Procedures for Design and Modification of the State Plane Coordinate System of 2022

Procedures Document
National Geodetic Survey
National Ocean Service
National Oceanic and Atmospheric Administration

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Associated NGS Documents:

"State Plane Coordinate System of 2022 Policy," *NGS 2019-1214-01*. <https://geodesy.noaa.gov/INFO/Policy/files/SPCS2022_Policy_NGS_2019-1214-01.pdf>

Dennis, M.L., 2018. "The State Plane Coordinate System: History, Policy, and Future Directions," *NOAA Special Publication NOS NGS 13*, National Oceanic and Atmospheric Administration, National Geodetic Survey, Silver Spring, Maryland. <https://geodesy.noaa.gov/library/pdfs/NOAA_SP_NOS_NGS_0013_v01_2018-03-06.pdf>

Authority/Reference: As original creator of the State Plane Coordinate System, the National Geodetic Survey (NGS) has sole authority to define and establish these procedures.

Supersedes: There are no prior procedures for the State Plane Coordinate System. Superseded policies are listed in the policy document associated with these procedures. However, the superseded policies include information that can be construed as procedures.

Review Schedule: At least once every two years.

Responsible Office/Position: The Observation and Analysis Division (OAD) Chief has the authority to review and approve these procedures. The OAD chief is responsible for ensuring these procedures are consistent with and reflect any changes made to the associated policy.

Purpose/Scope

These procedures define the roles and responsibilities for the National Geodetic Survey (NGS) and stakeholders in defining and modifying the State Plane Coordinate System of 2022 (SPCS2022), as well as its naming conventions and technical specifications. The procedures are divided into the following six sections:

1. NGS contact information, criteria for stakeholder input, and deadlines. NGS email and postal addresses for submissions, general submittal requirements, criteria for "consensus" stakeholder input, and deadlines for submitting requests and proposals, and for submittal of zone designs by stakeholders.
2. Requirements for stakeholder requests and proposals of SPCS2022 designs. Specifies requirements for stakeholders to make requests for SPCS2022 designs by NGS and for proposing designs by stakeholders.
3. Requirements for submittal of SPCS2022 designs by stakeholders. Specifies requirements for stakeholders when submitting their approved SPCS2022 zone designs.

4. NGS roles and responsibilities for SPCS2022 reviews and documentation. Specifies how NGS reviews requests, design proposals, and submitted designs, as well as what is documented by NGS.
5. Zone numbers, names, and abbreviations. Presents the protocols and requirements for numeric codes, zone names, and name abbreviations for SPCS2022 zones.
6. Technical specifications for SPCS2022 design and implementation. Detailed technical specifications to augment those given in SPCS2022 policy.

This procedures document provides supporting information for implementing SPCS2022 policy. It includes additional details to aid in interpreting and fulfilling the policy objectives.

The procedures are based on and derived from the SPCS2022 policy. If any items in these procedures are construed as being in conflict with policy, the policy shall prevail. Moreover, any information in the policy that is not addressed in these procedures should be considered as complete within the policy itself.

SPCS2022 is established for states, the Federal District, and selected insular areas of the United States. For brevity, the term "state" represents all of these areas throughout this document, as in the policy document.

Background

The policy associated with these procedures provides the necessary background information. Additional information on SPCS is given in *NOAA Special Publication NOS NGS 13*, which includes a comprehensive list of references to other NGS SPCS documents. These documents are a valuable resource for understanding SPCS in the context of its evolution, implementations, and usage since its original creation in the 1930s.

Exceptions

The NGS Director may exercise discretion to approve or deny special requests regarding initial design or subsequent changes of SPCS2022 that depart from these procedures (and associated policy), either in whole or in part.

Definitions of Terms

Not all technical terms used in this procedures document are defined below. Terms not defined in this list are either defined in the body of this document or by reference to *NOAA Special Publication NOS NGS 13*. Terms in *italics* in the definitions are also defined in this list.

- Conformal map projection. A projection where the *linear distortion* is unique (the same in every direction) at a point and, equivalently, the only angular distortion is the *convergence angle*. The three types of conformal projections used for SPCS are the Lambert Conformal Conic (LCC), Transverse Mercator (TM), and Oblique Mercator (OM).

- Convergence angle. The difference between geodetic and grid north (with sign convention as geodetic minus grid north); also known as mapping or map angle. Typically computed and used only for *conformal map projections*.
- Linear distortion. For *conformal map projections*, it is the amount by which a distance or length in a projected coordinate system differs from the "true" horizontal distance on or near the curved topographic surface of the Earth. Expressed as a ratio of distorted distance to true distance, for example as parts per million (ppm) or as a ratio (e.g., 100 ppm = 1:10,000). Also known as "scale error" when evaluated with respect to distances on the *reference ellipsoid* surface.
- Projection axis. For *conformal map projections*, it is the line or curve along which *linear distortion* is minimum and constant (or nearly constant) with respect to the *reference ellipsoid*. It is the central parallel for the Lambert Conformal Conic projection, the central meridian for the Transverse Mercator projection, and the skew axis of the Oblique Mercator projection (also known as initial or central line).
- Reference ellipsoid. An oblate ellipsoid of revolution that approximates the size and shape of the entire Earth geoid ("mean sea level") or a large portion of it. When oriented with respect to a geometric reference frame or datum, it defines the reference surface for projected coordinate systems. Also known as a reference "spheroid."
- Stakeholders. NGS customers and users of SPCS within a state most involved in the use, collection, and distribution of spatial data, and who have a substantial stake in how SPCS2022 is designed. Stakeholders consist of one or more of the following organizations:
  - State departments of transportation.
  - State GIS or cartographer offices.
  - State professional surveying and engineering societies.
  - State GIS or other professional geospatial organizations.
  - Universities, colleges, or other post-secondary educational institutions within a state that perform geospatial education or research.
  - Other departments, offices, and organizations within a state with roles and functions similar to those of the organizations listed above.

  National organizations can also provide input on SPCS2022 as stakeholders, but they cannot represent a specific state except in cases where one or more of the aforementioned state groups have granted them that authority, as documented in the required submittals for these procedures.
- Zone. A region on the surface of the Earth that defines the use area of a projected coordinate system, with extents usually based on a specified maximum *linear distortion* magnitude.

Procedures for Design and Modification of the State Plane Coordinate System of 2022

Design of SPCS2022 zones by NGS does *not* require input from states. If no consensus input is received from a state, the default SPCS2022 designs will be used, as described in §IV of SPCS2022 policy and §6.i of these procedures.

1. **NGS contact information, criteria for stakeholder input, and deadlines.** NGS welcomes input from stakeholders on their preferences for SPCS2022. Such input may consist of requests for particular SPCS2022 characteristics, as well as submittal of proposed SPCS2022 zone designs. Stakeholders are defined in the "Definitions of Terms" section of this document.

   a. NGS contact information for SPCS2022

      i. Questions and comments:

         - Email: **NGS.SPCS@noaa.gov**.
         - Postal mail: SPCS2022 Project Manager
           NOAA/NOS/National Geodetic Survey
           1315 East-West Hwy
           Silver Spring, MD 20910

      ii. Forms for submitting requests and proposals, and for submitting SPCS2022 zone designs, are available on the NGS State Plane Coordinate System web page (**https://geodesy.noaa.gov/SPCS/policy.shtml**).

   b. Requirements for submittal of stakeholder input. There are two types of stakeholder input. The first is required for all submittals. The second is only required for submittal of designs by stakeholders.

      i. Stakeholder requests and proposals for SPCS2022 designs. The requirements are given in §2 of these procedures and the associated form. A "request" is for NGS to design or modify SPCS2022 zones. A "proposal" is for SPCS2022 designs created and submitted by stakeholders.

      ii. Stakeholder submittal of SPCS2022 zone designs. The requirements are given in §3 of these procedures and the associated form. Note that the proposed designs must first be approved by NGS per §2.

   c. Qualifying criteria for stakeholder input. To act on requests, proposals, and contributions to SPCS2022, NGS requires consensus input from one or more stakeholder groups, as described below.

      i. Stakeholder input must be provided through at least one of the organizations listed in the "Definitions of Terms" section of this document. If more than one stakeholder provides input for a state, they are encouraged to do so collectively, rather than each stakeholder group providing input individually.

      ii. All requests and proposals for SPCS2022 zones must be submitted using the forms provided by NGS, as specified in the §2 of these procedures. NGS will only act on unanimous agreement of stakeholder groups. In the absence of unanimity, NGS has sole authority to design SPCS2022 zones for a state.

      iii. National groups, federal agencies, or regional groups consisting of multiple states, can provide input as stakeholders. But the input will only be considered as representing that of a state if at least one of the state stakeholder organizations is also listed on the request/proposal or design submittal forms.

iv. NGS will not act on input from individuals. Interested individuals should provide input through stakeholder organizations for their state.

d. Special use zones. Per SPCS2022 Policy §III.A.2.b, these zones are in more than one state and require approval of the NGS Director on a case-by-case basis. Use the SPCS2022 contact information above to make inquiries for a specific case.

e. Incorporating and confirming input to initial design of SPCS2022. Stakeholder input and design submittals received and approved by NGS by the dates given below will be part of SPCS2022 at the time of its official initial release.

i. Deadlines for requesting and submitting designs to NGS, and for NGS to provide confirmation of final design characteristics and computational results:

Requests for zones designed by NGS or proposals for zones designed by stakeholders **must be received by NGS no later than March 31, 2020**
For NGS-approved proposed designs by stakeholders, all final defining parameters **must be received by NGS no later than March 31, 2021**
Confirmation of final design characteristics and computations will be provided by NGS to stakeholders **no later than December 31, 2021**

ii. Stakeholder requests and design submittals received after the above deadlines will not be included in the initial release of SPCS2022. They will instead be treated as requested modifications to existing SPCS2022.

iii. If no consensus request or final design parameters are received by the above dates, NGS default designs will be used for initial release of SPCS2022.

2. Requirements for stakeholder requests and proposals of SPCS2022 designs

a. The required information is supplied using the NGS *SPCS2022 Request and Proposal Form*, available at **https://geodesy.noaa.gov/SPCS/policy.shtml**.

b. Must comply with all SPCS2022 policies and procedures, including all technical specifications.

c. Applies to requests and proposals for initial designs of SPCS2022 zone layers. Modifications of existing SPCS2022 zone layers will be based on an update to these procedures after the initial official release of SPCS2022.

d. Providing all required information is the responsibility of the submitter.

e. NGS will review requests/proposals and respond to inquiries as quickly as possible.

f. Proposed designs by stakeholders must be approved by NGS before any submitted designs are reviewed by NGS.

3. Requirements for submittal of SPCS2022 designs by stakeholders

a. The required information is supplied using the NGS *SPCS2022 Zone Design Submittal Form*, available at **https://geodesy.noaa.gov/SPCS/policy.shtml**.

b. Must comply with all SPCS2022 policies and procedures, including all technical specifications.

c. The design proposal must be approved by NGS before a submitted design will be reviewed (per §2) for inclusion in SPCS2022.

d. Providing all required information is the responsibility of the submitter.

e. NGS will review submitted designs and respond to inquiries as quickly as possible.

f. Customer technical support requests received by NGS for zones designed by stakeholders will be redirected to the state point of contact designated by the stakeholders.

4. NGS roles and responsibilities for SPCS2022 reviews and documentation

a. For requests, design proposals, and submitted designs, NGS will:

i. Confirm receipt of stakeholder requests and of stakeholder designs. If submittals are incomplete, NGS will notify submitter.

ii. Review requests and proposals for designs submitted by stakeholders. Only submittals with all required information will be reviewed.

iii. Review SPCS2022 zone designs submitted by stakeholders. Only submittals based on an approved proposal and containing all required information will be reviewed.

iv. Notify submitters when a request, proposal, or submitted design is approved or denied. If denied, the reason(s) will be provided.

v. Provide guidance on SPCS2022 zone design via workshops, presentations, webinars, website content, correspondence, and/or technical manuals.

vi. Maintain a record of finalized SPCS2022 zones on the NGS SPCS web page (**https://geodesy.noaa.gov/SPCS/zones.shtml**).

b. NGS will document all approved designs and associated parameters. The documentation will include the following:

i. Update of this policy and associated procedures, as necessary.

ii. Load SPCS2022 defining parameters for all zones into an NGS database.

iii. Publish an official NGS report completely defining SPCS2022, revised as needed to address any changes.

iv. Create and maintain a set of SPCS2022 web pages, with links to documents, defining parameters, and to applications and tools that use SPCS2022.

5. Zone numbers, names, and abbreviations. NGS will assign numbers and adopt names for SPCS2022 zones as described below. Examples are given in Table 1 at the end of this section.

Note: In later versions of these procedures, most of this section may be moved to a technical design manual or other ancillary support document.

a. Zone numeric code. Assigned by NGS and consists of six digits, where the first two digits correspond to the American National Standard Institute (ANSI) numeric code for the state (including leading zero placeholder). Formerly known as Federal Information Processing Standards (FIPS) codes.
    i. There is a one-to-one relationship between the zone number and its defining parameters. If any parameters change, the zone number will also change.
    ii. For a statewide zone, the third through fifth digits are zero (i.e., "000"), and the last (sixth) digit is 1 for the initially adopted design. This digit will increment from 2 through 9 sequentially if later replaced by a new statewide zone.
    iii. Multi-zone layers are indicated by a third digit that is not zero, and a maximum of two multi-zone layers can exist simultaneously. It increments sequentially from 1 through 9 to allow for zone replacement over time. For multi-zone layers that provide discontinuous (partial) coverage of a state, zones can be added without incrementing to a new layer number. In such cases, incrementing the layer number only occurs when parameters or extents of existing zones are changed, or when existing zones are removed or replaced by new zones.
    iv. For multi-zone layers (third digit not equal to zero), the last three digits are the sequential number for the zones in that layer (1 through 999). For zones designed by stakeholders, the zone numbers provided with the design are used.
    v. For zones consisting of more than one state, the ANSI numeric code of the state with the lowest ANSI number is used.
    vi. For special use zones (which are in more than one state and thus are not associated with any single state), all digits are zero, with the first special use zone designated as "000001" and increasing sequentially by one digit as zones are added.
b. Zone name. Begins with the state or territory name, followed by the zone name.
    i. For statewide zones, the name is the state or territory name followed by the word "Zone" (e.g., "Arizona Zone"). For combined states or territories, the name is hyphenated. There are two such zones currently in SPCS2022, the "Puerto Rico-Virgin Islands Zone" and the "Guam-Northern Mariana Islands Zone."
    ii. Multi-zone layers begin with the state or territory name followed by an alphanumeric descriptive name, and ending with word "Zone." The descriptive zone name should not exceed 30 characters, including spaces. Special characters are limited to the hyphen or dash (-) and the underscore (_).
    iii. Default zones and similar zone layouts use the existing zone SPCS 83 name scheme, as appropriate (e.g., "Central" for the middle zone of a 3-zone state).
    iv. Special use zones are assigned a name that references how they are defined, for example "Navajo Nation Zone" to match the official name.
c. Zone abbreviation. The official 2-character U.S. Postal Service code is used for the first two characters of a zone abbreviation corresponding to the state or territory.

i. The abbreviation for a statewide zone is the same as the state abbreviation (total of two letters).

ii. A subsequent string of 1 to 4 alphanumeric characters is used to abbreviate the name of multiple zones within a state. The characters used for a zone cannot include a space or underscore, because it is separated from the state code by a space or underscore (e.g., "AZ C" or "AZ_C" for Arizona Central Zone).

iii. Default zones and similar zone layouts use the existing zone SPCS 83 abbreviation scheme, as appropriate (e.g., "C" for Central Zone).

iv. For zones consisting of more than one state, the first and last state codes are concatenated in alphabetical order. There are currently two such zones, both consisting of two territories: "PRVI" for Puerto Rico and the U.S. Virgin Islands, and "GUMP" for Guam and the Northern Mariana Islands.

v. Special use zone are assigned a unique 2- to 4-character abbreviation consistent with the zone name, for example "NN" for the Navajo Nation.

vi. The entire zone abbreviation is unique for all SPCS2022 zones. For multi-zone layers, the length of the abbreviation ranges from a minimum of 4 to a maximum of 9 characters including the space or underscore separating the state from the zone abbreviation.

Table 1. Hypothetical examples of SPCS2022 zone number codes, names, and abbreviations (spaces in names and abbreviations can be replaced with underscores).

Zone layer description	Examples for each layer type		
	Number	**Name**	**Abbreviation**
Alaska zones in 3 layers. Zone added to LDP layer with partial coverage. Initial multi-zone layer with complete coverage later replaced by new multi-zone layer with complete coverage.			
Initial single statewide zone (designed by NGS)	020001	Alaska	AK
Initial multi-zone default layer, complete state coverage (10 zones, 021001-021010)	021004	Alaska 4	AK 4
Initial multi-zone layer with partial state coverage (47 zones, 022001-022047)	022033	Alaska Cordova	AK CORD
Initial multi-zone layer, new zone added (#48) without changing layer number	022048	Alaska Kodiak	AK KODK
New multi-zone layer with complete state coverage that replaces initial multi-zone layer (16 zones, 023001-023016; replaces all zones 021001-021010)	023012	Alaska North Slope	AK NSLP
Iowa zones in 2 layers. Multi-zone LDP layer with complete state coverage. No default 2-zone layer.			
Initial single statewide zone (designed by NGS)	190001	Iowa	IA
Initial multi-zone layer with complete state coverage (14 zones, 191001-191014)	191008	Iowa_Ames-Des Moines	IA_AMES

6. Technical specifications for SPCS2022 design and implementation. This section applies both to NGS and stakeholders. It provides details to augment general characteristics in §II of SPCS2022 policy.

Note: In later versions of these procedures, most of this section may be moved to a technical design manual or other ancillary support document.

a. Specific conformal projection types used for SPCS2022

i. **Lambert Conformal Conic** (LCC). Limited to the one-parallel form.

ii. **Transverse Mercator** (TM). Specifically the Gauss-Krüger form.

iii. **Oblique Mercator** (OM). Specifically the (rectified) Hotine form (also known as "rectified skew orthomorphic").

b. Geodetic Reference System of 1980 (GRS 80) ellipsoid

i. SPCS2022 computations are performed using the following parameters:

- Semi-major axis of $\boldsymbol{a}$ **= 6,378,137 meters** (*exact by definition*)
- Inverse geometric flattening of $\mathbf{1/}\boldsymbol{f}$ **= 298.257 222 101** (dimensionless derived quantity), to *at least* the 12 significant digits given here. A value with more significant digits may be used, but increasing the number of digits will change the projected coordinates by less than ±0.0001 mm. For reference, the computed value with 18 significant digits is $1/f$ = 298.257 222 100 882 744…

ii. All other ellipsoid parameters are derived from a and f using at least double-precision computations. For reference, two commonly used derived parameters are given to 16 significant digits:

- Semi-minor axis, b = 6,356,752.314 140 347… m
- First eccentricity squared, e^2 = 0.006 694 380 022 903 415…

iii. "Scaled" or otherwise modified versions of the reference ellipsoid cannot be used. Linear distortion can only be reduced be modifying projection axis scale, location, and/or orientation.

c. 2022 Terrestrial Reference Frames. SPCS2022 zones are assigned as follows:

i. *North American Terrestrial Reference Frame of 2022 (NATRF2022).* All zones in the conterminous U.S. and Alaska.

ii. *Caribbean Terrestrial Reference Frame of 2022 (CATRF2022).* All zones in Puerto Rico, the U.S. Virgin Islands, and other areas on the Caribbean plate.

iii. *Pacific Terrestrial Reference Frame of 2022 (PATRF2022).* All zones in Hawaii, American Samoa, and other islands on the Pacific plate.

iv. *Mariana Terrestrial Reference Frame of 2022 (MATRF2022).* All zones in Guam and the Commonwealth of the Northern Mariana Islands.

d. Linear distortion design criteria. Linear distortion is evaluated at the **topographic surface** for design, *not* the ellipsoid surface. NGS designs are based on both coverage area and population distribution (using data from the U.S. Census Bureau). Table 2 at the

end of this section gives zone width and height ranges corresponding to various linear distortion ranges.

i. The **linear distortion design criterion** is the smallest specific distortion range of ±5, ±10, ±20, ±30, ±40, ±50, ±75, ±100, ±150, ±200, ±300, or ±400 ppm that satisfies *all three* of the following *minimum* percentages:

- 90% of zone population.
- 75% of cities and towns (based on location only, irrespective of population).
- 50% of total zone area.

ii. For a known zone width (in km) perpendicular to the projection axis, an initial value of the linear distortion design criterion (in ±ppm) can be estimated as $\mathbf{\pm 0.00154 \times (km)^2}$. This equation gives the approximate total range in distortion for the ideal case of a zone with no variation in topographic height and with the projection axis passing through the zone midpoint.

iii. Zones designed by NGS will generally have a linear distortion design criterion between **±50 ppm** (1:20,000) and **±400 ppm** (1:2500). These criteria correspond to zone widths of approximately 180 and 510 km, respectively, for zones with no variation in topographic height. Multiple-zone systems designed by NGS for a state will provide complete coverage (i.e., NGS will not design a zone system with partial state coverage).

- Zones with linear distortion design criteria of less than ±50 ppm that have extents different from SPCS 83 will not be designed by NGS. Such zones must instead be designed by stakeholders, per §3. Zones designed by stakeholders do not require use of the aforementioned 90%, 75%, and 50% minimum percentages used by NGS, since it is assumed that the designs are optimized for maximum stakeholder benefit based on local knowledge.
- For NGS designs of new zones requested by state stakeholders, the maximum number of zones can be estimated by dividing the long dimension of the state in km by 180 km (corresponding to ±50 ppm), and rounding up to the next higher whole number. For example, an NGS design at ±50 ppm based on a state length of 600 km would likely have 600/180 = 3.33 → 4 zones. The actual number of zones may vary based on topographic relief, the shape of the state, and/or how the zone boundaries are defined.
- Exceptions where zones designed by NGS have a design criterion less than ±50 ppm are small states or existing SPCS 83 zones where lower distortion is achieved due to the small size of the existing zone.
- Exceptions where zones designed by NGS have a design criterion greater than ±400 ppm occur only for three statewide zones: New Mexico (±500 ppm), Texas (±1000 ppm), and Alaska (±5000 ppm).
- For a given distortion design criterion (in ±ppm), the zone width (in km) perpendicular to the projection axis can be estimated as $\mathbf{25.5 \times \sqrt{ppm}}$. For the

ideal case of no variation in topographic height and the projection axis passing through the zone midpoint, the distortion will be within the design criterion for the entire zone width.

- Linear distortion changes at a rate of 15.7 ppm per 100 m change in topographic height (or 4.8 ppm per 100 ft). It decreases (becomes more negative) with increasing height, and vice versa. For a given design criterion, the area of zone coverage typically decreases as the range in topographic height increases.

Table 2. Range in map projection linear distortion for various zone widths and ranges in topographic height.

Linear distortion range Expressed in parts per million (ppm) and as a ratio	**Corresponding zone dimension and height limits**	
	Zone width perpendicular to projection axis (for no variation in topographic height)	Topographic height range (independent of zone width)
±1 ppm (1:1,000,000)	25 km (16 miles)	13 m (42 ft)
±5 ppm (1:200,000)	57 km (35 miles)	64 m (209 ft)
±10 ppm (1:100,000)	81 km (50 miles)	127 m (418 ft)
±20 ppm (1:50,000)	114 km (71 miles)	255 m (836 ft)
±30 ppm (1:33,333)	140 km (87 miles)	382 m (1,254 ft)
±40 ppm (1:25,000)	161 km (100 miles)	510 m (1,672 ft)
±50 ppm (1:20,000)	180 km (112 miles)	637 m (2,090 ft)
±75 ppm (1:13,333)	221 km (137 miles)	956 m (3,135 ft)
±100 ppm (1:10,000)	255 km (158 miles)	1,274 m (4,180 ft)
±150 ppm (1:6,667)	312 km (194 miles)	1,911 m (6,271 ft)
±200 ppm (1:5,000)	360 km (224 miles)	2,548 m (8,361 ft)
±300 ppm (1:3,333)	441 km (274 miles)	3,823 m (12,541 ft)
±400 ppm (1:2,500)	510 km (317 miles)	5,097 m (16,722 ft)

e. Minimum zone size. Applies to zones designed by stakeholders. The objective is to create the largest zones possible that meet the distortion design criterion and thus avoid creating an excessive number of small SPCS2022 zones within a state.

i. The minimum zone width is based on the range in topographic height within the proposed zone:

- **50 km** (31 miles) for a zone with a topographic height range of 250 m (820 ft) or less.
- **10 km** (6 miles) for a zone with a topographic height range of more than 250 m (820 ft).

- Minimum zone size is evaluated as the short side of a rectangle with the smallest width that completely encloses the zone extents (minimum bounding rectangle by width). The rectangle must be in the same SPCS2022 projected coordinate system as the zone being evaluated and can be at any orientation.

ii. Well-defined geographic regions (such as counties, townships, urbanized areas, etc.) that do not meet the minimum size requirement should be aggregated with other areas to create zones that are larger than the minimum size.

iii. The presence of multiple zones within a state that are near the minimum size will make it more likely that the zone configurations will not be accepted by NGS for SPCS2022. NGS has sole authority to make the final determination as to whether zones meet the minimum dimension criterion.

f. Specifications for projection defining parameters

i. All projections are defined using the following five parameters (plus one additional parameter for the OM projection):

- Latitude of grid origin (same as central parallel for LCC projection).
- Longitude of grid origin (central meridian for LCC and TM projections).
- Scale on projection axis (central parallel for LCC, central meridian for TM, and skew axis at the local origin for OM projection).
- False northing (exactly zero for all TM projections).
- False easting.
- *OM projection only:* Skew axis azimuth at local (center) origin.

ii. The combined set of three geodetic parameters (origin latitude, origin longitude, and projection axis scale) must be unique for all SPCS2022 zones.

iii. The 2022 TRF geodetic origin latitude and longitude for all projections are defined in sexagesimal units (degrees-minutes) to a numerical precision of **not less than one arc-minute** (or the equivalent in decimal degrees).

- To avoid infinitely repeating decimal places in decimal degree representations, arc-minutes evenly divisible by 3 are recommended, if doing so does not compromise distortion performance.
- The latitude of grid origin for TM projections must have arc-minutes evenly divisible by 3.
- If decimal degree representations result in infinitely repeating digits, the parameter must be given to at least 12 decimal places.
- Definitions in decimal degrees must not result in fractional arc-minutes.

iv. Projection axis scale factors are defined to a numerical precision of **6 decimal places** or less, or, equivalently, 1 part per million (ppm) or greater. Numerical precision of 5 decimal places or less recommended for zones more than 100 km wide perpendicular to the projection axis.

v. Projection grid origins (false northings and eastings) are defined in meters using whole numbers evenly divisible by 1000 meters, selected such that SPCS2022 coordinates (northings and eastings) are positive at all locations within a zone.

vi. Parameters specific to each projection type:

- **LCC.** Defined using one central parallel that is also the latitude of grid origin.
- **TM.** False northing is exactly zero.
- **OM.** The false northing and easting is defined at the local (center) origin, not at the natural (true) origin. The skew axis (initial line) azimuth is defined as positive clockwise to the nearest whole degree, from ±(5° to 85°), at the local (center) origin. A two-point definition of the skew axis cannot be used.

g. Specifications for SPCS2022 distortion output

i. **Grid point scale factor.** Linear distortion at a point with respect to the reference ellipsoid surface. Can be considered as linear distortion due to curvature, and is a function of horizontal position only.

ii. **Height factor.** Linear distortion at a point due to its height above (or below) the reference ellipsoid surface. Computed using use the **ellipsoid height** and the GRS 80 **Geometric mean (Gaussian**) **radius of curvature** at the geodetic latitude of the point. Historically referred to as the "elevation factor."

iii. **Combined factor.** Total linear distortion at a point as the combined effect of distortion due to curvature and height. Computed as the product of the grid point scale and height factors.

iv. **Convergence angle.** Geodetic minus grid north, given in sexagesimal units (degrees, minutes, and decimal seconds).

h. Computational accuracy and methods.

i. The following accuracies are achieved by NGS for map projection computations within a zone:

- **Coordinates** to **±0.01 mm**, or better, for both the direct (geodetic to projected) and inverse (projected to geodetic) calculations.
- **Grid point scale factor** to at least **10 decimal places** (±0.0001 ppm).
- **Convergence angle** and **arc-to-chord correction** to **±0.001 arc-second**, or better.

ii. To the extent possible, and within the above accuracy requirements, NGS algorithms will conform to accepted and common practice within the geodetic community (both private and government) for performing map projection calculations.

i. Default SPCS2022 designs. In most cases the projection type and zone extents are the same as SPCS 83. The zone extents change for a small number of zones, and some adjacent SPCS 83 zones are combined into a single zone. However, in no case do these

changes cause the SPCS2022 linear distortion at the topographic surface to exceed the SPCS 83 scale error at the ellipsoid surface.

i. The default design approach used differs from that of SPCS 83 in the following ways, to comply with all SPCS2022 policy and procedure requirements:
   - The projection axis scale is modified as necessary to minimize linear distortion at the topographic surface, rather than at the reference ellipsoid surface. The scale is defined to six decimal places or less.
   - Lambert Conformal Conic projections are converted to the one-parallel definition and scaled in the same manner as the Transverse and Oblique Mercator projections.
   - Oblique Mercator projections parameters are defined using the local (center) origin, with the skew axis azimuth specified to the nearest whole degree.
   - Geodetic latitude and longitude origins are specified such that the defining arc-minutes are evenly divisible by 3 in situations where doing so does not compromise distortion performance, and in all cases for the origin latitude of TM projections.

ii. Examples of changes under consideration as defaults for existing SPCS 83 zones:
   - Replace several existing TM and LCC SPCS 83 zones with OM SPCS2022 zones, such as in Hawaii, Florida, New York, and New Jersey.
   - Include Guam and Commonwealth of Northern Mariana Islands (CNMI) in a single TM zone (CNMI currently has no SPCS zone).
   - Define an LCC zone for American Samoa (has no SPCS 83 zone).
   - Add a zone for the Washington, D.C. (District of Columbia).

iii. Statewide zones will be designed by NGS for every state. For states with only one default zone, the default and statewide zone are the same.

iv. NGS will not create default multiple-zone designs for states that have indicated that they will submit their own designs for the multiple-zone layer(s) or will only use the statewide zone designed by NGS.

RECORD OF REVIEW AND CHANGES

This is a living document that is reviewed at least once every two years. It will be updated, when appropriate, to reflect changes in controlling federal policies, organizational strategic goals/objectives, technology, or other matters that may have an impact on these procedures. Modifications made to this document are recorded in the below table. This record shall be maintained throughout the life of the document.

Version Number	Date	Section/ Page Affected	Summary of Change or Annual Review	Author / Reviewer
1	4/23/2019	All	Previous SPCS policy document replaced with a new policy and this new procedures document.	Michael Dennis