Technical Note 1

Subject: Derivation of Community Coordinate System Parameters

Date: Original publication May, 1996
Revised September 2003 for ArcGIS Projection File derivation
Revised September 2004 for Modification to U.S. Survey Foot
Revised January 2005 to add Topcon GPS projection parameters

From Burkholder, 1993:

"Two-dimensional rectangular coordinate systems are widely used in surveying, engineering and... geographic information systems (GIS) applications. This practice is acceptable to the extent that a flat earth can be assumed without sacrificing geometrical integrity. The National Geodetic Reference System (NGRS), established and supported by the National Geodetic Survey (NGS), provides very precise latitude and longitude coordinates for thousands of control points scattered throughout the United States. The problem is that latitude/longitude positions have angular coordinates of degrees, minutes and seconds. Most users find it more convenient to use two-dimensional plane coordinates, such as northings and eastings. A map projection "flattens" the earth, and permits use of latitude/longitude control points in a two-dimensional rectangular coordinate system. The geometrical integrity of the precisely surveyed NGRS is transferred to the two-dimensional system by using a properly designed and documented map projection. The state plane coordinate systems designed in the 1930s enable users of the NGRS to work with two-dimensional coordinates anywhere within a state or zone. Drawbacks to using state plane coordinate control have included... distortion: horizontal ground distance[s] may differ significantly from the [state plane] grid distance[s] shown on a survey map or plat. This drawback is particularly important in route-location surveys, construction layout, and accurate area computations."[1]

This Technical Note addresses this particular drawback of the Arizona State Plane Coordinate System as it applies to the Salt River Pima-Maricopa Indian Community, and a recommended solution for adjusting the Community's Geographic Information System (GIS) survey control points so that they accurately reflect at-ground surveyed distances.

The Arizona State Plane Coordinate System, or as it referred to by state statute, the Arizona Coordinate System (ACS), is referenced to the North American Datum of 1983 (NAD83). NAD83 is the measurement reference base that relates the earth's shape to derived latitude-longitude positions. Mapping projections (the mathematical process of projecting an ellipsoidal earth onto a flat surface) based on the NAD83 datum are referenced to the earth's ellipsoidal surface— or approximate sea level in the United States. Because this reference height is less than the average terrain elevation of the Community (1285 feet), surveying distances measured at this average ground elevation "shrink" by an approximate factor of 1 part in 20,000 when projected down to the NAD83 datum surface at sea level. A line measured at exactly 5,280.00 feet at surface elevation 1,285' on the Community will measure 5,279.68' at sea level. This shrinkage is termed the *elevation factor*. Combined with the elevation factor reduction is the distortion brought about by 'flattening' the earth's curved surface onto the State Plane coordinate plane surface. This *grid-scale factor*, as it is referred to, introduces another 1:10,000 error in measured ground distances versus State Plane coordinate system distances at sea level. The net effect is that a 5,280.00' surveyed line on the Community becomes a 5,279.15' line when stored in the Arizona Coordinate System.

A straightforward solution is to create a mathematical mapping projection surface for the Community related to average terrain elevation and earth flattening effects. Coordinates developed on this surface will

[1] Burkholder, Earl F. 1993. "Design of a Local Coordinate System for Surveying, Engineering and LIS/GIS". *ACSM Surveying and Land Information Systems*, Vol. 53, No. 1, 1993, pp. 29—40.

be referred to as the *Community Coordinate System* (CCS) for the remainder of this document. Projection parameters were established using the intersection of Chaparral Road and Country Club Drive, at the recommendation of Mason Womble, RLS.

The CCS surface is a tangent plane, parallel to the Arizona Coordinate System reference plane, and related to ACS coordinates by the following derivation (this wording is recommended to be included on any document displaying Community surveying coordinates):

All coordinates shown hereon are referenced to the Salt River Pima-Maricopa Indian Community Coordinate System, projected by a tangent plane method from the Arizona Coordinate System, 1983, Central Zone, by a combined factor (grid-scale factor multiplied by elevation factor) of 1.0001608, and translated by -600,000 in the X direction, and by -350,000 in the Y direction.

To convert coordinate values shown hereon to their corresponding Arizona Coordinate System, 1983, Central Zone values, utilize the following formulas:

$X_{ACS} = (X_{CCS} + 600{,}000) * .9998392$
$Y_{ACS} = (Y_{CCS} + 350{,}000) * .9998392$

where
X_{ACS} = X coordinate value on the Arizona Coordinate System
Y_{ACS} = Y coordinate value on the Arizona Coordinate System
X_{CCS} = X coordinate value on the Community's Coordinate System
Y_{CCS} = Y coordinate value on the Community's Coordinate System

Distances shown hereon are computed to an average ground elevation of 1285 feet above mean sea level. All bearings shown hereon are referenced to grid north of the Arizona Coordinate System, 1983, Central Zone.

Derivation notes for the CCS Combined Factor:

In the Central Zone of the Arizona Coordinate System, the grid distances along the Central Meridian (longitude 111° 55', approximately midway between Rural and McClintock Roads in Tempe) are shorter than surveyed ground distances by a grid-scale factor of 0.9999000 (1 part in 10,000 as prescribed by Arizona Revised Statutes §33-132). The grid-scale factor for the CCS was computed at the intersection of Chaparral Road and Country Club Drive (approximate longitude 111° 50'20") to be:

0.9999007 ground to grid
1.0000993 grid to ground

The sea level reduction factor, or elevation factor, was computed using a mean radius for the earth of 20,906,000 feet and the surveyed elevation above mean sea level for the intersection of Chaparral Road and Country Club Drive, 1,285 feet:

20906000/(20906000+1285) = 0.9999385 ground to sea level
(20906000+1285)/20906000 = 1.0000615 sea level to ground

The combined factors become:

(0.9999007 * 0.9999385) = 0.9998392 ground to State Plane
(1.0000993 * 1.0000615) = 1.0001608 State Plane to ground

Creation of an ArcGIS Projection File (.prj):

The parameters derived above for the Community's Coordinate System can be stored in an ESRI .prj projection file, compatible with Revision 8+ of ArcGIS.

An ESRI 8+ projection file has thirteen basic projection parameters stored in it. Here is the standard NAD83 Arizona State Plane Central Zone projection file (in the actual file, there are no line breaks. Parameters are separated by commas):

```
PROJCS["NAD_1983_StatePlane_Arizona_Central_FIPS_0202_Feet"],
GEOGCS["GCS_North_American_1983"],
DATUM["D_North_American_1983"],
SPHEROID["GRS_1980",6378137,298.257222101]],
PRIMEM["Greenwich",0],
UNIT["Degree",0.0174532925199432955]],
PROJECTION["Transverse_Mercator"],
PARAMETER["False_Easting",700000],
PARAMETER["False_Northing",0],
PARAMETER["Central_Meridian",-111.9166666666667],
PARAMETER["Scale_Factor",0.9999],
PARAMETER["Latitude_Of_Origin",31],
UNIT[""Foot",0.3048]]
```

The ArcGIS projection file developed for the Community's custom coordinate system was created, based on the NAD83 standard projection file. All the parameters were identical, except for the ones in **bold print** below:

```
PROJCS["Salt_River_Pima_Maricopa_Community_Project_Datum"],
GEOGCS["GCS_North_American_1983"],
DATUM["D_North_American_1983"],
SPHEROID["GRS_1980",6378137.0,298.257222101]],
PRIMEM["Greenwich",0.0],
UNIT["Degree",0.0174532925199433]],
PROJECTION["Transverse_Mercator"],
PARAMETER["False_Easting",100112.56],
PARAMETER["False_Northing",-350000.0],
PARAMETER["Central_Meridian",-111.9166666666667],
PARAMETER["Scale_Factor",1.00006078392],
PARAMETER["Latitude_Of_Origin",31.0],
UNIT["Foot",0.3048]]
```

Here are the derivation formulae for the Scale_Factor, False_Easting and False_Northing parameters:

Scale_Factor: combined factor (1.0001608, see previous page) * 0.9999 (the scale factor as defined for Central Zone in the standard project, 1/10,000) =
1.00006078392

False_Easting: combined factor (1.0001608, see previous page) * 700000 (False_Easting from the standard NAD83 projection file for AZ Central Zone) - User_Offset_X (600,000, see previous page) =
100112.56

False_Northing: combined factor (1.0001608, see previous page) * 0 (False_Northing from the standard NAD83 projection file for AZ Central Zone) - User_Offset_Y (350,000, see previous page) =
-350000.0

Conversion to U.S. Survey Foot, August 2004:

Although the State Plane Coordinate System legislated for use in Arizona uses the International Foot (1 International Foot = 0.3048 meter, exactly) as the standard unit of measurement, it was discovered in 2004 that the ECS Community surveyors were instead using the U.S. Survey Foot (1 U.S. Survey Foot = 1.000002 International Foot) as the basis for their measurement units.

There is no problem, per se, in using any measurement unit for conversion to the Community Coordinate System, as long as a proper projection file (see previous page) is supplied. To standardize the Community GIS, a new ArcGIS projection file was created by modifying the International Foot projection file detailed on the previous page. The modifications that were necessary to the International Foot ArcGIS projection file were as follows:

SRPMIC Community Coordinate System ArcGIS Projection File Parameters ('srpmic_usft.prj'):

```
PROJCS["Salt_River_Pima_Maricopa_Community_Project_Datum",
GEOGCS["GCS_North_American_1983",
DATUM["D_North_American_1983",
SPHEROID["GRS_1980",6378137.0,298.257222101]],
PRIMEM["Greenwich",0.0],
UNIT["Degree",0.0174532925199433]],
PROJECTION["Transverse_Mercator"],
PARAMETER["False_Easting",100112.360],
PARAMETER["False_Northing",-349999.300],
PARAMETER["Central_Meridian",-111.9166666666667],
PARAMETER["Scale_Factor",1.00006078392],
PARAMETER["Latitude_Of_Origin",31.0],
UNIT["Foot_US",0.3048006096012192 41]]
```

The False_Easting, False_Northing and Unit parameters were changed, in accordance with the use of the U.S. Survey Foot parameter.

Topcon GPS Projection File:

Topcon stores all coordinate reference systems for the United States in a file called "USA.map". This file is divided into (currently) ten sections, indicated by bracket ([]) symbols:

```
[VERSION]
[Spheroids]
[Datums]
[Units]
[Systems]
[SPC83]
[SPC27]
[WISCONSIN]
[MINNESOTA]
[Arizona]
```

To accommodate the SRPMIC custom coordinate system, changes were made in the USA.map file to these sections:

`[Systems]`: add this entry:

```
Arizona     AGG, Arizona
```

This indicated a new coordinate system would be found in the `[Arizona]` section of the file.

`[Arizona]`: added this section and these entries:

Parameter	Value	Comments (not a part of the file)
ZnID	SRPMIC	Zone for this coordinate system
DatumID	NAD83	Datum name from [Datums] section
ProjID	TMERC	Projection name: Transverse Mercator
Zone#	1	Only one zone defined for the SRPMIC system
Name	SRPMIC	Name for this coordinate system
Hunit	M	Horizontal unit is meters
Vunit	M	Vertical unit is meters
CM	-1115500.00000	Central Meridian of coordinate system, west longitude
Scale	1.00006078392	Scale factor—reference page 4 of this document
Lon0	-1115500.00000	Longitude for the SRPMIC coordinate system (same as State Plane)
Lat0	310000.00000	Latitude for the SRPMIC coordinate system (same as State Plane)
E0	30514.308288	False Easting value, meters
N0	-106680.00	False Northing value, meters

The entry made for the `[Arizona]` section in the USA.map file was as follows:

```
[Arizona]
//ZnID, DatumID, ProjID, Zone#, Name,   HUnit, VUnit, CM, Scale, Lon0, Lat0, E0, N0
SRPMIC, NAD83,   TMERC,    1,   SRPMIC, M,     M,    -1115500.00000, 1.00006078392, -
1115500.00000,   310000.00,    30514.308288,  -106680.
```