper or Changed Name

<u>Name Used</u>	<u>Proper Well Name</u>
UN-100N-17	199-N-85
1322-N	199-N-86
116-N-2	199-N-87
120-N-2	199-N-89
South Pond	199-N-88
119-N	199-N-84
199-91-43	699-96-43
199-93-46	699-91-46A
199-93-49B	699-93-48A
199-96-49	699-96-49
199-97-43	699-97-43
199-97-51A	699-97-51A
199-98-49A	699-98-49A
116-D-6	199-D5-25
116-D-9	199-D5-26
132-D-3	199-D5-28
116-D-3	199-D5-23
116-D-4	199-D5-24
130-D-1	199-D5-27
116-K-1	199-K-40
116-K-2	199-K-41
116-KE-4A	199-K-39
116-KW-3A	199-K-38
116-F-1A	116-F-3
11-B-5	116-B-5
116-B-1	116-B-1B
299-E29-PVC	299-E29-53
299-E25-170	299-E25-14
BG-DP-7	699-S37-E11E

7.0 Site Issues

The systematic review of all of the Hanford well locations produced an interesting side effect: recognition of the need for clarification of what constitutes a "Hanford well" and the need for an accounting of all known wells that meet the agreed-upon definition. The current HEIS definition of a well is rather broad, akin to a "measurement point," and could be interpreted as "a point location on the earth's surface from which soil or other materials at or beneath that point have been collected or measured for scientific study or other purposes."

Piezometer tubes inside wells are also included in HEIS and are given a separate name formed by appending a single letter (O, P, Q, R, S, T, U, or V) to the name of the parent well. Appendix B4 provides a list of the names of known piezometer tubes. The total number of wells and piezometer tubes for which we currently have coordinates is 3919.

We have identified the names of 540 additional wells for which we presently do not have horizontal coordinate data. The names of these wells are listed in Appendix B5. Six of these "wells" are soil sample locations.

8.0 References

Westinghouse Hanford Company. 1990. *Hanford Environmental Information System (HEIS) User's Manual*. Westinghouse Hanford Company, WHC-EP-0372, Richland, Washington.

Environmental Systems Research Institute, Inc. 1991. *Map Projections and Coordinate Management: Concepts and Procedures*. p. C-2.

Appendix A

Summary of Well Coordinate Conversion Results

Appendix A

Summary of Well Coordinate Data and Conversion Results

	<u>100-B</u> <u>/C</u>	<u>100-D</u> <u>/DR</u>	<u>100-F</u>	<u>100-H</u>	<u>100-KE</u> <u>/KW</u>	<u>100-N</u>	<u>200-</u> <u>East</u>	<u>200-</u> <u>West</u>	<u>300/</u> <u>1100/</u> <u>3000</u>	<u>400/</u> <u>600</u>	<u>Total</u>
Number of wells with sources of local coordinate data only ^(a)	5	15	4	1	14	7	737	880	125	936	2724
Number of wells with sources of WCS83S coordinate data only ^(a)	6	0	1	13	6	4	1	0	55	3	89
Number of wells with both local and WCS83S coordinate data sources ^(a)	24	36	28	37	19	79	130	149	59	282	843
Total no. of wells with location data in one or more coordinate systems ^(a)	35	51	33	51	39	90	868	1029	239	1221	3656
Number of points in registration point set (Local coord. system) ^(a)	See 600 Area	See 600 Area	See 600 Area	7 100-H ^(b)	9 100-K	4 100-N	See 600 Area	See 600 Area	11 Rich.	224 Plant ^(b)	—
Average transformation error (meters), registration points	—	—	—	0.015	0.044	0.010	—	—	0.181	0.305	—
RMS transformation error (meters), registration points	—	—	—	0.017	0.069	0.010	—	—	0.399	0.779	—
Average transformation error (meters), KEH-surveyed (local and WCS83S) Wells ^(c)	0.024	0.230	0.183	0.161	0.256	0.016	0.121	0.115	0.115	0.631	—
RMS transformation error (meters), KEH-surveyed (local and WCS83S) Wells ^(c)	0.031	0.413	0.273	0.273	0.533	0.017	0.222	0.147	0.339	1.255	—
Number of wells with unresolved coordinate data discrepancies	0	0	0	0	1	0	1	0	0	10	12
Number of wells recently resurveyed by USACE (1992 thru 08/31/1993)	11	4	10	27	14	71	50	80	53	173	493
Number of wells with no coordinate data (name only)	4	4	3	4	3	0	122	60	6	334	540
Number of wells that contain piezometer tubes	1	0	0	1	0	10	8	10	0	92	122
Number of piezometer tubes	2	0	0	4	0	34	19	37	0	289	385

(a) Well counts do not include piezometer tubes contained within a parent well.

(b) 600 Area Plant coordinate registration point set includes survey markers and surveyed wells in all Hanford areas, excluding surveyed locations that used the 100-H Area Plant coordinate datum.

(c) Includes wells that were used as registration points and other wells surveyed in both local and WCS83S coordinates.

Appendix B

Hanford Wells - Special Lists

Appendix B

Hanford Wells - Special Lists

B1. Resolved Well Location Source Errors

Coordinate Type: P = Plant coordinates
 L = Lambert NAD83 (WCS83S) coordinates
 N = 100-N Area coordinates

Coordinate Source: H = HEIS (Hanford Environmental Information System)
 WS = WELLSURV (WELLDX well survey database)
 HW = HANWELLS (WELLDX well construction/maintenance database)
 USACE = U.S. Army Corps of Engineers 1993 survey data

* indicates coordinate or well name in error

<u>Well Name</u>	<u>Coordinate Type/Source</u>	<u>E/W Coord.</u>	<u>N/S Coord.</u>	<u>Comments/Resolution</u>
116-D-2	P WS	-52778.8*	91988.2	KEH survey 06/18/92: -52615.6, 91988.2
(199-D5-22)	L WS	573847.09*	151586.76*	573818.59, 151515.74
199-B5-1	P H, WS	-82003.5	69916.9	KEH survey 12/17/92:
	P HW	-82000*	69930*	-82003.5, 69916.9
199-D5-16	P H	-52290.2	92436	KEH survey 06/18/92:
	P WS	-52906.2*	92436	-52290.2, 92436.2 (WS: E/W same as D5-17)
199-D5-20	P H	-54510.0	93680.7	KEH survey 06/18/92:
	P WS	54.51*	93680.7	-54510.0, 93680.7
199-D8-4	P WS	-53828.9	92876.7*	KEH survey 05/14/92: -53828.9, 93876.7
199-D8-5	L WS	573621.11*	152364.56*	KEH survey 05/14/92: 573537.39, 152243.73 (WS: Coords. same as D8-55)
199-F5-45	L WS	580841.44*	147684.16	KEH survey 02/24/93: 580706.99, 147684.16 (WS: E/W same as F5-46)
199-H4-2	P H	-38580.2	95199.5	KEH survey 08/29/86:
	P HW	-38565*	95200	-38580.2, 95199.5
199-N-70	N H	-8374.5*	8374.5	KEH survey 09/26/88: -4413.6, 8374.5

B1. (contd)

<u>Well Name</u>	<u>Coordinate Type/Source</u>		<u>E/W Coord.</u>	<u>N/S Coord.</u>	<u>Comments/Resolution</u>
199-N-73	N	H	-5779.1	5272.7*	KEH survey 12/11/91: -5779.1, 5275.7
	N	WS	-5779.1	5275.7	
299-E24-17	P	H,HW	-49070.4	39308.8	KEH survey 10/28/88: -49070.4, 39308.8 (WS: Coords. same as E24-18)
	P	WS	-50024.3*	39330.7*	
299-E25-170	P	H,HW	-65000*	41640*	New name for 299-E25-14, located at -46650, 41600
299-E25-2	P	H,HW	-47190*	41270*	KEH survey 09/17/90: -47175.1, 41265.5
	P	WS	-47175.1	41265.5	
299-E25-3	P	H,HW	-46960.04	39980.26	HEIS location consistent with other 299-E25- wells
	P	WS	-49960.04*	39980.26	
299-E27-1	P	H,WS	-50447.6	42833.1	KEH survey 12/08/92: -50447.6, 42833.1
	P	HW	-50440*	42833	
299-F27-13	L	WS	575065.1	136498.5*	KEH survey 01/04/90: 575065.1, 136489.5
299-E27-16	P	H,HW	-51544	44897	KEH survey 04/19/90: -51544, 44897
	P	WS	-56056*	44897	
299-E27-18	P	H	-51150	44745.6	KEH survey 08/12/92: -51150, 44745.6
	P	WS	-51510*	44745.6	
299-E27-7	P	H	-48150*	43100*	KEH survey 09/17/90: -48132.0, 43097.6
	P	WS,HW	-48132.0	43097.6	
299-E28-85	P	H,HW	-55102	48672*	N/S should be 43672
299-E33-18	P	H,WS	-52854.4	45626.5	KEH survey 10/27/92: -52854.5, 45626.5
	P	HW	-52825*	45624*	
299-E33-8	P	H	-53850	45840*	KEH survey 09/17/90: -53850.9, 45832.4
	P	WS,HW	-53850.9	45832.4	
299-E33-9	P	H,HW	-53285*	45960*	KEH survey 09/17/90: -53287.7, 45955.3
	P	WS	-53287.7	45955.3	
299-W10-3	P	H,HW	-75980*	43348*	KEH survey 09/11/90: -75985.1, 43349.2
	P	WS	-75985.1	43349.2	
299-W11-12	P	H,HW	-75340*	43098*	KEH survey 09/11/90: -75345.9, 43119.3
	P	WS	-75345.9	43119.3	
299-W11-24	P	H,HW	-75416*	43716*	KEH survey 09/11/90: -75390.2, 43581.0
	P	WS	-75390.2	43581.0	
299-W14-1	P	H,HW	-75261.5	42159.1	Transformed HEIS coords. agree with USACE WCS83S coords.
	P	WS	-75261.5	45159.1*	
299-W14-8*	-	HW			Named 299-W14-8B in HEIS

B.2

B1. (contd)

<u>Well Name</u>	<u>Coordinate Type/Source</u>		<u>E/W Coord.</u>	<u>N/S Coord.</u>	<u>Comments/Resolution</u>
299-W15-9	P	H,HW	-75890	39930	Transformed HEIS Plant coords. agree with USACE surveyed WCS83S coords. (1993): 566763.345, 135631.362 (WS: P,L coords. same as W15-19)
	P	WS	-77771.8*	41041.4*	
	L	WS	566189.380*	135968.950*	
299-W15-94*	P	H,HW	-75890	39930	Coords. same as W15-9; 299-W15-94 is a previous name for well 299-W15-9
299-W18-96	P	H,HW	-76790*	38825	E/W coord. same as W18-97; Transform result w/ E/W = -76970 agrees with USACE WCS83S survey
	L	USACE	566435.228	135293.826	
299-W19-31	L	H	566897.00	135127.48	KEH survey 4/1/91: 566897.00, 135127.48 (WS: Coords. same as W19-32)
	L	WS	566896.55*	135009.29*	
299-W19-90	P	H,HW	-73341*	37553	Transform result w/WS coords. agrees with USACE WCS83S survey
	P	WS	-72342.23	37551.05	
299-W22-42	P	H	73079.6*	36052.7	E/W should be -73079.6
	P	WS,HW	-73079.6	36052.7	
299-W6-12	L	H	566915.91	137635.3	KEH survey 08/07/92: 566915.91, 137635.30
	L	WS	574176.16*	137581.78*	
399-3-9	L	H	594504.7	115918.19	KEH survey 08/10/92: 594504.7, 115918.19
	L	WS	594213.95*	115918.19	
399-8-5C	L	H	593386.23	116573.92	KEH survey 01/23/92: 593386.23, 116573.92 (corrected from 1/8/92)
	L	WS	594161.02*	116573.92	
499-S1-8D	P	H,HW	-712*	-1295	E/W should be -7120
699-06-006*	P	WS	60011	60001.6	Same coords. as 699-60-60 (record should be deleted)
	L	WS	141764.25	571788.71	
699-06-057*	P	WS	60350.4	56604.9	Same coords. as 699-60-57 (record should be deleted)
	L	WS	141870.61	572623.65	
699-10-3C	P	H,HW	-3350	1015*	N/S should be 10150
699-10-54B	P	H	-53687	10125	E/W should be -53687
	P	HW	53687*	10125	
699-12-1K	P	H,HW	-1100	18800*	N/S should be 11880 (consistent w/ 12-1H and 12-1J)
699-16-E5	P	H,HW	470*	16300	E/W should be 4700
699-17-3	P	H,HW	2500*	16600	E/W should be -2500

B1. (contd)

<u>Well Name</u>	<u>Coordinate Type/Source</u>		<u>E/W Coord.</u>	<u>N/S Coord.</u>	<u>Comments/Resolution</u>
699-18-E3B	P	H	2600	17700	E/W should be 2600
	P	HW	26000*	17700	
699-18-E8	P	H	7830	18400	E/W should be 7830
	P	HW	78300*	18400	
699-22-70 (O,P,Q)	P	H,HW	-69259	19810*	Transform result w/ N/S = 21981 agrees with USACE WCS83S survey
	L	USACE	568798.297	130165.727	
699-36-E3	P	H	2890	35506	E/W should be 2890
	P	HW	-2890*	35506	
699-37-E1	P	H	1273	36953	E/W should be 1273
	P	HW	-1273*	36953	
699-37-25	P	H	-248510*	37305	E/W should be -24851
	P	HW	-24851	37305	
699-48-77B	P	H	77013.3*	47590	E/W should be -77013.3
699-5-E6	P	H,HW	-6100*	5200	E/W should be 6100
699-54-18B	P	H	-17700	54100	E/W should be -17700
	P	HW	17700*	54100	
699-55-50B	P	H,HW	-5000*	54900	E/W should be -50000
699-55-55	P	WS	-54641	54669*	KEH survey 01/21/92: P: -54641, 54669* L: 573227.11, 140149.99 Transformations indicate Plant N/S should be 54699
	P	HW	-55000*	55000*	
	L	H,WS	573227.11	140149.99	
	L	USACE	573227.56	140150.54	
699-59-100*	P	H,HW	-100659	58919	Same coords. as 699-59-101; 699-59-100 is a previous name for 699-59-101
699-60-53F	P	H	-52760	60334	E/W should be -52760
	P	HW	52760*	60334	
699-7-E1A	P	H,HW	-500*	6800	E/W should be 500
699-7-E2	P	H,HW	2100	-7400*	N/S should be 7400
699-8-E3A*	P	H,HW	2000	7550	Same coords. as 699-8-E2A; 8-E2A and 8-E3A have same former well name (1B-SP-10)
699-9-E5A	P	H	5112	9148	E/W should be 5112
	P	HW	51120*	9148	

B1. (contd)

<u>Well Name</u>	<u>Coordinate Type/Source</u>	<u>E/W Coord.</u>	<u>N/S Coord.</u>	<u>Comments/Resolution</u>
699-96-49	P H, WS	-49215.6	96384.9	KEH Survey 01/11/93:
	P HW	-49232*	96388*	-49215.6, 96384.9
699-96-49O	P H, HW	-49232*	96388*	(Piezometers O and P should
699-96-49P	P H, HW	-49232*	96388*	have same loc. as parent well)
699-96-52	P H, WS	-51526.6	95966	KEH Survey 01/11/93:
	P HW	-51568*	95982*	-51526.6, 95966.0
699-96-52P	P H, HW	-51568*	95982*	(Piezometer P should have same
				loc. as parent well)
699-97-43	P H, WS	-43240.8	97132.1	KEH Survey 01/11/93:
	P HW	-43241	97143*	-43240.8, 97132.1
699-97-43O	P H, HW	-43241	97143*	(Piezometers O and P should
699-97-43P	P H, HW	-43241	97143*	have same loc. as parent well)
699-S22-E9B	P H	-9027.0*	-22210	E/W should be 9027.8
	P WS	9027.8	-22210	
699-S22-E9C	P H	-9004.2*	-22222.3	E/W should be 9004.2
	P WS	9004.2	-22222.3	
699-S34-E15 (3099-45-16)	P HW	14780*	-34269*	KEH survey 01/23/92: 14957.2, -34262.9
699-S36-12B*	L H	593718.086	112500.972	Correct name is 699-S36-E12B

B2. Unresolved Well Location Source Discrepancies and Probable Errors

Coordinate Type: P = Plant coordinates
L = Lambert NAD83 (WCS83S) coordinates

Coordinate Source: H = HEIS (Hanford Environmental Information System)
WS = WELLSURV (WELLDON well survey database)
HW = HANWELLS (WELLDON well construction/maintenance database)

* indicates coordinate or well name suspected to be in error

Well Name	Coordinate Type/Source	E/W Coord.	N/S Coord.	Comments
199-K-12	P H,HW	-68803	76104	K-12, K-13: same plant coords.; Transformed K-13 coords. do not agree with USACE WCS83S survey (see Appendix B3)
199-K-13	P H	-68803*	76104*	
299-E25-181	P H,HW	-77040*	41685	E/W not in or near 200-East (E/W = -47040 ?)
699-8-8A	P H,HW	-8167*	8319*	Same coords. as 699-8-8B (Seismic shot hole - abandoned)
699-8-8B	P H,HW	-8167*	8319*	Same coords. as 699-8-8A (Seismic shot hole - abandoned)
699-13-E14*	P H,HW	13573	0*	Name, N/S not consistent (E/W coords. match 699-2-E14)
699-19-E9	P H,HW	9400	1900*	Name, N/S not consistent (N/S = 19000 ?)
699-4-E16*	P H,HW	15500	5875*	Name, N/S not consistent (699-6-E16: 15500, 5890)
699-48-77A*	P H	-77020	47602.7	GW well; KEH 10/7/92 rev. of 6/22/92 survey indicates name changed from 48-77A to 48-77B
	L H	566413.57	137969.02	
699-48-77B*	P,L WS	(P,L same as above)		
699-48-77B*	P H	(-)77013.3	47590	Abandoned; KEH 10/7/92 rev. of 6/22/92 survey indicates name changed from 48-77 to 48-77A
	L H	566415.60	137965.15	
699-48-77A*	P,L WS	(P,L same as above)		
699-80-62	P H,HW	-62000	81900*	Name, N/S not consistent
699-S0-112A*	P H	-115651*	-3017*	Name not consistent with either E/W or N/S coord.
	P HW	-115650*	-3017*	
699-S0-112B*	P H	-115608*	-3012*	Name not consistent with either E/W or N/S coord.
	P HW	-115610*	-3012*	

B3. USACE Surveyed Wells With Erroneous Local Coordinates

Wells with > 5 meters difference between surveyed and transformed locations:

<u>Well Name</u>	<u>Transformed Local Coords.</u>		<u>USACE WCS83S Survey</u>		<u>Difference (meters)</u>
	<u>E/W</u>	<u>N/S</u>	<u>E/W</u>	<u>N/S</u>	
199-F5-4	580522.448	147594.137	580583.190	147533.731	85.665
199-F5-7	580385.142	147664.261	580356.369	147685.179	35.573
199-K-13	568894.708	146661.291	569037.727	146682.130	144.529
199-K-19	569442.825	147241.012	569458.517	147386.640	146.471
199-K-20	569708.318	147699.168	569520.516	147687.239	188.180
199-K-23	569137.899	147240.134	569081.848	146635.800	606.928
199-K-27	569139.303	146752.254	569155.956	146763.797	20.262
199-K-28	569121.052	146736.955	569171.711	146772.768	62.040
199-K-29	569207.824	146782.944	569205.075	146790.128	7.692
199-K-30	569230.693	146783.010	569238.117	146780.961	7.702
299-E13-1	573664.211	134391.218	573655.723	134404.512	15.773
299-E13-3	573619.162	134370.971	573631.949	134361.232	16.073
299-E28-61	573860.708	136824.473	573856.186	136821.099	5.642
299-E33-58	573807.843	137388.388	573797.295	137388.475	10.548
299-W18-12	566440.043	135301.723	566439.772	135308.001	6.284
299-W18-19	566608.538	135196.392	566610.485	135202.530	6.439
299-W18-20	566586.291	135074.430	566590.085	135081.760	8.254
299-W18-168	566562.750	135360.848	566562.572	135391.142	30.295
299-W18-175	566548.063	135383.368	566547.078	135392.144	8.831
299-W22-75	567603.063	134513.790	567594.191	134490.421	24.996
299-W26-1	566280.348	133582.841	566433.606	133436.036	212.226
699-19-58	572153.393	129251.399	572133.468	129298.752	51.374
699-25-55	573083.351	131206.061	573089.050	131212.146	8.337
699-28-55	573139.100	132017.679	573138.387	132010.950	6.767
699-30-55	573138.895	132628.443	573138.500	132621.578	6.876
699-31-65	569981.254	132776.622	569987.671	132774.881	6.649
699-32-77	566421.901	133156.851	566416.794	133152.488	6.717
699-33-56	572831.555	133535.542	572922.693	133627.235	129.282
699-35-66	569855.584	134094.040	569857.861	134099.244	5.680
699-38-70	568491.206	135091.062	568500.942	135089.196	9.913
699-39-79	565892.374	135406.356	565890.922	135411.870	5.702
699-40-62	571149.086	135755.557	571164.292	135764.444	17.613
699-44-64	570458.460	136895.838	570390.651	136897.434	67.828

B3. (contd)

<u>Well Name</u>	<u>Transformed Local Coords.</u>		<u>USACE WCS83S Survey</u>		<u>Difference (meters)</u>
	<u>E/W</u>	<u>N/S</u>	<u>E/W</u>	<u>N/S</u>	
699-44-70	568508.220	136816.650	568495.347	136805.853	16.801
699-47-60	571513.232	137840.377	571474.380	137968.732	134.106
699-49-57	572539.620	138398.719	572544.276	138389.240	10.561
699-56-43	576760.725	140635.881	576756.291	140627.536	9.450
699-57-25A	582116.731	140799.264	582020.517	140713.313	129.014
699-57-29A	581124.451	140901.906	581133.960	140899.725	9.756
699-57-83A	564584.959	140834.949	564582.814	140825.130	10.051
699-58-24	582510.295	141183.373	582308.824	141345.922	258.868
699-59-80B	565633.106	141578.374	565637.671	141574.964	5.698
699-61-55B	573025.301	141985.613	573010.915	141983.406	14.554
699-61-57	572416.696	142192.995	572608.219	142435.066	308.674
699-61-66	569873.677	142079.799	569787.591	142007.963	112.121
699-63-51	574446.654	142547.499	574446.762	142553.674	6.176
699-63-90	562364.356	142618.818	562367.221	142612.351	7.073
699-65-38	578296.761	143608.281	578466.126	143435.810	241.725
699-65-50	574590.684	143201.414	574590.787	143187.852	13.562
699-65-59A	571910.738	143301.046	571913.723	143278.674	22.570
699-66-103	558546.860	143550.209	558538.772	143553.252	8.642
699-67-98	560003.382	143712.753	559944.001	143714.657	59.412
699-70-68	569037.040	144838.767	569021.847	144845.401	16.578
699-72-88	563201.761	145426.760	563247.287	145359.927	80.866
699-72-98	559907.685	145418.525	559954.498	145429.177	48.010
699-77-54	573377.503	146855.928	573385.973	146854.795	8.545
699-81-38	578172.031	148273.188	578172.347	148241.561	31.629
699-83-36	578887.109	148788.435	578749.270	148715.313	156.033
699-83-47	575505.761	148735.843	575492.044	148705.248	33.529
699-88-41	577223.155	150179.041	577221.545	150333.764	154.731
699-89-35	579120.106	150549.153	579121.737	150543.514	5.870
699-90-34	579408.815	150789.051	579410.129	150782.646	6.538
699-97-47	575439.715	152966.498	575451.610	152953.226	17.822

B4. List of Piezometer Wells

199-B3-2P	199-B3-2Q	199-H4-15CP	199-H4-15CQ	199-H4-15CR
199-H4-15CS	199-N-10O	199-N-10P	199-N-12O	199-N-12P
199-N-13O	199-N-13P	199-N-1O	199-N-1P	199-N-1Q
199-N-2O	199-N-2P	199-N-2Q	199-N-2R	199-N-3O
199-N-3P	199-N-3Q	199-N-3R	199-N-4O	199-N-4P
199-N-4Q	199-N-4R	199-N-4S	199-N-5O	199-N-5P
199-N-5Q	199-N-8P	199-N-8Q	199-N-8R	199-N-8S
199-N-8T	199-N-8U	199-N-8V	199-N-9O	199-N-9P
299-E13-20O	299-E13-20P	299-E13-20Q	299-E13-20R	299-E16-1P
299-E16-1Q	299-E16-1R	299-E23-2O	299-E23-2P	299-E23-2Q
299-E24-8P	299-E25-29P	299-E25-29Q	299-E25-30P	299-E25-30Q
299-E25-32P	299-E25-32Q	299-E27-3O	299-E27-3P	299-W11-13O
299-W11-13P	299-W11-13Q	299-W11-2O	299-W11-2P	299-W11-2Q
299-W11-2R	299-W11-2S	299-W11-2T	299-W14-3P	299-W15-5O
299-W15-5P	299-W15-5Q	299-W15-5R	299-W15-5S	299-W19-1O
299-W19-1P	299-W19-4O	299-W19-4P	299-W19-4Q	299-W19-4R
299-W19-4S	299-W22-11O	299-W22-11P	299-W22-14O	299-W22-14P
299-W22-24O	299-W22-24P	299-W22-24Q	299-W22-24R	299-W22-24S
299-W22-24T	299-W22-27O	299-W22-27P	299-W22-27Q	299-W22-27R
299-W22-27S	699-10-E12O	699-10-E12P	699-10-E12Q	699-10-E12R
699-10-E12S	699-12-1P	699-12-1Q	699-12-1R	699-12-1S
699-14-38P	699-14-38Q	699-14-38R	699-14-38S	699-14-E6P
699-14-E6Q	699-14-E6R	699-14-E6S	699-14-E6T	699-15-15AP
699-15-15AQ	699-15-15AR	699-15-15AS	699-15-15AT	699-17-26BP
699-17-26BQ	699-17-26BR	699-17-26CP	699-17-26CQ	699-17-26CR
699-18-25BP	699-18-25BQ	699-18-25BR	699-19-26BP	699-19-26BQ
699-19-58P	699-2-33AO	699-2-33AP	699-2-33AQ	699-2-33AR
699-20-39O	699-20-39P	699-20-39Q	699-20-39R	699-20-39S
699-20-39T	699-20-E12O	699-20-E12P	699-20-E12Q	699-20-E12R
699-20-E12S	699-20-E5P	699-20-E5Q	699-20-E5R	699-20-E5S
699-20E5T	699-22-70O	699-22-70P	699-22-70Q	699-24-1P
699-24-1Q	699-24-1R	699-24-1S	699-24-1T	699-25-33BP
699-25-33BQ	699-25-70O	699-25-70P	699-25-70Q	699-25-70R
699-25-70S	699-26-35DP	699-26-35DQ	699-28-40O	699-28-40P
699-28-40Q	699-28-40R	699-28-40S	699-29-70AP	699-29-70AQ
699-29-70CP	699-29-70CQ	699-29-70CR	699-29-70CS	699-29-70CT

B4. (contd)

699-29-70CU	699-29-70DP	699-31-31O	699-31-31P	699-31-31Q
699-31-31R	699-31-31S	699-31-31T	699-31-53BO	699-31-53BP
699-31-53BQ	699-31-65O	699-31-65P	699-31-65Q	699-31-65R
699-32-62O	699-32-62P	699-32-62Q	699-32-62R	699-32-72O
699-32-72P	699-32-72Q	699-32-72R	699-32-72S	699-34-88O
699-34-88P	699-34-88Q	699-34-88R	699-34-88S	699-34-88T
699-36-46P	699-36-46Q	699-36-46R	699-36-46S	699-36-61BO
699-36-61BP	699-36-61BQ	699-36-61BR	699-36-93O	699-36-93P
699-36-93Q	699-36-93R	699-36-93S	699-36-93T	699-37-43O
699-37-43P	699-37-43Q	699-37-43R	699-37-82AO	699-37-82AP
699-37-82AQ	699-37-82AR	699-37-82AS	699-37-82BO	699-37-82BP
699-37-82BQ	699-37-82BR	699-37-82BS	699-37-82BT	699-38-65O
699-38-65P	699-38-65Q	699-38-70O	699-38-70P	699-38-70
699-39-79O	699-39-79P	699-42-42O	699-42-42P	699-42-42Q
699-42-E9AO	699-42-E9AP	699-43-104P	699-43-41CP	699-43-41CQ
699-43-41DP	699-43-42AP	699-43-42BP	699-43-42BQ	699-43-42BR
699-43-42CP	699-43-42CQ	699-43-42DP	699-43-42DQ	699-43-42DR
699-43-42EP	699-43-42EQ	699-43-42ER	699-43-42FP	699-43-42FQ
699-43-42GP	699-43-42GQ	699-43-42GR	699-43-42HP	699-43-42HQ
699-43-91AP	699-43-91AQ	699-44-64O	699-44-64P	699-44-91P
699-44-91Q	699-44-91R	699-44-91S	699-44-91T	699-44-91U
699-47-80AP	699-47-80AQ	699-47-80CP	699-47-80CQ	699-47-80CR
699-47-80CS	699-47-80CT	699-47-80CU	699-47-80DP	699-48-48AO
699-48-48AP	699-48-48AQ	699-48-48AR	699-48-48AS	699-50-42P
699-50-85O	699-50-85P	699-50-85Q	699-50-85R	699-50-85S
699-51-75O	699-51-75P	699-51-75Q	699-53-55AO	699-53-55AP
699-53-55AQ	699-53-55AR	699-53-55AS	699-55-50AO	699-55-50AP
699-55-50AQ	699-55-70P	699-55-76O	699-55-76P	699-55-89O
699-55-89P	699-55-95P	699-55-95Q	699-57-83AO	699-57-83AP
699-57-83AQ	699-57-83AR	699-57-83BP	699-57-83BQ	699-57-83BR
699-60-60P	699-65-59AP	699-66-23P	699-66-38O	699-66-38P
699-66-38Q	699-67-51P	699-67-51Q	699-67-86P	699-67-86Q
699-67-86R	699-67-86S	699-69-45O	699-69-45P	699-69-45Q
699-69-45R	699-72-92O	699-72-92P	699-72-92Q	699-74-48O
699-74-48P	699-80-43P	699-80-43Q	699-80-43R	699-80-43S
699-81-58O	699-81-58P	699-84-35AO	699-84-35AP	699-84-35AQ
699-84-35AR	699-84-35AS	699-96-49O	699-96-49P	699-96-52P

B4. (contd)

699-97-43O	699-97-43P	699-S11-E12AP	699-S12-29O	699-S12-29P
699-S12-29Q	699-S14-20AO	699-S14-20AP	699-S18-E2AO	699-S18-E2AP
699-S31-1P	699-S6-E14AO	699-S6-E14AP	699-S6-E14AQ	699-S6-E4CO
699-S6-E4CP	699-S6-E4CQ	699-S6-E4CR	699-S7-34P	699-S7-34Q

B5. List of Wells with Missing Location Data

1199-29-12B	299-E24-130	299-E25-59	299-W10-193	299-W19-86
1199-34-15B	299-E24-131	299-E25-60	299-W10-194	299-W19-87
1199-45-12	299-E24-132	299-E25-64	299-W10-195	299-W21-84
199-B3-48	299-E24-133	299-E25-65	299-W10-84	299-W22-68
199-B4-10	299-E24-134	299-E25-93	299-W10-85	299-W22-70
199-B5-3	299-E24-135	299-E25-94	299-W10-86	299-W22-76
199-B5-4	299-E24-136	299-E25-95	299-W10-87	299-W22-77
199-D5-10	299-E24-137	299-E25-96	299-W11-22	3099-41-14B
199-D5-11	299-E24-138	299-E27-120	299-W11-71	399-3-4
199-D7-1	299-E24-139	299-E27-121	299-W11-72	399-4-6
199-D7-2	299-E24-140	299-E27-122	299-W11-73	499-S1-8J
199-F1-1	299-E24-141	299-E27-123	299-W11-74	699-10-30B
199-F2-4	299-E24-142	299-E27-124	299-W11-75	699-100-43
199-F2-5	299-E24-143	299-E27-136A	299-W11-76	699-100-54
199-H4-14B	299-E24-144	299-E27-136B	299-W11-77	699-103-25
199-H4-15C	299-E24-145	299-E27-136C	299-W11-78	699-103-53A
199-H4-18B	299-E24-146	299-E27-136D	299-W11-83	699-103-53B
199-H4-2C	299-E24-147	299-E27-136E	299-W11-84	699-105-1
199-K-14	299-E24-148	299-E27-136F	299-W11-85	699-108-20
199-K-17	299-E24-149	299-E27-136G	299-W14-30	699-11-23B
199-K-26	299-E24-150	299-E27-136H	299-W15-150	699-114-11
299-E15-17	299-E24-151	299-E27-136I	299-W15-151	699-117-11
299-E17-45	299-E24-152	299-E27-136J	299-W15-157	699-118-87
299-E22-51	299-E24-153	299-E27-136K	299-W15-21	699-119-11
299-E22-52	299-E24-154	299-E27-148	299-W15-218	699-12-26
299-E22-53	299-E24-40	299-E27-152	299-W15-83	699-12-4D
299-E22-54	299-E24-41	299-E27-153	299-W15-87	699-122-11
299-E22-55	299-E24-74	299-E28-72	299-W15-88	699-13-1C
299-E22-56	299-E24-75	299-E28-79	299-W15-89	699-13-28A
299-E24-111	299-E25-132	299-E28-80	299-W15-90	699-13-28B
299-E24-114	299-E25-170	299-E28-81	299-W15-91	699-13-E14
299-E24-115	299-E25-181	299-E28-82	299-W15-92	699-14-28
299-E24-116	299-E25-222	299-E28-83	299-W15-93	699-15-24
299-E24-117	299-E25-223	299-E28-92A	299-W18-106	699-15-25A
299-E24-120	299-E25-224	299-E28-93	299-W18-107	699-15-25B
299-E24-124A	299-E25-225	299-E33-1B	299-W18-108	699-15-25C
299-E24-124B	299-E25-226	299-E33-230	299-W18-111	699-15-25D
299-E24-124C	299-E25-227	299-E33-247	299-W18-112	699-15-25E
299-E24-124D	299-E25-228	299-E33-271	299-W18-161	699-16-22
299-E24-124E	299-E25-229	299-E33-291	299-W18-50	699-16-30B
299-E24-124F	299-E25-230	299-E33-292	299-W19-66	699-16-30C
299-E24-124G	299-E25-231	299-E33-293	299-W19-78	699-17-24
299-E24-124H	299-E25-232	299-E33-294	299-W19-79	699-17-26D
299-E24-124I	299-E25-233	299-E33-295	299-W19-80	699-17-26E
299-E24-124J	299-E25-234	299-E37-7	299-W19-81	699-17-26F
299-E24-126	299-E25-29	299-W10-131	299-W19-82	699-17-26H
299-E24-127	299-E25-30	299-W10-132	299-W19-83	699-17-27
299-E24-128	299-E25-32	299-W10-169	299-W19-84	699-18-25F
299-E24-129	299-E25-32B	299-W10-170	299-W19-85	699-18-27A

B5. (contd)

699-18-27B	699-37-82C	699-50-53A	699-70-36	699-87-2
699-18-27C	699-37-82D	699-50-95	699-72-86	699-87-23
699-18-27D	699-39-84C	699-51-7	699-73-25	699-87-24
699-18-27E	699-39-84H	699-52-46B	699-76-34	699-87-37
699-18-27F	699-4-E6	699-53-25	699-76-90	699-87-40
699-18-27G	699-40-11C	699-54-037C	699-77-44	699-87-42B
699-18-27H	699-40-11D	699-55-60C	699-78-36	699-87-42C
699-18-27I	699-40-11E	699-55-95O	699-79-104	699-88-36
699-18-27J	699-40-11F	699-56-21A	699-80-11	699-88-47
699-18-27K	699-40-11G	699-56-21B	699-80-2	699-88-48
699-18-27L	699-40-12A	699-56-23	699-80-39A	699-90-37
699-18-27M	699-40-33B	699-56-24	699-80-43	699-90-38
699-18-33	699-40-33C	699-56-40C	699-80-73A	699-90-47
699-19-20	699-40-E8	699-56-41	699-80-73B	699-90-49
699-19-34B	699-41-41	699-56-42A	699-81-5	699-90-90
699-19-51	699-42-12B	699-56-42B	699-81-64A	699-91-45
699-2-33B	699-42-12C	699-56-42C	699-81-64B	699-91-48B
699-2-33BP	699-42-41B	699-56-42D	699-81-64C	699-92-47
699-2-33BQ	699-42-42	699-56-42E	699-82-34	699-93-46
699-20-18B	699-42-42F	699-56-42F	699-82-35	699-93-49
699-20-18C	699-43-042B	699-57-21	699-82-38	699-93-49B
699-20-18D	699-43-1	699-57-26	699-82-45B	699-93-93
699-20-32	699-43-41C	699-57-41A	699-82-46	699-94-47
699-20-41	699-43-41D	699-57-41B	699-83-11	699-94-48
699-20-41P	699-43-41H	699-57-41C	699-83-16	699-95-83
699-20-41Q	699-43-42A	699-57-41D	699-83-38	699-96-52B
699-20-41R	699-43-42C	699-57-41E	699-83-5	699-97-48
699-20-E19	699-43-42D	699-57-41F	699-84-16	699-97-52
699-20-E5A	699-43-42E	699-57-42	699-84-20	699-98-49B
699-20-E8	699-43-42F	699-58-25	699-84-34A	699-98-54A
699-21-30A	699-43-42G	699-58-26	699-84-35	699-98-54B
699-24-95	699-43-42H	699-58-41C	699-84-35B	699-98-54C
699-26-83B	699-44-118	699-58-41E	699-84-36B	699-ALY-MNR
699-26-83BP	699-44-39	699-58-41F	699-84-36C	699-ATH
699-26-83BQ	699-44-43	699-58-48	699-84-36D	699-HAN-13
699-26-83BR	699-44-46	699-59-100	699-84-36E	699-HAN-29
699-26-E19	699-45-69	699-59-24	699-84-36F	699-HAN-30
699-32-49B	699-45-69B	699-6-57	699-84-37	699-HAN-31
699-32-49C	699-46-21A	699-60-53A	699-84-46	699-HAN-32
699-32-49D	699-46-E3	699-60-53B	699-84-61A	699-HAN-33
699-33-25A	699-47-46	699-60-53C	699-85-11	699-HAN-34
699-33-84	699-48-49T	699-60-53D	699-85-21	699-HAN-35
699-34-26A	699-48-77	699-60-53E	699-85-40B	699-HAN-36
699-34-41A	699-48-96	699-61-16B	699-86-11	699-HAN-37
699-34-98	699-49-48	699-61-24	699-86-35A	699-HAN-38
699-34-E13	699-49-50	699-61-26B	699-86-35B	699-HAN-39
699-35-26A	699-49-57A	699-61-84	699-86-35C	699-HAN-40
699-35-26B	699-49-86A	699-62-57	699-86-36A	699-LANDFILL
699-36-46	699-49-86B	699-63-91	699-86-36B	699-MATHEWS
699-36-58A	699-50-27	699-65-25	699-86-37	699-ORV-1
699-36-58B	699-50-48	699-67-77	699-86-95	699-ORV-2

B5. (contd)

699-RCH-CEM	699-S14-20C	699-S27-E9	699-S48-E12	699-S54-E5
699-S1-E18A	699-S17-24	699-S36-12B	699-S49-E2	699-S54-E6
699-S1-E18B	699-S17-25	699-S36-13B	699-S52-E2A	699-S55-E6
699-S1-E18C	699-S17-28	699-S37-E11E	699-S52-E2B	699-S6-E4H
699-S1-E18D	699-S17-30A	699-S37-E13A	699-S52-E3A	699-S6-E4J
699-S1-E18E	699-S17-30B	699-S4-E4	699-S52-E3B	699-VAL-RCH
699-S13-88	699-S17-30C	699-S41-E10C	699-S52-E3C	699-WBR-RCH
699-S14-20B	699-S18-E2B	699-S41-E14A	699-S53-E2	699-WTT-BLF

Appendix C

Coordinate Transformation Software

Appendix C

Coordinate Transformation Software

C1. Description of Transformation Algorithms Used in CTRANS

Two-Dimensional Transformations

The coordinate transformation algorithms used in CTRANS are based on three basic operations that, when applied together in a specified order, transform the coordinates of a set of points in a given two-dimensional Cartesian coordinate grid into a second Cartesian coordinate grid. These three operations, performed in the order given, are: linear translation (offset), performed independently in x and y; rotation in a clockwise direction about the origin; and scaling, performed either by applying independent scale factors in x and y (independent scaling) or by assuming the same scale factor in both x and y (uniform scaling). Given a point $P_s(x_s, y_s)$ in the original (source) coordinate system, we can generate corresponding coordinates $P_d(x_d, y_d)$ in the destination coordinate system by applying the following equations for translation, rotation, and scaling:

Translation by an amount T_x in the x-direction and T_y in the y-direction:

$$(1) \quad x_t = x_s + T_x$$

$$(2) \quad y_t = y_s + T_y$$

Clockwise rotation of the translated values through an angle α about the origin:

$$(3) \quad \begin{aligned} x_{tr} &= x_t \cos \alpha + y_t \sin \alpha \\ &= (x_s + T_x) \cos \alpha + (y_s + T_y) \sin \alpha \end{aligned}$$

$$(4) \quad \begin{aligned} y_{tr} &= -x_t \sin \alpha + y_t \cos \alpha \\ &= -(x_s + T_x) \sin \alpha + (y_s + T_y) \cos \alpha \end{aligned}$$

Scaling of the translated and rotated values, by a scale factor of S_x in the x-direction, and a scale factor of S_y in the y-direction:

$$(5a) \quad \begin{aligned} x_d &= x_{trs} = S_x x_{tr} \\ &= S_x (x_s + T_x) \cos \alpha + S_x (y_s + T_y) \sin \alpha \end{aligned}$$

$$(6a) \quad \begin{aligned} y_d &= y_{trs} = S_y y_{tr} \\ &= -S_y (x_s + T_x) \sin \alpha + S_y (y_s + T_y) \cos \alpha \end{aligned}$$

By rearranging terms, equations (5a) and (6a) can be rewritten as:

$$(5b) \quad x_d = (S_x \cos \alpha) x_s + (S_x \sin \alpha) y_s + (S_x T_x \cos \alpha + S_x T_y \sin \alpha)$$

$$(6b) \quad y_d = (-S_y \sin \alpha) x_s + (S_y \cos \alpha) y_s + (S_y T_y \cos \alpha - S_y T_x \sin \alpha)$$

$$\text{Letting } a = S_x \cos \alpha$$

$$b = S_x \sin \alpha$$

$$c = S_x T_x \cos \alpha + S_x T_y \sin \alpha$$

$$d = -S_y \sin \alpha$$

$$e = S_y \cos \alpha$$

$$f = S_y T_y \cos \alpha - S_y T_x \sin \alpha$$

we can rewrite (5b) and (6b) as:

$$(5c) \quad x_d = a x_s + b y_s + c$$

$$(6c) \quad y_d = d x_s + e y_s + f$$

Three-Point Affine Transformation

Equations (5c) and (6c) can be used to calculate the position of a point P in the destination coordinates, given its position in source coordinates and the values of the transformation coefficients a, b, c, d, e, and f (or alternatively, the translation, rotation, and scaling parameters as described above). Suppose, however, that we do not know the values of the transformation coefficients, but we know the x and y coordinate values of several points (called registration points or reference points) in both coordinate systems. If we have three such points, we can write three instances each of equations (5c) and (6c) using the known values of x_d , y_d , x_s , and y_s at the three reference points, and then we can solve the resulting six equations for the values of the six coefficients a, b, c, d, e, and f. The solution of the six equations yields the following expressions for the coefficients of the three-point affine transformation (subscripts s1, s2, s3, d1, d2, and d3 indicate the source and destination coordinates of the three reference points).

$$(7) \quad a = \frac{x_{d1}(y_{s2} - y_{s3}) - x_{d2}(y_{s1} - y_{s3}) + x_{d3}(y_{s1} - y_{s2})}{x_{s1}(y_{s2} - y_{s3}) - x_{s2}(y_{s1} - y_{s3}) + x_{s3}(y_{s1} - y_{s2})}$$

$$(8) \quad b = \frac{x_{s1}(x_{d2} - x_{d3}) - x_{s2}(x_{d1} - x_{d3}) + x_{s3}(x_{d1} - x_{d2})}{x_{s1}(y_{s2} - y_{s3}) - x_{s2}(y_{s1} - y_{s3}) + x_{s3}(y_{s1} - y_{s2})}$$

$$(9) \quad c = x_{d1} - a x_{s1} - b y_{s1}$$

$$(10) \quad d = \frac{y_{d1}(y_{s2} - y_{s3}) - y_{d2}(y_{s1} - y_{s3}) + y_{d3}(y_{s1} - y_{s2})}{x_{s1}(y_{s2} - y_{s3}) - x_{s2}(y_{s1} - y_{s3}) + x_{s3}(y_{s1} - y_{s2})}$$

$$(11) \quad e = \frac{x_{s1}(y_{d2} - y_{d3}) - x_{s2}(y_{d1} - y_{d3}) + x_{s3}(y_{d1} - y_{d2})}{x_{s1}(y_{s2} - y_{s3}) - x_{s2}(y_{s1} - y_{s3}) + x_{s3}(y_{s1} - y_{s2})}$$

$$(12) \quad f = y_{d1} - d x_{s1} - e y_{s1}$$

where equations (9) and (12) have been written in terms of the preceding calculated values of a and b, or d and e, for simplification. Now that the transformation coefficients are known, we can transform the coefficients of any point location from source coordinates to destination coordinates. CTRANS uses equations (7) through (12) together with equations (5c) and (6c) to implement the three-point affine transformation.

Two-Point Uniform Scaling Transformation

If we assume that the scale factors S_x and S_y in equations (5b) and (6b) are equal (uniform scaling), then $e = a$ and $d = -b$, and the equations become:

$$(5d) \quad x_d = a x_s + b y_s + c$$

$$(6d) \quad y_d = -b x_s + a y_s + f$$

Now there are four coefficients with unknown values: a, b, c, and f. We need only two registration points to solve for these coefficient values. The solution to the resulting four equations yields the following expressions for the coefficients of the two-point uniform scaling transformation:

$$(13) \quad a = \frac{(x_{s1} - x_{s2})(x_{d1} - x_{d2}) + (y_{s1} - y_{s2})(y_{d1} - y_{d2})}{(x_{s1} - x_{s2})^2 + (y_{s1} - y_{s2})^2}$$

$$(14) \quad b = \frac{(y_{s1} - y_{s2})(x_{d1} - x_{d2}) - (x_{s1} - x_{s2})(y_{d1} - y_{d2})}{(x_{s1} - x_{s2})^2 + (y_{s1} - y_{s2})^2}$$

$$(15) \quad c = x_{d1} - a x_{s1} - b y_{s1}$$

$$(16) \quad f = y_{d1} + b x_{s1} - a y_{s1}$$

Again, equations (15) and (16) have been written in terms of the preceding calculated values of a and b for simplification. CTRANS uses equations (13) through (16) together with equations (5d) and (6d) to implement the two-point uniform scaling transformation.

Criterion for Selection of Transformation Results

Although CTRANS calculates both the two-point and three-point transformations for each point, only one coordinate pair result per point must ultimately be selected for input to the database and the geographic information system. CTRANS uses a non-colinearity criterion to determine, for each individual point being transformed, which of the two transformation results are likely to be more accurate. Given that the three selected registration points are accurate and well-spaced, the three-point affine transformation typically will be slightly more accurate than the two-point uniform scaling transformation. However, if two of the three registration points are much nearer to each other than to the third point, or if the three points lie in a nearly straight line, errors due to numerical instability are introduced into the results of the affine transformation. To detect this condition, CTRANS computes the angles of the triangle formed by connecting the three registration points. If the minimum angle of this triangle is less than a threshold angle, the two-point transformation results are used. Otherwise, the three-point transformation results are used. From experiences in using CTRANS for registration point verification, the authors found that a threshold angle of 30 degrees generally produces the desired effect of screening out colinearity errors.

Accuracy Considerations

The assumption of uniform scaling is valid for coordinate transformations on the Hanford site, since all local systems use units of feet, WCS83S uses units of meters, and the measurement units are uniform in both coordinate directions. Thus both the two-point uniform scaling transformation and the more general three-point affine transformation are applicable to the Hanford coordinate systems, within the limitations noted below. There are two primary factors that can introduce errors into the transformations. Errors in the reported source and/or destination coordinates of a registration point will result in errors of similar magnitude in the transformed coordinates of points that use the erroneous registration point. A second source of error is the curvature of the earth. The transformation algorithms presented here are based on an implicit assumption of two-dimensional co-planar coordinate systems. Over small distances and areas, the earth's surface approximates a planar surface. As the distances from the target conversion point to each registration point and from one registration point to another become greater, the curvature-related errors become greater. Thus it is important to have a relatively uniform and sufficiently dense spatial distribution of accurate registration points over

the area containing the target points to be converted so that the CTRANS program can find, for each target point, at least two and preferably three registration points within a sufficiently short distance. From the authors' experience of converting the Hanford well locations, registration points that are within approximately two miles of the point to be converted were generally found to produce transformation errors of less than 0.5 meters, given an accurate set of registration points.

C2. CTRANS Input/Output Specifications

Input Files

CTTRANS requires two ASCII (text) input files. The first input file contains a list of the registration points to be used to perform the transformations. Each record, representing one registration point, contains five fields as shown in Table C2-1. Each of the fields can begin anywhere in the input record, provided they are separated by one or more spaces and their relative position in the record is in the order shown in the table. East and North coordinate values are positive.

The second input file contains a list of the wells or other points to be converted. This file also contains free-format records, one for each point to be transformed. Table C2-2 describes the seven fields in this file.

Note that values of the destination coordinates may be entered in Fields 4 and 5 of the conversion input file. If non-zero values are supplied in these fields, CTRANS will report the difference between these values and the transformed coordinates for comparison or verification purposes. (The use of zero to indicate unknown destination coordinates in the conversion input file is appropriate for the Hanford conversion application, because all WCS83S coordinates of points within and near the Hanford Site are positive numbers.)

When CTRANS reads the registration input file, it ignores everything beyond the fifth field in each record. Thus Fields 6 and 7 of Table C2-2 can optionally be added to the registration file so that it can be used as both the registration input file and the conversion input file for performing registration point verification.

An example of a conversion input file is shown in Appendix C4, Table C4-3. As discussed above, registration input files are structured identically to conversion input files with the exception that Fields 6 and 7 are not required and non-zero destination coordinates must be supplied in Fields 4 and 5.

Table C2-1. Registration Input File Fields.

<u>Field Description</u>	<u>Field Type</u>	<u>Maximum Length</u>
1. Well or point name	Character	13
2. Source (local) E/W coord. value	Decimal	unrestricted
3. Source (local) N/S coord. value	Decimal	unrestricted
4. Destination (WCS83S) E/W coord. value	Decimal	unrestricted
5. Destination (WCS83S) N/S coord. value	Decimal	unrestricted

Table C2-2. Conversion Input File Fields.

<u>Field Description</u>	<u>Field Type</u>	<u>Maximum Columns</u>
1. Well or point name	Character	13
2. Source (local) E/W coord. value	Decimal	unrestricted
3. Source (local) N/S coord. value	Decimal	unrestricted
4. Destination (WCS83S) E/W coord. value (enter 0.0 if unknown)	Decimal	unrestricted
5. Destination (WCS83S) N/S coord. value (enter 0.0 if unknown)	Decimal	unrestricted
6. Data source of local coordinate values	Integer	1
1 = WELLDX database		
2 or 3 = KEH survey		
4 = USACE survey		
5 = Other survey		
6 = HEIS database		
7 = Test data		
7. Data source of WCS83S coordinate values	Integer	1
1,6,7 = (same as above)		
0 = Estimated or not supplied		
2 = KEH survey, NAD83		
4 = USACE survey, NAD83/91 adj.		
5 = Independent GPS survey (PNL or WHC)		

Output Files

CTRANS produces three output ASCII (text) files: a detailed report or log file, a summary file, and a specially formatted database loader input file to be used by HEIS software to load the coordinate values into the HEIS database tables. The following paragraphs describe each of these output files. Example output files resulting from the CTRANS verification/validation test can be found in Appendix C4.

Log File. The log (report) file contains the current run date/time and CTRANS version number, a listing of the reference points used and their source and destination coordinates, and a report on the transformation of each input point. Each transformation report lists the three nearest registration points selected and their distances from the input conversion point, the transformation coefficients calculated from the selected reference points, and the transformation results (destination coordinate values) for both the two-point and the three-point transformation. If known or estimated destination coordinate values were supplied in the conversion input file, the distance error between the transformed and supplied destination locations and the differences in the coordinate values are also reported. An example of a log file is shown in Appendix C4, Figure C4-2.

Summary File. The summary output file contains one record for each point converted and is intended to summarize the results of the individual transformations. For each point converted, the reported destination coordinates in the summary file are copied from Fields 4 and 5 of the corresponding record of the conversion input file if the WCS83S data source (Field 7) indicated a survey or database source (codes 1 through 7) and the supplied WCS83S Easting and Northing coordinates were both non-zero. If Field 7 of the conversion input file was zero (indicating unknown or estimated WCS83S coordinates), either the three-point or the two-point transformation results, selected on the basis of the non-colinearity criterion described in Appendix C1, are written to the coordinate fields of the summary output file. In addition to the well or point name and the WCS83S coordinates, the summary file contains fields indicating the data sources of both the local coordinates and the WCS83S coordinates; the source of the WCS83S coordinates written to this output record (i.e. from Fields 4 and 5 of the input file or from the "3-pt." or "2-pt." transformation results); and the distance error between the supplied WCS83S location (if any) and the selected transformation results. An example summary file is shown in Appendix C4, Table C4-4.

Loader File. The HEIS database loader file written by CTRANS contains one record for each well or point in the conversion input file, with the exception of records for which the WCS83S source code in Field 7 is equal to 6 or 7 (HEIS database or test data). A loader record is not created for wells that already have WCS83S coordinates stored in HEIS. Such records are included for verification purposes only, and it is assumed that the WCS83S coordinates stored in the HEIS database are correct until proven otherwise. Test data is of course not intended for loading into the database. The loader file has special question-mark (" ") delimiters between fields as required by HEIS loader software conventions. Four data fields are written to the loader file: the well name, the WCS83S Easting and Northing coordinates (selected from either the conversion input file or the transformation results by applying the same rules as described above for the summary output file), and an integer code to be stored in the database to indicate the source (lineage) of the stored well coordinates. This code is similar to the data source fields of the input files, but it also contains codes

for coordinate transformations from the various local coordinate systems. Table C2-3 shows the various codes used in the coordinate lineage field of the loader file. An example database loader file is shown in Appendix C4, Figure C4-1.

Table C2-3. Coordinate Lineage Codes

<u>Integer Value</u>	<u>Description</u>
1	Obtained from WELLDON database
2	Obtained from KEH survey (NAD83)
3	Obtained from KEH survey (NAD27) and converted to NAD83 (NADCON conversion)
4	Obtained from USACE survey (NAD83/91 adj.)
5	Obtained from independent GPS survey (PNL or WHC)
6	Transformed from Plant coordinates using 100-H datum registration points
7	Transformed from 100-N area coordinates
8	Transformed from Plant coordinates (all areas except 100-H)
9	Transformed from Richland coordinates (300, 1100, and 3000 areas)

C3. CTRANS User Instructions

CTTRANS exists on UNIX Workstations as a compiled executable file named CTRANS.EXE. The directory location of this file may be different on each system, so a system variable is defined to permit operation of the program from any current working directory by simply typing **CTTRANS** at the operating system prompt. If this does not work on your system, contact your system administrator for assistance.

CTTRANS prompts you to enter the names of two input files, three output files, and a coordinate lineage code. Detailed file specifications are contained in Appendix C2. The prompt messages are shown below in bold type in the sequence in which they appear.

Enter name of file containing reference points:

Enter the name of the input file containing the reference (registration) points for converting from the desired source coordinate system to the desired destination coordinate system.

Enter name of file containing points to be converted:

Enter the name of the input file containing the names and source coordinates of the points you wish to transform to the destination coordinate system.

Enter name of output summary (list) file to be created:

Enter the desired name of the summary file to be created by CTRANS.

Enter name of detailed report (log) file to be created:

Enter the desired name of the report (log) file to be created.

Enter name of coordinate loader file to be created:

Enter the desired name of the database coordinate loader file to be created.

Enter coordinate lineage code indicating input coord. system:

- 6 – Plant coordinates, 100-H Area datum**
- 7 – 100-N Area coordinates**
- 8 – Plant coordinates, all Areas except 100-H**
- 9 – Richland coordinates**

Enter a number between 6 and 9 to indicate the coordinate system from which the input points will be transformed.

The program will then proceed to completion. If CTRANS completes normally without detecting an unresolvable error, it will print the following message:

<n> points converted.

where <n> is replaced by the number of points that CTRANS successfully read from the conversion input file and transformed to the destination coordinate system. If an error is encountered during program operation, a brief error message will be printed on your terminal. Table C3-1 lists the possible error messages and their interpretation.

Table C3-1. CTRANS Error Messages

Message	Interpretation
Error opening input conversion file.	CTTRANS was unable to open the requested conversion file. Make sure you have specified a file that exists in your current working directory or in the path specified.
Error opening input reference file.	CTTRANS was unable to open the requested registration point file. Make sure you have specified a file that exists in your current working directory or in the path specified.
Error reading input conversion file, line number <n>.	CTTRANS was unable to successfully read line number <n> of the input conversion file. Check the input file to insure that the fields conform to the file specifications contained in Appendix C2 of this report.
Error opening output report file.	CTTRANS was unable to create a new output report file. Make sure that the file does not already exist, that you have requested a valid path name, and that you have "write" privilege for the current or specified directory.
Error opening output summary file.	CTTRANS was unable to create a new output summary file. Make sure that the file does not already exist, that you have requested a valid path name, and that you have "write" privilege for the current or specified directory.
Error opening coord. loader file.	CTTRANS was unable to create a new output loader file. Make sure that the file does not already exist, that you have requested a valid path name, and that you have "write" privilege for the current or specified directory.
The maximum number of registration points was reached: <n>	The maximum number of registration points (shown as <n>) was exceeded. Reduce the number of records in your registration file or contact the CTRANS developers to request an increase in the number of allowable registration points.
ERROR - Reference file contains less than 4 reference points.	There must be at least four registration points in the file.
WARNING - Ref. points <name1> and <name2> are identical.	Two points in the registration input file have identical coordinate values. Remove one of them from the file.

C4. CTRANS Software Test Plan

1.0 Introduction

CTTRANS is a Fortran-77 program that converts (transforms) a set of point locations in one two-dimensional Cartesian coordinate system to a second coplanar two-dimensional Cartesian coordinate system. A set of four or more registration points (points with known locations in both coordinate systems) must be supplied for each pair of coordinate systems for which transformations are to be performed. This test plan contains instructions and an input data set (base test case) for testing the operation of CTRANS.

2.0 Installation

The following steps should be performed to install CTRANS and the base test case files on your Unix-based system. (Contact the CTRANS developers for instructions to install the software on a non-Unix system.)

1. Select a file system directory in which to store the executable CTRANS program files. Also select a directory from which you will perform your testing. You may choose to use the same directory for both purposes.
2. Contact the CTRANS developers to obtain electronic copies of the required files.
3. Copy the following files into your CTRANS installation directory:

```
ctrans.exe  
test_ctrans
```

4. Copy the following test case files into your testing directory:

```
ctest1.ref  
ctest1.inp  
ctest1_base.summ  
ctest1_base.rept  
ctest1_base.load
```

5. Insert the following lines into your account's .login file, substituting the full path names of the directories you have chosen for installation and testing as indicated by the text enclosed in angle brackets < >:

```
alias ctrans <your CTRANS installation directory path>/ctrans.exe  
alias test_ctrans source <CTTRANS installation directory path>/test_ctrans  
alias ctrans_dir cd <your CTRANS testing directory path>
```

This completes the installation of CTRANS and the base test case files on your system.

3.0 Testing Procedure

The base test case described herein was designed to permit validation of the correct operation of the transformation algorithms used by CTRANS. Verification that the operation of CTRANS is consistent with the user documentation must also be performed. The formal testing of CTRANS involves the following steps:

1. Obtain a copy of the CTRANS user documentation.
2. Create or obtain the base test case input files described and listed in Section 4 of this test plan.
3. Run CTRANS using the base test case input files, following the instructions contained in Section 5 of this test plan.
4. Verify that the user interaction proceeds according to the CTRANS user documentation and the instructions in this test plan.
5. Verify that the resulting output files produced by CTRANS are in agreement with the test case output files listed in this test plan.
6. Verify that the coordinates of each transformed point location calculated and reported by CTRANS agree to at least two decimal places with the hand calculated coordinate values listed in this test plan. For the range and precision (three decimal places) of the coordinate values included in the base test case, agreement to two decimal places is considered acceptable.
7. Compare the operation of CTRANS to that documented in the CTRANS User Instructions as contained in Appendix C3. Verify that the documentation is consistent with the actual operation of the program.
8. The tester should generate and run at least one additional independent test case. This is done by selecting a set of five or more point locations to be transformed, defining the coordinate transformation (in terms of the translation, rotation, and scaling parameters) to be performed on those points, and then using the translation, rotation, and scaling equations documented in Appendix C1 (Equations 1, 2, 3, 4, 5a, and 6a) to calculate the correct transformed coordinates of those points. See Section 4 of this test plan for an example of how to generate a test case. Select at least four of these points to be used as registration points. The registration points should be selected to provide representative coverage of the entire spatial area covered by the set of points to be transformed (i.e., there should be at least one registration point located reasonably near to each of the four corners of a bounding rectangle that encloses the set of points to be transformed), and the spacing between registration points should be roughly uniform. Construct the required input files as documented in Appendix C2. Then run this independent test case following the procedures outlined in this test plan.

4.0 Description of Base Test Case

Six point locations, as defined in Table C4-1, were arbitrarily selected and plotted in a Cartesian coordinate space. Successive operations of translation, rotation, and scaling, as defined below, were then applied by hand calculations to each of the six points, producing the transformed locations of the points with reference to a second Cartesian coordinate space that shares the same plane as the original coordinate system.

Translation: The points were translated by the amount (2000, -1000).

Rotation: The points were rotated 30 degrees in the clockwise direction.

Scaling: The points were scaled by a factor of 0.3 in both coordinate directions. Both transformation algorithms used by CTRANS, a three-point affine transformation and a two-point uniform scaling transformation, are thus applicable to this test case.

Table C4-1 presents a listing of the original and transformed coordinates, as determined by hand calculations, at each step of the transformation for each of the six test points. The results of the final scaling operation, as shown in the last two columns of Table C4-1, are the final transformed coordinates.

For the test case, the first five data points (A,B,C,D,E) in Table C4-1 were used to create a registration point file, ctest1.ref, as shown in Table C4-2.

Table C4-1. Transformation of Test Point Coordinates by Hand Calculation

<u>Point</u>	<u>Original</u>	<u>Translated</u>	<u>Rotated</u>	<u>Scaled</u>
A	(0, 5000)	(2000, 4000)	(3732.051, 2464.102)	(1119.615, 739.230)
B	(2000, 0)	(4000, -1000)	(2964.102, -2866.025)	(889.230, -859.808)
C	(6000, 4000)	(8000, 3000)	(8428.203, -1401.924)	(2528.461, -420.577)
D	(2500, 3000)	(4500, 2000)	(4897.114, -517.949)	(1469.134, -155.385)
E	(-2000, -2000)	(0, -3000)	(-1500.000, -2598.076)	(-450.000, -779.423)
F	(3000, 1000)	(5000, 0)	(4330.127, -2500.000)	(1299.038, -750.000)

Table C4-2. Registration Point File (ctest1.ref) for CTRANS Test.

<u>Point Name</u>	<u>Input Coordinates</u>		<u>Destination Coords.</u>	
	<u>Easting</u>	<u>Northing</u>	<u>Easting</u>	<u>Northing</u>
Point_A	0.000	5000.000	1119.615	739.230
Point_B	2000.000	0.000	889.230	-859.808
Point_C	6000.000	4000.000	2528.461	-420.577
Point_D	2500.000	3000.000	1469.134	-155.385
Point_E	-2000.000	-2000.000	-450.000	-779.423

The column headings in Table C4-2 are included for data identification only. They are not a part of the actual registration point file.

All six test points were then used to create a CTRANS conversion input file called ctest1.inp, as shown in Table C4-3.

Again, the column headings in Table C4-3 are included for data identification only and are not a part of the input file. With the exception of Point F, the hand-calculated destination coordinates are included in the input file so that CTRANS can compare and report the differences (distances) between these "known" coordinate values and the transformed values generated by the program. The destination coordinates of Point F are set to zero (indicating to CTRANS that the destination coordinates are unknown or not supplied) to allow this option to be tested. Columns 6 and 7 contain integer codes identifying the data sources of the input and destination coordinate pairs. A zero in Column 7 indicates that the destination coordinates were either not supplied or that the supplied values (Columns 4 and 5) were estimated for purposes of comparison only. See Appendix C2 for a complete description of the data source codes.

Table C4-3. Conversion Input File (ctest1.inp) for CTRANS Test.

2Point Name	<u>Input Coordinates</u>		<u>Destination Coords.</u>		<u>Data Source</u>	
	<u>Easting</u>	<u>Northing</u>	<u>Easting</u>	<u>Northing</u>	<u>Input</u>	<u>Dest.</u>
Point_A	0.000	5000.000	1119.615	739.230	7	0
Point_B	2000.000	0.000	889.230	-859.808	7	7
Point_C	6000.000	4000.000	2528.461	-420.577	7	6
Point_D	2500.000	3000.000	1469.134	-155.385	8	0
Point_E	-2000.000	-2000.000	-450.000	-779.423	2	4
Point_F	3000.000	1000.000	0.0	0.0	6	0

5.0 Performing the Test Case

CTRANS requires you to specify the names of two input files, three output files, and a coordinate lineage code. Detailed specifications of these files and the coordinate lineage code are provided in Appendices C2 and C3. The input files to be used in this test plan (described in the Section 4 above) are normally provided as part of the CTRANS installation. Before CTRANS is run, the current working directory must be set to the directory that contains the input files to be used. On Unix-based systems, this can normally be accomplished by entering the following command at the Unix shell prompt:

test_ctrans

This command will set your working directory to the test area and will then start the execution of CTRANS.

If your working directory is already set to the test area or to another directory containing your own test files, you may run CTRANS from your active directory by entering the following command at the operating system prompt:

ctrans

The first prompt message displayed by CTRANS should appear:

Enter name of file containing reference points:

Enter the name of the input file containing the reference (registration) points for converting from the desired source coordinate system to the desired destination coordinate system. For the test case, enter the following:

ctest1.ref

The following prompt message should now appear:

Enter name of file containing points to be converted:

Enter the name of the input file containing the names and source coordinates of the points you wish to transform to the destination coordinate system. For the test case, enter the following:

ctest1.inp

The following prompt message should now appear:

Enter name of output summary (list) file to be created:

Enter the name of the summary file to be created by CTRANS. For the test case, enter:

ctest1.summ

The following prompt message should now appear:

Enter name of detailed report (log) file to be created:

Enter the name of the report file to be created. For the test case, enter:

ctest1.rept

The following prompt message should now appear:

Enter name of coordinate loader file to be created:

Enter the name of the database coordinate loader file to be created. For the test case, enter:

ctest1.load

Finally, the following coordinate lineage code menu prompt should appear:

Enter coordinate lineage code indicating input coord. system:

- 6 -- Plant coordinates, 100-H Area datum
- 7 -- 100-N Area coordinates
- 8 -- Plant coordinates, all Areas except 100-H
- 9 -- Richland coordinates

The coordinate systems being used in the test case were arbitrarily created and do not correspond to any of the Hanford coordinate systems above. However, for testing purposes we will assume the input coordinates are Richland coordinates. To test the proper detection of acceptable inputs to this prompt, enter a number that is less than 6 or greater than 10. For example, enter:

5

CTTRANS should display the following message:

Please enter a value between 6 and 9.

The coordinate lineage code menu will then be displayed again. This time enter a number between 6 and 9. For the test case, enter:

9

This input should be accepted, and CTRANS should then proceed to normal completion (i.e., with no unresolvable errors). The following message will be printed upon completion of the test case:

6 points converted.

The number of points converted should agree with the number of points that were contained in the conversion input file.

After completion of the program, verify that the requested output files (ctest1.summ, ctest1.rept, and ctest1.load) were created in your current working directory. An examination of the summary file (ctest1.summ) should reveal only small differences (e.g. in the third decimal place) or no differences between the supplied and transformed destination coordinates for the first five points, indicating that the CTRANS coordinate transformation algorithms were operating properly.

Table C4-4 and Figures C4-1 and C4-2 show the summary, loader, and report files that should be produced by CTRANS for this test case. These files can be electronically compared to the reference base test case output files that are located in the CTRANS installation directory: ctest1_base.summ, ctest1_base.rept, and ctest1_base.load. Note that the test report file will contain the current date and time that the program was run, which will differ from the date and time contained in the reference report file to which it is compared.

Table C4-4. Summary Output File from CTRANS Test Case: ctest1.summ

<u>Point Name</u>	<u>Easting</u>	<u>Northing</u>	<u>DATA SOURCES</u>		<u>Reported coords.</u>	<u>Distance Error</u>
			<u>Input coords.</u>	<u>Result coords.</u>		
Point_A	1119.615	739.230	Testing	Est.	2-pt	0.000
Point_B	889.230	-859.808	Testing	Testing	Testing	0.000
Point_C	2528.461	-420.577	Testing	HEIS	HEIS	0.001
Point_D	1469.134	-155.385	Unknown	Est.	3-pt	0.000
Point_E	-450.000	-779.423	KEH	USACE	USACE	0.001
Point_F	1299.038	-750.000	HEIS	---	2-pt	

6 points converted.

Point_A?	1119.615?	739.230?9
Point_D?	1469.134?	-155.385?9
Point_E?	-450.555?	-779.423?4
Point_F?	1299.038?	-750.000?9

Figure C4-1. Database Coordinate Loader File from CTRANS Test Case: ctest1.load

```

*** Coordinate transformation program, v1.1 *** Tue Jun  8 21:57:11 1993
Ref. points file: ctest1.ref
Input points file: ctest1.inp
Output report (log) file: ctest1.rept
Output summary (list) file: ctest1.summ
Coord. loader file: ctest1.load
  Transform ID number (coordinate lineage code):  9

```

Reference points:

Point_A	0.000	5000.000	1119.615	739.230
Point_B	2000.000	0.000	889.230	-859.808
Point_C	6000.000	4000.000	2528.461	-420.577
Point_D	2500.000	3000.000	1469.134	-155.385
Point_E	-2000.000	-2000.000	-450.000	-779.423

Target point: Point_A Input coord. source: Testing Result coord. source: Est.

The three nearest reference points are:

Point_B	-- distance in input coord. units:	5.385165E+03
Point_C	-- distance in input coord. units:	6.082763E+03
Point_D	-- distance in input coord. units:	3.201562E+03

----- 3-point (affine) transform -----

```

*** Angles:  35.538  29.055 115.408 -- Minimum =  29.055
a,b,c,d,e,f:  2.598077E-01  1.500001E-01  369.615 -1.499999E-01  2.598077E-01  -559.808
"known" result coords.  Transformed (calculated)  Diff.(calc. - known)  Distance error
    1119.615    739.230    1119.615    739.230         0.000         0.000         0.000

```

----- 2-point (uniform scaling) transform -----

```

a,b,c,f:  2.598077E-01  1.500001E-01  369.61  -559.81
"known" result coords.  Transformed (calculated)  Diff.(calc. - known)  Distance error
    1119.615    739.230    1119.615    739.230         0.000         0.000         0.000

```

#####

Target point: Point_B Input coord. source: Testing Result coord. source: Testing

The three nearest reference points are:

Point_A	-- distance in input coord. units:	5.385165E+03
Point_E	-- distance in input coord. units:	4.472136E+03
Point_D	-- distance in input coord. units:	3.041381E+03

----- 3-point (affine) transform -----

```

*** Angles:  67.286  26.042  86.673 -- Minimum =  26.042
a,b,c,d,e,f:  2.598076E-01  1.500000E-01  369.615 -1.500000E-01  2.598076E-01  -559.808
"known" result coords.  Transformed (calculated)  Diff.(calc. - known)  Distance error
    889.230   -859.808    889.230   -859.808         0.000         0.000         0.000

```

----- 2-point (uniform scaling) transform -----

```

a,b,c,f:  2.598076E-01  1.500000E-01  369.62  -559.81
"known" result coords.  Transformed (calculated)  Diff.(calc. - known)  Distance error
    889.230   -859.808    889.230   -859.808         0.000         0.000         0.000

```

#####

Target point: Point_C Input coord. source: Testing Result coord. source: HEIS

The three nearest reference points are:

Point_A	-- distance in input coord. units:	6.082763E+03
Point_B	-- distance in input coord. units:	5.656854E+03
Point_D	-- distance in input coord. units:	3.640055E+03

----- 3-point (affine) transform -----

```

*** Angles:  29.539  31.264 119.197 -- Minimum =  29.539
a,b,c,d,e,f:  2.598076E-01  1.500001E-01  369.615 -1.499999E-01  2.598076E-01  -559.808
"known" result coords.  Transformed (calculated)  Diff.(calc. - known)  Distance error
    2528.461   -420.577    2528.461   -420.577         0.000         0.000         0.000

```

----- 2-point (uniform scaling) transform -----

```

a,b,c,f:  2.598077E-01  1.500001E-01  369.61  -559.81
"known" result coords.  Transformed (calculated)  Diff.(calc. - known)  Distance error
    2528.461   -420.577    2528.461   -420.578         0.000        -0.001         0.001

```

#####

Figure C4-2. Report (Log) Output File from CTRANS Test Case: ctest1.rept

```

Target point: Point_D      Input coord. source: Unknown      Result coord. source: Est.
The three nearest reference points are:
Point_A      -- distance in input coord. units:  3.201562E+03
Point_B      -- distance in input coord. units:  3.041381E+03
Point_C      -- distance in input coord. units:  3.640055E+03
----- 3-point (affine) transform -----
*** Angles:  58.736  66.801  54.462 -- Minimum =  54.462
a,b,c,d,e,f:  2.598077E-01  1.500001E-01  369.615 -1.499999E-01  2.598076E-01  -559.808
"known" result coords.  Transformed (calculated)  Diff.(calc. - known)  Distance error
1469.134  -155.385  1469.134  -155.385  0.000  0.000  0.000
----- 2-point (uniform scaling) transform -----
a,b,c,f:  2.598076E-01  1.500000E-01  369.61  -559.81
"known" result coords.  Transformed (calculated)  Diff.(calc. - known)  Distance error
1469.134  -155.385  1469.134  -155.385  0.000  0.000  0.000
#####
Target point: Point_E      Input coord. source: KEH      Result coord. source: USACE
The three nearest reference points are:
Point_A      -- distance in input coord. units:  7.280110E+03
Point_B      -- distance in input coord. units:  4.472136E+03
Point_D      -- distance in input coord. units:  6.726812E+03
----- 3-point (affine) transform -----
*** Angles:  29.539  31.264  119.197 -- Minimum =  29.539
a,b,c,d,e,f:  2.598076E-01  1.500001E-01  369.615 -1.499999E-01  2.598076E-01  -559.808
"known" result coords.  Transformed (calculated)  Diff.(calc. - known)  Distance error
-450.000  -779.423  -450.001  -779.424  -0.001  -0.001  0.001
----- 2-point (uniform scaling) transform -----
a,b,c,f:  2.598077E-01  1.500001E-01  369.61  -559.81
"known" result coords.  Transformed (calculated)  Diff.(calc. - known)  Distance error
-450.000  -779.423  -450.001  -779.423  -0.001  0.000  0.001
#####
Target point: Point_F      Input coord. source: HEIS      Result coord. source: ----
The three nearest reference points are:
Point_D      -- distance in input coord. units:  2.061553E+03
Point_B      -- distance in input coord. units:  1.414214E+03
Point_C      -- distance in input coord. units:  4.242641E+03
----- 3-point (affine) transform -----
*** Angles:  115.408  35.538  29.055 -- Minimum =  29.055
a,b,c,d,e,f:  2.598077E-01  1.500000E-01  369.615 -1.499999E-01  2.598077E-01  -559.808
Transformed (calculated)
1299.038  -750.000
----- 2-point (uniform scaling) transform -----
a,b,c,f:  2.598077E-01  1.500001E-01  369.61  -559.81
Transformed (calculated)
1299.038  -750.000
#####
6 points converted.

```

Figure C4-2. (contd)

C5. CTRANS - Software Testing Report

Tested by: Rose Byrum

July 13, 1993

1.0 Introduction

This Appendix describes the independent testing of a Fortran-77 software program called CTRANS that performs point location coordinate conversions. The testing proceeded in accordance with the instructions contained in the **CTTRANS Software Test Plan** (Appendix C4).

2.0 Testing Summary

The CTRANS program was found to operate as stated in the test plan and user documentation. The output files from the test cases indicated that the coordinate conversion algorithm as coded in CTRANS is operating properly. Some inconsistencies in the error messages produced under certain conditions by CTRANS were noted and are documented in Section 4 of this report along with some suggestions for improving the program's operation.

A summary of the testing process and the results that were obtained is presented below. The item numbers correspond to the numbers for the testing steps as documented in the test plan.

1. Copies of the CTRANS test plan and user documentation were obtained and reviewed.
2. The base test case input files were obtained. The three aliases were set up following the installation procedures contained in the test plan.
3. Because the ctrans.exe file did not initially have executable privileges, the following text should be added to the installation instructions in the test plan document at Section 2.0, at the end of Item 3:

At the operating system prompt, type the following commands:

```
chmod 755 ctrans.exe
chmod 755 test_ctrans
```

4. CTRANS was run using the base test case as instructed in the test plan. User interaction corresponded to the test plan description.
5. The three requested output files for the base test case (ctest1.summ, ctest1.rept, and ctest1.load) were correctly created by the program in the working directory.

6. The three output files were compared with the reference output files for the base case and found to agree within the limits stated in the test plan. The coordinate values contained in the summary output file were compared with the hand-calculated coordinate values as documented in the test plan for each transformed point. The two sets of coordinates were found to agree to within the required two decimal places.
7. In comparing the CTRANS user documentation with the operation of CTRANS, the documentation was found to be consistent with the actual operation.
8. Two independent test cases were created and run. Details of these additional test cases are described in the following section.

3.0 Independent Test Cases

Test Case A. For the first independent test (Case A), the translation, rotation, and scale factors selected were:

Translation 2000, -1000
 Rotation 21.5 degrees cw
 Scale Factor 0.5

Four points were defined as the registration (reference) point set. Two additional points were selected and added to the four reference points to make up the set of points to be converted. Hand calculations were performed using the aforementioned translation, rotation, and scale factors to produce the destination coordinates for the four registration points and the correct transformed coordinates for the remaining two input points. The input files ctest2.ref and ctest2.inp, shown in Tables C5-1 and C5-2 respectively, were created.

Point_A	-2000.000	-2000.000	-549.751	-1395.626
Point_B	4000.000	5000.000	3524.255	761.331
Point_C	-3000.000	6000.000	451.044	2509.294
Point_D	5000.000	-2500.000	2615.084	-2910.985

Figure C5-1. Registration Point File (ctest2.ref) for Independent Test Case A

Point_A	-2000.000	-2000.000	-549.751	-1395.626	6	4
Point_B	4000.000	5000.000	3524.255	761.331	2	4
Point_C	-3000.000	6000.000	451.044	2509.294	8	6
Point_D	5000.000	-2500.000	2615.084	-2910.985	7	6
Point_E	0.000	3000.000	0.0	0.0	7	0
Point_F	1000.000	2000.000	0.0	0.0	2	0

Figure C5-2. Conversion Input File (ctest2.inp) for Independent Test Case A.

The CTRANS program was started and the names of the two input files were entered. The output file names ctest2.summ, ctest2.rept, and ctest2.load were then entered. A coordinate lineage code of 8 was entered in response to the coordinate lineage prompt and menu.

The hand-calculated transformed output coordinates for Case A are shown in Table C5-3. The results generated by CTRANS in the output file ctest2.summ are presented in Table C5-4.

Table C5-3. Independent Test Case A: Hand Calculations

<u>Point Name</u>	<u>Original</u>	<u>Translated (2000,-1000)</u>	<u>Rotated (21.5 deg. cw)</u>	<u>Scaled (0.5)</u>
Point_A	-2000.000, -2000.000	0, -3000	-1099.503, -2791.252	-549.751, -1395.626
Point_B	4000.000, 5000.000	6000, 4000	7048.510, 1522.663	3524.255, 761.331
Point_C	-3000.000, 6000.000	-1000, 5000	902.089, 5018.589	451.044, 2509.294
Point_D	5000.000, -2500.000	7000, -3500	5230.168, -5821.970	2615.084, -2910.985
Point_E	0.000, 3000.000	2000, 2000	2593.838, 1127.833	1296.919, 563.916
Point_F	1000.000, 2000.000	3000, 1000	3157.754, -169.086	1578.877, -84.543

Table C5-4. Summary Output File for Independent Test Case A

<u>Point Name</u>	<u>DATA SOURCES</u>					
	<u>Easting</u>	<u>Northing</u>	<u>Input coords.</u>	<u>Result coords.</u>	<u>Reported coords.</u>	<u>Distance Error</u>
Point_A	-549.751	-1395.626	HEIS	USACE	USACE	0.001
Point_B	3524.255	761.331	KEH	USACE	USACE	0.001
Point_C	451.044	2509.294	Unknown	HEIS	HEIS	0.001
Point_D	2615.084	-2910.985	Testing	HEIS	HEIS	0.001
Point_E	1296.919	563.916	Testing	---	3-pt	
Point_F	1578.877	-84.543	KEH	---	3-pt	

6 points converted.

Conclusion: The distance error was 0.001 coordinate units for each of the four reference points. The probable reason for this uniformity is that the hand calculations were truncated at three decimal points instead of rounding them. The destination coordinates computed by CTRANS for the two additional points (Point_E and Point_F) matched the hand calculated coordinate values to three decimal places.

Test Case B. For the second independent test (Case B), the translation, rotation, and scale factors used were:

Translation -2000, 3000
 Rotation 35.0 degrees cw
 Scale Factor 0.8

Four points were defined as the registration (reference) point set. Two additional points were selected and added to the four reference points to make up the set of points to be converted. Hand calculations were performed using the aforementioned translation, rotation, and scale factors to produce the destination coordinates for the four registration points and the correct transformed coordinates for the remaining two input points. The input files ctest3.ref and ctest3.inp, shown in Tables C5-5 and C5-6 respectively, were created.

The CTRANS program was started and the names of the two input files were entered. The output file names ctest3.summ, ctest3.rept, and ctest3.load were then entered. A coordinate lineage code of 6 was entered in response to the coordinate lineage prompt and menu.

The hand-calculated transformed output coordinates for Case B are shown in Table C5-7. The results generated by CTRANS in the output file ctest3.summ are presented in Table C5-8.

Point_A	4500.000	5000.000	5309.192	4095.420
Point_B	-3500.000	-5500.000	-4751.421	885.432
Point_C	-3000.000	4000.000	-64.580	6881.557
Point_D	6000.000	-5000.000	1703.564	-3146.088

Figure C5-5. Registration Point File (ctest3.ref) for Independent Test Case B.

Point_A	4500.000	5000.000	5309.192	4095.420	2	7
Point_B	-3500.000	-5500.000	-4751.421	885.432	6	7
Point_C	-3000.000	4000.000	-64.580	6881.557	7	4
Point_D	6000.000	-5000.000	1703.564	-3146.088	2	6
Point_E	2000.000	1000.000	0.0	0.0	8	0
Point_F	4000.000	-1500.000	0.0	0.0	7	0

Figure C5-6. Conversion Input File (ctest3.inp) for Independent Test Case B.

Table C5-7. Independent Test Case B: Hand Calculations

<u>Point Name</u>	<u>Original</u>	<u>Translated (-2000, 3000)</u>	<u>Rotated (35.0 deg. cw)</u>	<u>Scaled (0.8)</u>
Point_A	4500.000, 5000.000	2500, 8000	6636.491, 5119.275	5309.192, 4095.420
Point_B	-3500.000, -5500.000	-5500, -2500	-5939.277, 1106.790	-4751.421, 885.432
Point_C	-3000.000, 4000.000	-5000, 7000	-80.725, 8601.946	-64.580, 6881.557
Point_D	6000.000, -5000.000	4000, -2000	2129.455, -3932.610	1703.564, -3146.088
Point_E	2000.000, 1000.000	0, 4000	2294.305, 3276.608	1835.444, 2621.287
Point_F	4000.000, -1500.000	2000, 1500	2498.669, 81.575	1998.935, 65.260

Table C5-8. Summary Output File for Independent Test Case B

<u>DATA SOURCES</u>						
<u>Point Name</u>	<u>Easting</u>	<u>Northing</u>	<u>Input coords.</u>	<u>Result coords.</u>	<u>Reported coords.</u>	<u>Distance Error</u>
Point_A	5309.192	4095.420	KEH	Testing	Testing	0.001
Point_B	-4751.421	885.432	HEIS	Testing	Testing	0.001
Point_C	-64.580	6881.557	Testing	USACE	USACE	0.000
Point_D	1703.564	-3146.088	KEH	HEIS	HEIS	0.001
Point_E	1835.444	2621.286	Unknown	----	3-pt	
Point_F	1998.935	65.260	Testing	----	3-pt	

6 points converted.

Conclusion: The distance error in coordinate units was 0.001 or less for each of the four reference points. The destination coordinates computed by CTRANS for the two additional points (Point_E and Point_F) were within 0.001 coordinate units of the hand calculated values. Rounding was used in the hand calculations for Case B.

4.0 Other Tests, Observations and Recommendations

1. If the user wishes to terminate the program execution, <control-C> does interrupt the program and creates a 'ctrans.exe.trace' file in the ctrans directory.
2. The misspelling of the name of one of the input files results in the message "Error opening output report file." Change error message to: "Error opening input file."

3. The input reference file was removed from the testing area. The resulting error message should have been "Error opening input reference file" but instead was "Error opening output report file." Error message needs to be changed.
4. The input conversion file was removed from the testing area. The resulting error message should have been "Error opening input conversion file" but instead was "Error opening output report file." Error message needs to be changed.
5. Line three of numerical data in the input conversion file was replaced with random alphabetical characters. The resulting error message should have been "Error reading input conversion file, line number <n>" but instead was "Error opening output report file." Error message needs to be changed.
6. The output report file was left in the testing area while removing the other two output files from a previous run. The proper error message "Error opening output report file" was displayed.
7. The output summary file was left in the testing area while removing the other two output files from a previous run. The proper error message "Error opening output summary file" was displayed. An empty coordinate loader file was created, as was a short output report file.
8. The coordinate loader file was left in the testing area while removing the other two output files from a previous run. The proper error message "Error opening coord. loader file" was displayed. A short output report file was created.
9. The second line (beginning with Point_B) in the reference file was removed, leaving only 3 reference points. A short output report was produced by the program, and the proper error message "ERROR - Reference file contains less than 4 points" was displayed.
10. Point_B and Point_C were given identical coordinate values in the registration input file. A short output report file was created, but the error message "Error opening output report file" was displayed instead of "WARNING - Ref. points <name1> and <name2> are identical." Error message needs to be changed.
11. When an unnoticed error is made in the spelling of an input file, the user interaction proceeds all the way through the prompting for all file names and the choosing of a coordinate lineage code before stopping and displaying an error message. The presence of each input file should be checked upon entry of the file name by the user.
12. It would be helpful to have clearer documentation on the flexibility of naming input and output files (page 1, Appendix C3). State if any name is allowable, or if there are restrictions on what names are preferred or acceptable.
13. User documentation could be made more readable by breaking up large blocks of text into paragraphs (page 4, Appendix C1).

14. If output files still exist from a previous run, the user must go completely through all interaction before being told "Error opening output report file." Each output file could be checked upon entry and optionally overwritten upon user confirmation.
15. The operation of CTRANS is consistent regardless of where the test case input files are located (i.e., within the CTRANS installation directory or in a separate testing directory).

C6. CTRANS Peer Review Comments

Date: April 26, 1993

Presented by: Bob Burnett, Spyros Tzemos

Reviewers: Ron Schalla, Bruce Rex, Rick Bates

(Note: David Millard also reviewed and provided comments on the draft report but was unable to attend the review meeting.)

1. The accuracy of the transformation for a particular set of points depends on the accuracy of the input coordinates and the accuracy and placement of the set of registration points used. There was concern regarding the accuracy of the Hanford well location data and registration points. To the extent possible, it is important to estimate the local and global conversion errors attributable to registration point inaccuracies.
2. The process of selecting and validating registration points, as documented in the report, is somewhat subjective in that it is difficult to isolate errors contributed by individual candidate registration points, and so a certain amount of human judgment must ultimately be brought into play to decide which candidate registration points are eliminated and which are retained.
3. The summary and introduction needs to state more clearly why the algorithm and coordinate conversion effort is needed.
4. The expectations of the reader need to be clearly defined and limited in the summary and introduction. State the limitations of the described algorithm and process as applied to the Hanford well location conversion work.
5. It may be possible to correlate registration point errors (and hence errors in transformed locations that use those registration points) to distance from the local coordinate system's primary survey baseline. However, since different surveyed points use different control points, and there are considerable inconsistencies in the manner in which control and closure information is documented on the Hanford survey data sheets, it would be difficult to quantify this distance relationship.
6. The use of more than three registration points for each target point to be converted should be explored. For example, a convex hull could be used to select registration points near the target point and successively reduced until the number of selected registration points falls within a specified range. A simpler way to select points would be to specify a minimum and maximum number of points desired and a maximum allowable distance (radius) from the target point. It was suggested that, for the Hanford Site data, the simpler method is probably better.
7. We should develop the best possible set of registration points for each local coordinate system from the currently available data, convert the well locations using those registration points, report and disseminate the results, and then stop. Frequent corrections could be counterproductive. Reconversion should be considered only following completion of a major survey effort (e.g., USACE) that provides a significant number of new survey points and/or significantly more accurate location information on previously surveyed wells.

C7. CTRANS Program Listing

```
C ctrans.for
C
C *** Coordinate transformation program, Version 1.1 ***
C— R.A.Burnett / Battelle Pacific Northwest Laboratories / April 1993
C
C ***** Purpose: *****
C—Transform input points from a source coord. system to a destination coord.
C system (e.g. from Plant to Waah. State Plane Lambert NAD83) using
C nearest 2 reference points (2-point uniform scaling transformation) and
C nearest 3 reference points (3-point affine transformation). Select
C either 2-pt. or 3-pt. results based on co-linearity of the three
C reference points.
C
C ***** Description: *****
C—Read in a list of reference (registration) points having known coordinate
C values in 2 coord. systems ("source" and "destination" coordinates).
C Also read in points to be transformed, having source coord. values only
C (they may also have "known" destination coordinate values for purposes
C of comparison; e.g., the points to be transformed can be the same
C list as the reference points, for performing reference point
C cross-verification/validation).
C—For each point to be transformed, find the three nearest reference points
C and use those points to solve 2 sets of 3 eqns./3 unknowns each to get
C transformation parameters for affine (3-point) transformation.
C—Also for each point, find the 2 nearest ref. points and use those points
C to solve 4 eqns./4 unknowns to get conversion parameters for
C uniform-scaling (2-point) transformation.
C—Use derived transformation parameters to perform 3-pt. and 2-pt.
C conversions on source coords. for all points to be converted
C and compare the transformed results with the "known" destination
C coordinates (if supplied) of each point.
C—Generate three output files: (1) a log/report file containing details of
C each transformation; (2) a summary file of point names (e.g. well names)
C and the resulting destination coordinates (selected from either 2-pt.
C or 3-pt. results). This file can be used to create a map coverage
C in Arc/Info or other geographic information systems; and (3) a specially
C formatted database loader input file containing the well name, resulting
C coordinates, and a numeric code indicating the source of the coordinate
C data. The latter file will be used by HEIS database loader software to
C load the well coordinate information into HEIS.
C
C implicit none
C— Fortran logical I/O units
C integer lref,lconv,lrept,lload,lsumm,ldebug
C parameter (lref=12)
C parameter (lconv=11)
C parameter (lrept=13)
C parameter (lload=14)
C parameter (lsumm=15)
C parameter (ldebug=16)
C— Number of "well transformation reports" per page of report (log) file
C integer nperpage
C parameter (nperpage=4)
```

C- MAXP is maximum number of reference points

```

integer MAXP
parameter (MAXP=250)
double precision xs1,xs2,xs3,ys1,ys2,ys3
double precision xd1,xd2,xd3,yd1,yd2,yd3
double precision denom,ca,cb,cd,ce, edistout
double precision dist(3),distn,xst,yst,xout,yout
double precision xdt,ydt,xdest2,ydest2,xdiff2,ydiff2
double precision xdest3,ydest3,xdiff3,ydiff3,edist2,edist3
double precision aerrsum,rmsum,aerr,rmserr
integer indx(3),maxof3,nbeg,k1,k2,k3,nchrs
integer i,j,k,m,np,ns,n,ncon,konfid,npg
character*120 aline
character*13 pname(MAXP),cname
character*4 convtype
character*48 fref,fconv,frept,fload,fsumm
double precision xfrom(MAXP),yfrom(MAXP),xto(MAXP),yto(MAXP)
double precision a,b,c,d,e,f,deltax,deltay
double precision ang12,ang13,ang23,ada,adb,adc,admin
double precision ang21,ang31,ang32
integer ilocal, ilamb
character*7 l83src,localsrc
character*26 curtime, ctime
integer*4 stime, time
logical ident12, ident13, ident23, use2, report_errs
double precision pi, angle_limit
data pi / 3.141592654 /

```

C- angle_limit is the angle threshold in degrees, such that if the

C minimum angle in the triangle connecting the 3 "nearest neighbor"

C reference points is less than this threshold, use 2-pt transform

data angle_limit / 30.0 /

C

2 write(*,*)

\$*** CTRANS coordinate transformation program ***

write(*,*)

\$ ' Enter name of file containing reference points:'

read (*,801) fref

801 format(a48)

write(*,*)

\$ ' Enter name of file containing points to be converted:'

read (*,801) fconv

write(*,*)

\$ ' Enter name of output summary (list) file to be created:'

read (*,801) fsumm

write(*,*)

\$ ' Enter name of detailed report (log) file to be created:'

read (*,801) frept

write(*,*)

\$ ' Enter name of coordinate loader file to be created:'

read (*,801) fload

```

3   write(*,803)
803  format(
    $' Enter coordinate lineage code indicating input coord. system:/'
    $'      6 - Plant coordinates, 100-H Area datum/'
    $'      7 - 100-N Area coordinates/'
    $'      8 - Plant coordinates, all Areas except 100-H/'
    $'      9 - Richland coordinates')
    read(*,*,err=4) konfid
    if (konfid .lt. 6 .or. konfid .gt. 9) then
4      write(*,*) ' Please enter a value between 6 and 9.'
      go to 3
    endif
    open (unit=lrept,file=frept,status='new',err=995)
CCC $ ,carriagecontrol='fortran')
    open (unit=lref,file=fref,status='old',err=996)
C *****
C *** Write current date and time to report file ***
    stime = time()
    curtime = ctime(stime)
    write (lrept,601) curtime
601  format(
    $' *** Coordinate transformation program, v1.1 *** ',a26)
C *****
    write(lrept,*) ' Ref. points file: ',fref
    write(lrept,*) ' Input points file: ',fconv
    write(lrept,*) ' Output report (log) file: ',frept
    write(lrept,*) ' Output summary (list) file: ',fsumm
    write(lrept,*) ' Coord. loader file: ',fload
    write(lrept,*)
    $ ' Transform ID number (coordinate lineage code):',konfid
    write(lrept,401)
401  format('/ Reference points:')
C    write (*,701) MAXP
C701  format(
C $ ' Enter from 4 to ',I3,' reference points. For each point,/'
C $ ' enter the following 5 fields in the order shown on one line:/'
C $ ' Point name, Source E/W coord., Source N/S coord.,/'
C $ ' Destination E/W coord., Destination N/S coord./'
C $ ' Use space or comma to separate fields./'
C $ ' Enter CTRL-Z after last point./')
C    write (*,*) ' Enter first point:'
C
    np = 0
5    continue
    np = np + 1
    if (np .gt. MAXP) then
        write (*,901) MAXP
901  format(' Maximum no. of reference points reached: ',I4)
        go to 10
    endif
7    aline = ' '
    read(lref,802,end=10) ns,(aline(i:i),i=1,min(ns,120))
802  format(Q,120a1)

```

```

C--Find first non-blank in input line
  do j = 1,ns
    if (aline(j:j).ne.' ') then
      k=j
      go to 13
    endif
  enddo
C-- Entire line is blank -- ignore it.
  go to 7
13  continue
C-- Find first blank or comma after first non-blank in input line
  do m = k+1,k+12
    if (aline(m:m).eq.' ' .or. aline(m:m).eq.',') then
      n = m-1
      go to 14
    endif
  enddo
  n = k+12
14  continue
  pname(np) = ' '
  i = 0
  do j = k,n
    i = i + 1
    pname(np)(i:i) = aline(j:j)
  enddo
  read(aline(n+2:120),*) xfrom(np),yfrom(np),xto(np),yto(np)
C-- Echo data on this point to output file
  write(lrept,808) pname(np),xfrom(np),yfrom(np),xto(np),yto(np)
808  format(1x,a,4f13.3)
C
C   write (*,*) ' Enter next point:'
  go to 5
C
10  continue
  close (unit=lref)
  np = np - 1
  if (np.lt.4) then
    write (*,*) ' ERROR - Reference file contains less than 4 points'
    STOP
  endif
C -----
C-- Open input file of points to be converted
  open (unit=lconv,file=fconv,status='old',err=994)
C-- Open coord. loader file
  open (unit=lload,file=fload,status='new',err=993)
C-- Open output summary file
  open (unit=lsumm,file=fsumm,status='new',err=992)
C-- Write header to summary file
  write (lsumm, 699)
699  format(40x,'-DATA SOURCES-',/,
$    40x,'Input Result Reported Distance',/,
$    ' Point Name',7x,'Easting',4x,'Northing',
$    3x,3('coords. '),4x,'Error'/)

```

```

C
11  continue
    ncon = 0
C- Put "nperpage" well transformation reports on each page
    npg = nperpage
C- Initialize error sum and rms sum
    rmasum = 0.0
    aerrsum = 0.0
    report_errs = .true.

C
C***** TOP OF MAIN PROGRAM LOOP *****
C
C-Read the next point to be converted
2005  continue
      ident12 = .false.
      ident13 = .false.
      ident23 = .false.
      ncon = ncon + 1
2007  aline = ' '
C ** Exit out of main program loop on End-of-File **
      read(lconv,802,end=2088) ns,(aline(i:i),i=1,min(ns,120))
      npg = npg + 1
      if(npg .gt. nperpage) then
C - Write a form-feed (new page) to report file
        npg = 1
        write(lrept,2006)
2006  format('<FF>')
      endif
C-Find first non-blank in input line
      do j = 1,ns
        if (aline(j:j).ne.' ') then
          k=j
          go to 2013
        endif
      enddo
C- Entire line is blank -- ignore it.
      go to 2007
2013  continue
C- Find first blank or comma after first non-blank in input line
      do m = k+1,k+12
        if (aline(m:m).eq.' ' .or. aline(m:m).eq.',') then
          n = m-1
          go to 2014
        endif
      enddo
      n = k+12
2014  continue
      cname = ' '
      nchrs = 0
      do j = k,n
        nchrs = nchrs + 1
        cname(nchrs:nchrs) = aline(j:j)
      enddo
      read(aline(n+2:120),*,err=2021) xst,yst,xdt,ydt,ilocal,ilamb
      go to 22

```

```

C
C--Read error: Assume the data source fields were blank
2021 ilocal = 0
    ilamb = 0
    read(aline(n+2:120),*,err=2031) xst,yst,xdt,ydt
    go to 22
C
C-- Assume the destination coord. fields were blank
2031 xdt = 0.0
    ydt = 0.0
    read(aline(n+2:120),*,err=991) xst,yst
C
22 continue
C-- For each target point, find the 3 closest points (in source coords.)
    j = 0
    do k = 1,3
        if (pname(k) .ne. cname) then
            j = j + 1
            dist(j) = (xfrom(k)-xst)**2 + (yfrom(k)-yst)**2
            indx(j) = k
        endif
    enddo
C
    if(j.eq.2) then
        indx(3) = 4
        dist(3) = (xfrom(4)-xst)**2 + (yfrom(4)-yst)**2
        nbeg = 5
    else
        nbeg = 4
    endif
C--Find out which of 3 "starter" points is the farthest from target point
    call maxey3(dist,maxof3)
C-- If there were only 3 points total, or if there were 4 points and the
C target point is one of them, then we already have our "nearest 3"
    if (nbeg .le. np) then
        do n = nbeg, np
            if (pname(n).ne.cname) then
                distn = (xfrom(n)-xst)**2 + (yfrom(n)-yst)**2
                if (distn .lt. dist(maxof3)) then
C-- We have a new member of the 3 musketeers (nearest neighbors)
                    indx(maxof3) = n
                    dist(maxof3) = distn
                endif
            endif
        enddo
    endif
C-- Find the new max. distance of the 3 nearest ref. points
    call maxey3(dist,maxof3)
    endif
endif

```

C

```

k1 = indx(1)
k2 = indx(2)
k3 = indx(3)
dist(1) = sqrt(dist(1))
dist(2) = sqrt(dist(2))
dist(3) = sqrt(dist(3))
if (ilocal .eq. 1) then
  localsrc = 'WELLDX'
else if (ilocal .eq. 2) then
  localsrc = 'KEH'
else if (ilocal .eq. 3) then
  localsrc = 'KEH'
else if (ilocal .eq. 4) then
  localsrc = 'USACE'
else if (ilocal .eq. 5) then
  localsrc = 'Other'
else if (ilocal .eq. 6) then
  localsrc = 'HEIS'
else if (ilocal .eq. 7) then
  localsrc = 'Testing'
else
  localsrc = 'Unknown'
endif
if (ilamb.gt.0.and.(xdt.eq.0. .or. ydt.eq.0.)) then
  l83src = 'missing'
else if (ilamb.eq.0.and.xdt.ne.0. .and. ydt.ne.0.) then
  l83src = 'Est.'
else if (ilamb .eq. 1) then
  l83src = 'WELLDX'
else if (ilamb .eq. 2) then
  l83src = 'KEH-L83'
else if (ilamb .eq. 3) then
  l83src = 'KEH-L27'
else if (ilamb .eq. 4) then
  l83src = 'USACE'
else if (ilamb .eq. 5) then
  l83src = 'Ind.GPS'
else if (ilamb .eq. 6) then
  l83src = 'HEIS'
else if (ilamb .eq. 7) then
  l83src = 'Testing'
else
  l83src = '___'
endif
write(lrept,921) cname,localsrc,l83src,
$   pname(k1),dist(1),pname(k2),dist(2),pname(k3),dist(3)
921 format(' Target point: ',a,
$   ' Input coord. source: ',a7,
$   ' Result coord. source: ',a7/
$   ' The three nearest reference points are: '/
$   3(1x,a,' - distance in input coord. units: ',1pe14.6/),
$   '----- 3-point (affine) transform -----')
```

C

```
xs1 = xfrom(k1)
ys1 = yfrom(k1)
xd1 = xto(k1)
yd1 = yto(k1)
xs2 = xfrom(k2)
ys2 = yfrom(k2)
xd2 = xto(k2)
yd2 = yto(k2)
xs3 = xfrom(k3)
ys3 = yfrom(k3)
xd3 = xto(k3)
yd3 = yto(k3)
```

C— For the lines joining the three nearest neighbor ref. points,
C compute angles ang12, ang13, ang23 from the horizontal
C (-90 < angle in degrees < 90)

C

C— Line from point 1 to point 2

```
deltax = xs2 - xs1
deltay = ys2 - ys1
if (deltax .eq. 0. .and. deltax .eq. 0.) then
```

C— Points 1 and 2 are identical

```
ident12 = .true.
write(*,891) pname(k1),pname(k2)
write(lrept,891) pname(k1),pname(k2)
```

891 format(' *** WARNING - Ref. points ',a,' and ',a,
\$ ' are identical ***')

C— Force 2-pt transform to use points 2 and 3

```
maxof3 = 1
go to 123
else
  ident12 = .false.
endif
ang12 = 180.*asin(deltay/sqrt(deltax**2 + deltax**2))/pi
```

CC write(lrept,*) ' ANG12 = ',ang12

```
if (deltax .lt. 0.) then
  ang21 = -ang12
  ang12 = ang21 + 180.0
  if (ang12 .gt. 180.0) ang12 = ang12 - 360.
else
  ang21 = ang12 + 180.0
  if (ang21 .gt. 180.0) ang21 = ang21 - 360.
endif
```

C— Line from point 1 to point 3

```
deltax = xs3 - xs1
deltay = ys3 - ys1
if (deltax .eq. 0. .and. deltax .eq. 0.) then
```

C— Points 1 and 3 are identical

```
ident13 = .true.
write(*,891) pname(k1),pname(k3)
write(lrept,891) pname(k1),pname(k3)
```



```

C- Force 2-pt transform to use points 2 and 3
    maxof3 = 1
    go to 123
    else
        ident13 = .false.
    endif
    ang13 = 180.*asin(deltay/sqrt(deltax**2 + deltay**2))/pi
CC   write(lrept,*) ' ANG13 = ',ang13
    if (deltax .lt. 0.) then
        ang31 = -ang13
        ang13 = ang31 + 180.0
        if (ang13 .gt. 180.0) ang13 = ang13 - 360.
    else
        ang31 = ang13 + 180.0
        if (ang31 .gt. 180.0) ang31 = ang31 - 360.
    endif
C- Line from point 2 to point 3
    deltax = xa3 - xa2
    deltay = ya3 - ya2
    if (deltax .eq. 0. .and. deltay .eq. 0.) then
C- Points 2 and 3 are identical
        ident23 = .true.
        write(*,891) pname(k2),pname(k3)
        write(lrept,891) pname(k2),pname(k3)
C- Force 2-pt transform to use points 1 and 2
        maxof3 = 3
        go to 123
    else
        ident23 = .false.
    endif
    ang23 = 180.*asin(deltay/sqrt(deltax**2 + deltay**2))/pi
CC   write(lrept,*) ' ANG23 = ',ang23
    if (deltax .lt. 0.) then
        ang32 = -ang23
        ang23 = ang32 + 180.0
        if (ang23 .gt. 180.0) ang23 = ang23 - 360.
    else
        ang32 = ang23 + 180.0
        if (ang32 .gt. 180.0) ang32 = ang32 - 360.
    endif
C-Compute differences in angles with horiz. to get true angles of
C   triangle connecting the three nearest neighbor ref. pts.
C-Then find the minimum angle. If less than threshold, use
C   2-pt conversion results, otherwise use 3-pt. results
CC   write(lrept,*) '12/13/21/23/31/32: ',
CC   $      ang12,ang13,ang21,ang23,ang31,ang32
        ada = abs(ang12 - ang13)
        if (ada .gt. 180.) ada = 360. - ada
        adb = abs(ang21 - ang23)
        if (adb .gt. 180.) adb = 360. - adb
        adc = abs(ang31 - ang32)
        if (adc .gt. 180.) adc = 360. - adc
C- find min. angle
        admin = min(ada, adb, adc)
        write(lrept,892) ada,adb,adc,admin
892   format(' *** Angles: ',3f9.3,' - Minimum = ',f9.3)

```

```

C
C- Do the 3-point transform math and store coeffs. in a,b,c,d,e,f
  denom = xs1*(ys2-ys3) - xs2*(ys1-ys3) + xs3*(ys1-ys2)
C- If denominator = 0, the transform failed
  if (denom .eq. 0.) then
    write(lrept,897)
897    format(
      $ ' **** Denominator is zero - 3-pt transform failed.' )
    use2 = .true.
  else
C- Denominator was not zero - continue the calculations
    ca = xd1*(ys2-ys3) - xd2*(ys1-ys3) + xd3*(ys1-ys2)
    cb = xs1*(xd2-xd3) - xs2*(xd1-xd3) + xs3*(xd1-xd2)
    a = ca/denom
    b = cb/denom
    c = xd1 - a*xs1 - b*ys1
C ##### Alternate ways to calculate c #####
CC  c2 = xd2 - a*xs2 - b*ys2
CC  c3 = xd3 - a*xs3 - b*ys3
CC  cc = (xs1*(ys2*xd3 - ys3*xd2) - xs2*(ys1*xd3 - ys3*xd1)
CC  $    + xs3*(ys1*xd2 - ys2*xd1))/denom
C #####
    cd = yd1*(ys2-ys3) - yd2*(ys1-ys3) + yd3*(ys1-ys2)
    ce = xs1*(yd2-yd3) - xs2*(yd1-yd3) + xs3*(yd1-yd2)
    d = cd/denom
    e = ce/denom
    f = yd1 - d*xs1 - e*ys1
C ##### Alternate ways to calculate f #####
CC  f2 = yd2 - d*xs2 - e*ys2
CC  f3 = yd3 - d*xs3 - e*ys3
CC  ff = (xs1*(ys2*yd3 - ys3*yd2) - xs2*(ys1*yd3 - ys3*yd1)
CC  $    + xs3*(ys1*yd2 - ys2*yd1))/denom
C #####
    use2 = .false.
C- Write transform coefficients to output file
  write(lrept,903) a,b,c,d,e,f
903  format(' a,b,c,d,e,f: ',2(1p2e14.6,0pf12.3))
C- Compute destination coords. from source coords. for target point
  xdest3 = a*xst + b*yst + c
  ydest3 = d*xst + e*yst + f
  xdiff3 = xdest3 - xdt
  ydiff3 = ydest3 - ydt
  if (xdiff3.eq.0. .and. ydiff3.eq.0.) then
    edist3 = 0.
  else
    edist3 = sqrt (xdiff3**2 + ydiff3**2)
  endif
C- Report the results
  if (xdt .ne. 0.) then
    write(lrept,919) xdt,ydt,xdest3,ydest3,xdiff3,ydiff3,edist3
919  format(' "known" result coords.',4x,"Transformed (calculated)",
    $      6x,"Diff.(calc. - known) Distance error"/
    $      1x,3(2f12.3,3x),f12.3)
  else
    write(lrept,929) xdest3,ydest3

```

```

929 format(27x,"Transformed (calculated)',/,28x,2f12.3)
      endif
      write(lrept,969)
969   format(
$'----- 2-point (uniform scaling) transform -----')
      endif
C
123   continue
C-- Now do a "uniform scaling" (2-point) transform using 2 nearest ref. pts.
      if (maxof3 .eq. 1) then
          k1 = indx(2)
          k2 = indx(3)
      else if (maxof3 .eq. 2) then
          k1 = indx(1)
          k2 = indx(3)
      else
          k1 = indx(1)
          k2 = indx(2)
      endif
      xs1 = xfrom(k1)
      ys1 = yfrom(k1)
      xd1 = xto(k1)
      yd1 = yto(k1)
      xs2 = xfrom(k2)
      ys2 = yfrom(k2)
      xd2 = xto(k2)
      yd2 = yto(k2)
C- Do the 2-point transform math and store results in a,b,c,d
      denom = (xs1-xs2)**2 + (ys1-ys2)**2
      ca = (xd1-xd2)*(xs1-xs2) + (yd1-yd2)*(ys1-ys2)
      cb = (xd1-xd2)*(ys1-ys2) - (yd1-yd2)*(xs1-xs2)
      a = ca/denom
      b = cb/denom
      c = xd1 - a*xs1 - b*ys1
      f = yd1 + b*xs1 - a*ys1
C ##### Alternate ways to calculate c and f #####
CC   cc = ( xs1*(xd2*(xs1-xs2) + ys2*(yd1-yd2))
CC $   - xs2*(xd1*(xs1-xs2) + ys1*(yd1-yd2)) )/denom
CC $   + (ys1-ys2)*(ys1*xd2 - ys2*xd1)
CC   ff = ( (xs1-xs2)*(xs1*yd2 - xs2*yd1)
CC $   + ys1*(yd2*(ys1-ys2) + xs2*(xd1-xd2))
CC $   - ys2*(yd1*(ys1-ys2) + xs1*(xd1-xd2)) )/denom
C #####
C-- Write transform coefficients to report file
      write(lrept,1103) a,b,c,f
1103 format(' a,b,c,f: ',1p2e14.6,0p2f12.2)
C-- Compute destination coords. from source coords. for target point
      xdest2 = a*xst + b*yst + c
      ydest2 = -b*xst + a*yst + f
      xdiff2 = xdest2 - xdt
      ydiff2 = ydest2 - ydt
      if (xdiff2.eq.0. .and. ydiff2.eq.0.) then
          edist2 = 0.
      else
          edist2 = sqrt (xdiff2**2 + ydiff2**2)
      endif

```

```

C- Report the results
  if (xdt .ne. 0.) then
    write(lrept,919)
    $      xdt,ydt,xdest2,ydest2,xdiff2,ydiff2,edist2
    else
      write(lrept,929) xdest2,ydest2
    endif
    write (lrept,949)
949  format(1x,78('#'))
C
C *** Decide what to write to summary file and coord. loader file
C
C- Decide whether to use 3-pt. or 2-pt. transformation results
  if (ident12.or.ident13.or.ident23.or.use2
    $      .or.admin.lt.angle_limit) then
    xout = xdest2
    yout = ydest2
    convtype = '2-pt'
    edistout = edist2
  else
    xout = xdest3
    yout = ydest3
    convtype = '3-pt'
    edistout = edist3
  endif
  if (xdt.ne.0. .and. ydt.ne.0. .and. report_errs) then
    aerrsum = aerrsum + edistout
    rmasum = rmasum + edistout**2
  else
    report_errs = .false.
  endif

C
  if (ilamb.ge.6 .and. xdt .ne. 0. .and. ydt .ne. 0.) then
C-HEIS or Test destination coords. - included for comparison
C   with transformed coords. -
C-Write transformed coords. to summary file but not to loader file
    write(lsumm,936) cname,xdt,ydt,localsrc,l83src,l83src,edistout
936  format(1x,a,2f12.3,3(2x,a7),f12.3)
    else if (ilamb.ge.1 .and. xdt.ne.0. .and. ydt.ne.0.) then
C- Result coords. are from WELLDX, KEH survey, USACE survey, or indep. GPS
C   -write to both summary and coord. loader file
    write(lsumm,936) cname,xdt,ydt,localsrc,l83src,l83src,edistout
    write(lload,939) (cname(i:i),i=1,nchrs),xdt,ydt,ilamb
    else
C- Write either 3-pt or 2-pt to both summary and coord. loader file
    if(xdt.ne.0. .and. ydt.ne.0.) then
      write(lsumm,937)
    $      cname,xout,yout,localsrc,l83src,convtype,edistout
937  format(1x,a,2f12.3,2(2x,a7),2x,a4,3x,f12.3)
    else
      write(lsumm,1937)
    $      cname,xout,yout,localsrc,l83src,convtype
937  format(1x,a,2f12.3,2(2x,a7),2x,a4)
    endif
    write(lload,939) (cname(i:i),i=1,nchrs),xout,yout,konfid

```

```

939   format(1x,<nchrs>a1,'?',2(f10.3,'?'),11)
      endif
C
C- Go back to top of loop and read next conv. point from input file
      go to 2005
C
C- Come here on EOF on conversion input file
2088 continue
      ncon = ncon - 1
      write (*,*) ncon, ' points converted'
      if(report_errs) then
         rmserr = sqrt(rmssum/ncon)
         aerr = aerrsum/ncon
         write (lrept,8801) ncon, aerr, rmserr
         write (lsummm,*)
         write (lsummm,8801) ncon, aerr, rmserr
8801   format(' Points converted:',I6,' Ave.dist.error:',f11.3,
$       ' RMS error:',f11.3)
      else
         write (lrept,*) ncon, ' points converted.'
         write (lsummm,*) ncon, ' points converted.'
      endif
      close (unit=lrept)
      close (unit=lsummm)
      close (unit=lload)
      close (unit=lconv)
      STOP
C
991   write (*,3991) ncon
3991   format(
$ ' Error reading input conversion file, line number ',I5)
      STOP
992   write (*,*) ' Error opening output summary file.'
      STOP
993   write (*,*) ' Error opening coord. loader file.'
      STOP
994   write (*,*) ' Error opening input conversion file.'
      STOP
995   write (*,*) ' Error opening output report file.'
      STOP
996   write (*,*) ' Error opening input reference file.'
999   STOP
      end
C
      subroutine maxey3(dist,maxid)
C
C- Compute maximum of three distances, store the index (pointer to max. dist.) in maxid
C
      integer maxid
      double precision dist(3)

```

C

```
if (dist(1) .gt. dist(2)) then
  if (dist(1) .gt. dist(3)) then
    maxid = 1
  else
    maxid = 3
  endif
else
  if (dist(2) .gt. dist(3)) then
    maxid = 2
  else
    maxid = 3
  endif
endif
return
end
```

Appendix D

Data Verification and Validation Process

Appendix D

Data Verification and Validation Process

D1. Verification and Validation Plan for Hanford Site Well Location Data

1.0 Purpose

This appendix describes a plan and process for verifying and validating the Hanford Site well location data that will ultimately be stored in the HEIS database and used to build a comprehensive geographic information system (GIS) spatial data set. Sources of the data to be subjected to this verification and validation process include survey reports, site databases such as HEIS and WELLDOX, and the coordinate transformations described in the main body of this report. Within the context of this plan, data verification refers to the process of insuring that the information contained in the resultant data set or from which the resultant data set was derived is consistent with the original data sources (i.e., insuring that no transcription errors have occurred). Data validation refers to the process of attempting to determine the relative accuracy of the resultant data set (i.e., evaluating the degree to which the well location data for each well represents the true location of that well).

Verification, validation, and testing of the coordinate transformation software is described separately in the CTRANS Software Test Plan (Appendix C4) and in the CTRANS Software Testing Report (Appendix C5).

2.0 Scope

The scope of this verification and validation plan is limited to wells listed on survey data sheets and those contained in the HEIS and WELLDOX databases. Accuracy estimates are limited to those derived from survey closure information listed on survey sheets and information contained in the coordinate transformation results. The term "well" in the context of this plan and the Hanford well location conversion task includes any significant man-made intrusion into the ground, such as ground-water monitoring wells, vadose wells, drinking water wells, boreholes, and test pits. Historical wells within or near the Site boundary that have been abandoned and are no longer used are also included where possible.

3.0 Approach

The following steps will be taken to verify and, to the extent possible, validate the well location data. The results of each step will be documented in a draft verification and validation report which will be reviewed by PNL and WHC personnel. After satisfactory completion of the reviews, the verification and validation report will be incorporated into the final well location report.

1. For each known well in the intended scope of this plan, verify that the well is included in the well location results or has not been included because no location data have been found for the well. To facilitate this effort, a list of wells for which location data is available in one or more coordinate systems will be compiled by well name from all data sources within the scope of this plan. This list of well names will be electronically compared to an inventory of well names from the working sets of well locations being used in the coordinate transformation process for each local coordinate system and datum. A list of well names for which location data is not available from any of the sources included in the scope of this plan will also be generated by this step.
2. Generate maps of all wells included in the scope of this study and visually examine each well location to determine if the well is in fact located in or near the area or grid cell indicated by its name. Attempt to resolve these and other well location or name discrepancies (including those listed in Appendix B) by re-examining all available data sources for those wells and by soliciting expert opinion from the data custodians of the wells in question and from other Hanford personnel who may be familiar with those wells.
3. For many Hanford wells, locational data is available only in local coordinates of unknown accuracy. Because it would be prohibitive to resurvey all such wells, the validation process for such wells will be largely subjective, based on visual examination of the relative location of the wells with respect to buildings, roads, fences, and other known features as displayed on base maps generated by a geographic information system (GIS). This validation step will be performed by Hanford personnel who have a working knowledge of the relative locations of wells to be validated. Maps containing the base features and the presumed well point locations will be created and distributed to these personnel for their examination and comments. Wells that appear to be incorrectly located will be re-examined for possible data errors and may eventually be resurveyed using GPS equipment. The effectiveness of this validation step may be compromised somewhat by spatial errors in the base map features.
4. Independent researchers (i.e., individuals not directly involved in developing or running CTRANS) will validate the registration point files for each local coordinate system/datum used in the well location transformations by using CTRANS to perform "identity" transformations (self-transformations) on these registration point files and then examining the results.
5. Independent researchers will verify that the documented process for running CTRANS for each Hanford local coordinate system/datum has indeed been followed and that the input and output data files identified in the CTRANS application log files were the files that were actually used to produce the documented results.

D2. Visual Location Verification Instructions and Participants

Date: July 7, 1993

To: Well verifiers

The HEIS project team appreciates you taking time to verify the positions of the wells shown on the attached maps. The wells were positioned on these maps after all non-Lambert coordinates were translated into Lambert coordinates.

We understand that this visual inspection cannot correct but the most obvious mistakes, and the way to identify the wells properly is to resurvey them. Although resurveying of many wells is currently being done, some wells will never be resurveyed and this verification effort will be the best way to capture your knowledge on the well locations.

The results of this effort will be reviewed by HEIS personnel and recommendations will be made to the HEIS configuration control board on whether the locations of some wells need to be corrected in the database. All the accumulated information will form the pedigree of the well locations.

In addition to the maps, there are four attachments to this letter. The first attachment is a form that will guide you in reporting the type of information we need. Please make as many photocopies of this form as you need and use one copy for each well or cluster of wells that you report on. Also please mark on the maps your estimate of well positions that need correcting.

The second attachment is a list of "problem" wells for which we found significant location discrepancies between two or more data sources (including the coordinate transformations), or there were other suspected errors or problems such as inconsistency between the well name and the location data. This list has two parts: the first part contains wells with location problems that we believe have been resolved, and the second part contains wells with problems that have not been resolved. The wells in the resolved problems list are included in the plots. Please examine both parts of the list and report to us any knowledge you may have that either confirms, refutes, or resolves any of the problems or locations in question.

The third attachment contains a list of "wells" which we have assumed are piezometer tubes by their name and/or location relative to other similarly named wells. As indicated by the comments in the right-most column, some of these are questionable as to their status as piezometer tubes or as to their parent well. If you are knowledgeable on piezometer wells in general or on any of the specific wells in this list, please provide us with any information that will help us resolve these issues.

The fourth attachment is a list of well names followed by the word "blank". These wells were included by name in at least one of the well databases (HEIS or WELLDON) but had no location data associated with them in either database.

Please return the maps and your comments by July 20, 1993, to:
Robert Burnett, ISB1 Room 324, Mail Stop K7-22 (375-2313)

Well Location Qualification Information

This form is intended to help identify "obvious" mistakes in the horizontal positioning of the Hanford wells.

Name of Well: _____

How close to its true position is the aforementioned well? To within:

- ☐ 5 meters
- ☐ 10 meters
- ☐ 30 meters
- ☐ 100 meters
- ☐ specify _____
- ☐ I do not know

Should the well position be corrected? ☐ If yes, indicate on your map the proper position.

How did you estimate the well position?

- ☐ Past experience
- ☐ Proximity to
 - ☐ building, specify _____
 - ☐ road, specify _____
 - ☐ fence, specify _____
 - ☐ other map feature, specify _____

Do you think any of the base map features (buildings, roads, etc.) are incorrectly placed? If yes, list those features below and mark on the map the incorrect features and your estimated correct position.

How confident are you of your assessment of the position of this well?

- ☐ very confident (76%-100%)
- ☐ confident (51%-75%)
- ☐ somewhat confident (26%-50%)
- ☐ not at all (0%-25%)

Comments: _____

Please provide:

Name:

Affiliation:

Phone:

The following Hanford personnel provided well location verification information:

Mickie Chamness (PNL)
John Evans (PNL)
Rod Ledgerwood (WHC)
John McDonald (PNL)
Ercy Morse (WHC)
Bob Raidl (WHC)
Rich Raymond (PNL)
Ron Schalla (PNL)
Aaron Schatz (WHC)
Vince Vermeul (PNL)
Bill Webber (PNL)
David Weekes (WHC)
Jim Young (PNL)

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