National Mapping Program Technical Instructions

Part 2
Specifications

Standards for
Raster Feature Separates
Version 1.0

U.S. Department of the Interior
U.S. Geological Survey

CONTENTS

FIGURES

2. SPECIFICATIONS

This part of the standard provides specific information on the production of RFSs. As described in Part 1, this standard is for an internal USGS archive format and lacks the metadata content necessary to be a saleable product.

2.1 DATA SOURCES

RFSs are made from two sources:

(1) From outputs of digital map revision processes.

(2) From scans of original mylar map materials or stable-base copies of these materials.

RFSs are not made from paper map scans, except possibly as a last resort when all original materials for a map have been lost or destroyed. Creation of RFSs from analog separates does not imply any revision or update of the materials.

2.2 COVERAGE

The standard area of coverage of an RFS is the entire area that contributes to a printed map, including the map collar, overedge areas, and insets.

At this time, the USGS has no program designed to make a complete set of RFSs for any map series. Production of RFSs will be driven by the requirements of map revision programs and the availability of funding.

2.3 RFS SETS AND FEATURE REGISTRATION

One published map or one DRG is derived from a particular set of RFSs. The RFSs in this map set have precise relationships to each other through the map and DRGs they are part of. However, these relationships are not stored in the RFS image files. The RFS files that are part of a map set do not point to each other--these relationships must be maintained in external databases that are outside the scope of this standard.

The RFS images in a map set must register. If the images are digitally "stacked" exactly on top of each other, feature registration must match that of the source map. If the data are georeferenced, ground coordinate values must match throughout the layers.

2.4 RFS RESOLUTION

The scan resolution of an RFS is 1,000 dpi or higher. Scanning at lower resolutions and upsampling is not acceptable.

The nominal scan resolution will be stored in the TIFF tags Xresolution (282.d, 11a.h) and Yresolution (283.d, 11b.h). The values of these tags should be such that an application that uses this value to print the image will print it at the scale intended by the data producer.

2.5 GEOREFERENCING

RFSs may or may not be georeferenced. Georeferencing means the data contain all the information needed to transform image coordinates to a ground coordinate system. This information is carried in the image file's GeoTIFF tags. See section 2.10.2 for more details of these requirements.

There is no requirement to use any particular procedure or transformation model to georeference the image. Any procedure that meets the required product accuracy requirements is acceptable.

2.5.1 Projections and Horizontal Datums

Most USGS georeferenced RFSs use the UTM projection and coordinate system.

An RFS that is not georeferenced is required to preserve the projection and geometry of the source materials accurately. For example, distances between neatline corners must meet the same accuracy standards as the analog materials.

A georeferenced RFS is not required to use the same projection or coordinate system as its associated published map. Changing the map projection in the RFS creates an apparent conflict between the RFS metadata and the printed map collar that is part of the RFS image. This is not a true conflict, because the map collar contains metadata for the printed map. The digital data make up a different product that does not need to have identical geometry. However, for applications that use RFSs to print paper maps, care must be taken to print collar information that is correct for the new printout.

The USGS attempts to retain the datum of the published map in georeferenced RFSs, but this is not a requirement. Changing the datum also creates an apparent conflict between the map collar and

the RFS image and metadata. Changing the datum of the scanned map image changes the coordinate values of the neatlines and grids, which means that coordinate values printed in the map margins will not match software readouts. RFS producers should be aware that this can be very confusing for end users.

2.5.2 Overedge and Map Insets

Overedge areas and map insets need not be georeferenced, even if the main area of the map is. Georeferencing these areas is technically difficult; specialized software, advanced GIS expertise, or both are usually needed. Some transformations commonly used for DRG and RFS georeferencing require control points to be evenly spaced. The 2.5-minute tick marks meet this requirement for standard cells, but slivers outside the standard cell boundary cannot be included. Similarly, insets are maps within maps and can be very complicated to georeference without creating separate image files.

USGS RFSs do not georeference overedge areas or map insets. Although software may display ground coordinates for these areas, the coordinate values are simple extensions of the image plane and will not necessarily have a meaningful relationship to the Earth's surface.

2.6 HORIZONTAL ACCURACY

It is not possible to improve the accuracy of a map significantly by scanning it, but it is possible to retain the accuracy of the source map. In practice, small errors tend to be introduced during scanning or by inexact point selection during georeferencing. These errors from RFS production tend to be smaller than errors present in the source map.

See section 2.8.2 for horizontal accuracy evaluation techniques and tolerances.

2.7 COLORS

RFSs are required to conform to the base TIFF standard for 8-bit palette-color images (see section 5 of the TIFF 6.0 standard).

RFSs are also required to have the following additional characteristics.

Like a DRG, color slot 1 will contain the map background, which will always be white (255,255,255).

Nonbackground pixels must be stored in palette slot 2. RFS files will contain only two colors, and therefore will have only pixel values that reference slots 1 and 2. Slot 2 will always be black (0,0,0).

RFSs therefore could be stored as TIFF bilevel images. The TIFF palette-color type is required by this standard to make RFS data similar to DRG data because the bilevel type is not as widely implemented in software.

2.8 DATA QUALITY

In general, the goal of RFS production is to duplicate the quality of original analog map materials. Errors in the original map can only be fixed by revising the map, a process that is always much more expensive and time consuming than fixing an RFS error.

2.8.1 Image Completeness and Quality

Image completeness is checked by visually inspecting each RFS image. Different parts of the image are inspected for gaps, color errors, and other visual artifacts. Unbroken lines on the map must remain unbroken in the RFS. Any introduced linework breakage or dropout makes an image unacceptable. Text must be completely legible both inside and outside the neatline.

Lithographic screen dots must not be present in an RFS. An exception to this rule is permitted when open-window plates are not available in the original materials and screened plates must be scanned. In this case, it may not be technically practical to completely descreen the scanned images.

2.8.2 Positional Accuracy

RFS accuracy is measured by comparing grid ticks on the map with their theoretically correct positions. The average displacement must be less than 3 pixels, and the maximum displacement must be less than 6 pixels. In addition, the entire RFS map set must register as described in section 2.3.

2.8.3 Georeferencing

The georeferencing of each RFS is confirmed by viewing the image in GIS software other than the software used to make the image.

2.9 METADATA

Federal agencies are required by Executive Order 12906 (April 11, 1994) to include metadata with all digital geospatial data. Executive Order 12906 established the National Spatial Data Infrastructure and adopted the FGDC's Content Standard for Digital Geospatial Metadata to provide a consistent approach and format for the description of data characteristics.

This version of the standard defines an internal USGS archive format and does not include a requirement for FGDC metadata. Enhancing this standard to define a saleable USGS product would require that a mechanism be added to carry metadata.

Defining this mechanism for RFSs will be difficult. Historically, feature separates have fairly simple relationships to both cartographic features and published maps. During the original 7.5-minute mapping program, one separate was part of one and only one map. All the features on one separate had the same currentness date. All features in the map set had only a small number of currentness dates, which were relatively close together.

Today, none of these things are true. A map revision may include several different data sources with many different currentness dates. Some layers may be revised, while other layers are left untouched. Even a single separate may be only partially revised by updating selected features, limited areas of the cell, or both.

A complete metadata description therefore would require feature-level metadata, which is not practical for raster images. But even including metadata at the separate level is difficult because there are so many different possible cases that must be described. The USGS has never before collected metadata at this level of detail for graphic data.

2.10 FILE FORMATS

An archive USGS RFS comprises one physical file; an image file in TIFF format with optional GeoTIFF extensions. The file must conform to TIFF 6.0 and GeoTIFF 1.0. No specific convention for naming this file is required.

The TIFF, GeoTIFF, and GeoKey requirements described below are summarized in appendix 2-A.

2.10.1 TIFF Requirements

The Tagged Image File Format (TIFF) is a copyrighted standard of Adobe Systems, Inc. An RFS image file is required to conform to the TIFF standard, version 6.0. See figure 2-1 for an example of a TIFF tag listing from an RFS image. This listing is an output of the libtiff utility program 'tiffinfo'.

```
TIFF Directory at offset 0x1226070
    Subfile Type: (0 = 0x0)
    Image Width: 24000 Image Length: 30000
    Bits/Sample: 8
    Compression Scheme: PackBits
    Photometric Interpretation: palette color (RGB from colormap)
    Artist: "U.S. Geological Survey, public domain data"
    Date & Time: "2002:02:05 13:28:09"
    Software: "USGS production software makedrg $Revision: 1.4 $"
    Document Name: "Crystal Lake | IL | 24000 | 10937 | 0"
    Image Description: "USGS Raster Feature Separate | infrastructure"
    Orientation: row 0 top, col 0 lhs
    Samples/Pixel: 1
    Rows/Strip: 1
    Planar Configuration: single image plane
    Page Name: "black"
    Color Map: (present)
```

Figure 2-1
Sample TIFF tag listing.

The RFS image must have the following characteristics, which are restrictions of the TIFF standard:

(1) An RFS must be an 8-bit palette-color image. The PhotometricInterpretation tag (262.d, 106.h) must have a value of 3, the BitsPerSample tag (258.d, 102.h) must have a value of 8, and the ColorMap tag (320.d, 140.h) must have a value of 768 (=3*(2**8)). Palette-color requirements are defined in section 5 of the TIFF 6.0 standard.

(2) The Xresolution (282.d, 11a.h) and Yresolution (283.d, 11b.h) TIFF tags must be populated. If the image is printed at the resolution specified by these tags, the printout will be at the map scale intended by the data producer. These values are nominal scan resolutions and may not be exactly consistent with the ground resolution values in the ModelPixelScaleTag.

(3) The image origin (not to be confused with any cartographic coordinate system origin) must be in the visual upper left. The Orientation tag (274.d, 112.h) must have a value of 1.

(4) Although the TIFF standard supports five types of data compression, only PackBits compression (run length encoding) is allowed in an RFS. The Compression tag (259.d, 103.h) will therefore have a value of either 1 (no compression) or 32773.d (PackBits).

(5) The color map must be organized as specified in section 2.7. A specific color map organization is an unusual requirement for a TIFF image. Specialized

software may be needed to create files that meet this requirement.

(6) The DateTime tag (306.d, 132.h) must be populated. The contents of this tag should be obtained from the system clock to guarantee that RFS images created at different times will have different time stamps.

(7) The ImageDescription tag (270.d, 10e.h) will have the following form:

USGS Raster Feature Separate | <national map layer>

where

<national map layer> is a description of *The National Map* theme that this separate belongs to. This field must be valued with one or more of the following strings. Whenever possible, exactly one theme should be named. If more than one theme must be listed, delimit with commas. Allowed values are as follows:

image
elevation
hydrography
transportation
infrastructure
boundaries
names
land cover
na

A "not applicable" (na) value is needed because some things shown on a graphic map are not part of any theme in *The National Map*. Examples are the map collar and UTM grid.

Non-USGS data producers may use this tag any way they choose and should at least make changes necessary to clearly identify the producer. This should be done even for USGS RFSs that have been modified by other organizations.

(8) The DocumentName tag (269.d, 10d.h) will have the following form:

<cell name> | <state(s)> | <scale> | <cell id> | <product id>

where

<cell name> is the name of the standard cell for this quadrangle, taken from the Geographic Names Information System (GNIS).

<state(s)> is one or more two-character postal abbreviations for the States of this quadrangle, also taken from the GNIS. If the quadrangle is in more than one State, the first is always the State that contains the cell name feature. Separate the State abbreviations with a single hyphen.

<scale> is the scale denominator of the source map, without commas (for example, "24000").

<cell id> is the primary key of the GNIS for the standard geographic cell of this map.

<product id> is a numeric identifier for this file. This number is a primary key to the USGS archive database. Including this value in the tag is optional; a value of 0 may be used to indicate a null. If present and nonzero, the value must be unique; that is, no two USGS RFS files may have the same product id.

(9) The PageName tag (285.d, 11d.h) will contain a text string designating the color of this separate. For example, "red", "blue", "black".... The field must contain no more than one color. No limited set of allowable values is defined by this standard.

(10) Private tags will not be present in RFS images.

2.10.2 GeoTIFF Requirements

The GeoTIFF Format Specification is a public domain extension of TIFF that provides a robust and flexible method of storing georeferencing information in a TIFF file. A consortium of private companies and government agencies defined GeoTIFF in 1994-95. The USGS did not play a significant role in defining this standard, but the USGS DRG program was one of the first large GeoTIFF implementations.

Georeferencing is optional for RFSs. However, these guidelines must be followed:

- If the image is not georeferenced, then no GeoTIFF tags or GeoKeys other than ASCII citation keys may be populated. No tags or keys with numeric types will be populated.

- All RFSs, regardless of whether or not they are georeferenced, must maintain feature registration between layers (see section 2.3). Nongeoreferenced RFSs must preserve the projection and geometric accuracy of the source material (see section 2.5.1).

- A georeferenced RFS must conform to all guidelines in sections 2.10.2.1 and 2.10.2.2. It is not acceptable to populate a subset of tags and keys that incompletely describe the image projection, datum, and coordinate system.

The RFS implementation of GeoTIFF is similar but not identical to the DRG implementation.

Sections 2.10.2.1 and 2.10.2.2 describe the requirements for georeferenced RFSs. See figure 2-2 for an example of a GeoTIFF tag and GeoKey listing from the same RFS image. This listing is the output of the libgeotiff utility program 'listgeo'. The projection information below the line "End_Of_Geotiff" is implied by the standard projection and is not stored explicitly in the data file. The descriptions are retrieved from libgeotiff lookup tables in the listgeo application.

```
Version: 1
Key_Revision: 1.0
Tagged_Information:
   ModelTiepointTag (2,3):
      0               0               0
      384625.48       4679378.1       0
   ModelPixelScaleTag (1,3):
      0.581301        0.581301        0
   End_Of_Tags.
Keyed_Information:
   GTModelTypeGeoKey (Short,1): ModelTypeProjected
   GTRasterTypeGeoKey (Short,1): RasterPixelIsArea
   GTCitationGeoKey (Ascii,45): "RFS unapproved draft standard | GeoTIFF v1.0"
   ProjectedCSTypeGeoKey (Short,1): PCS_NAD27_UTM_zone_16N
   PCSCitationGeoKey (Ascii,25): "UTM Zone 16 N with NAD27"
   End_Of_Keys.
End_Of_Geotiff.

PCS = 26716 (NAD27 / UTM zone 16N)
Projection = 16016 (UTM zone 16N)
Projection Method: CT_TransverseMercator
   ProjNatOriginLatGeoKey: 0.000000 (  0d 0' 0.00"N)
   ProjNatOriginLongGeoKey: -87.000000 ( 87d 0' 0.00"W)
   ProjScaleAtNatOriginGeoKey: 0.999600
   ProjFalseEastingGeoKey: 500000.000000 m
   ProjFalseNorthingGeoKey: 0.000000 m
GCS: 4267/NAD27
Datum: 6267/North American Datum 1927
Ellipsoid: 7008/Clarke 1866 (6378206.40,6356583.80)
Prime Meridian: 8901/Greenwich (0.000000/  0d 0' 0.00"E)
Projection Linear Units: 9001/metre (1.000000m)
```

Figure 2-2
Sample GeoTIFF tag and GeoKey listing.

2.10.2.1 GeoTIFF-Specific TIFF Tags

The GeoTIFF standard uses a MetaTag (GeoKey) approach to encode dozens of data elements into just six TIFF tags. Four of these six tags are required in a georeferenced RFS; two are optional:

(1) ModelPixelScaleTag (33550.d, 830e.h) (required, unless ModelTransformationTag is populated). The X and Y values must be populated and be equal to the ground distance of one RFS pixel. These values are not required to be exactly equal, nor are they required to be exactly consistent with the scan resolution values of the Xresolution and Yresolution tags. Those tags may store nominal scan resolution, but the ModelPixelScaleTag will store the best attainable value for the actual ground pixel size.

For 1:24,000-scale maps at 1,000 dpi scan resolution, these values will be near 0.6096 (meters). See section 2.6.1 of the GeoTIFF standard.

(2) ModelTiepointTag (33922.d, 8482.h) (required, unless ModelTransformationTag is populated). This tag specifies the (X,Y) ground coordinates of the (0,0) image pixel, by convention in the upper left corner of the image. In most USGS RFSs, the UTM grid is the ground coordinate system. GeoTIFF allows considerable flexibility in how an image is tied to the ground, but RFS data should be tied to the (0,0) pixel whenever possible. The Z coordinate value should be set to 0. See section 2.6.1 of the GeoTIFF standard.

(3) GeoAsciiParamsTag (34737.d, 87b1.h) (required). This tag is used to store all the ASCII-valued GeoKeys. For the most part, the only keys that are ASCII valued

are citation keys. See section 2.4 of the GeoTIFF standard.

(4) GeoKeyDirectoryTag (34735.d, 87af.h) (required). This tag references all non-ASCII GeoKeys. All projection and datum information is stored in GeoKeys. See section 2.10.2.2 of this standard and section 2.4 of the GeoTIFF standard.

(5) GeoDoubleParamsTag (34736.d, 87b0.h) (optional). This tag is used to store all of the double-value GeoKeys, referenced by the GeoKeyDirectoryTag. The presence of this tag depends on whether or not there are any GeoKeys of type double in the file, which in turn depends mostly on the coordinate system used. Standard coordinate systems can be specified in GeoTIFF without using data of type double. See section 2.4 of the GeoTIFF standard.

(6) ModelTransformationTag (34264.d, 85d8.h) (optional). This tag may be used to specify the transformation matrix between the raster space and the model space. It may or may not be needed, depending on the rotation of the image.

2.10.2.2 GeoKeys

GeoKeys are structurally similar to TIFF tags, but at one lower level of abstraction. The following GeoKeys are used in USGS RFSs:

(1) GTModelTypeGeoKey (1024.d, 400.h) (required). The required value is 1 (ModelTypeProjected).

(2) GTRasterTypeGeoKey (1025.d, 401.h) (required). The required value is 1 (RasterPixelIsArea).

(3) GTCitationGeoKey (1026.d, 402.h) (required). The purpose of this key is "...to give an ASCII reference to published documentation on the overall configuration of this GeoTIFF file" (GeoTIFF v1.0 section 2.7.2). This key will hold two pieces of information: the version number of the USGS Raster Feature Separate standard and the version number of the GeoTIFF standard. These two fields will be separated by a pipe (|) character. For example, this key might be populated with strings such as the following:

RFS unapproved draft standard | GeoTIFF v1.0

USGS RFS standard v1.0 | GeoTIFF v1.0

Other than the pipe delimiter, the text in this field has no required format characteristics, so application software should not attempt to parse it. Note that this key is not populated in DRGs.

(4) GeogCitationGeoKey (2049.d, 801.h) (optional, depending on data characteristics). This key is a "General citation and reference for all geographic coordinate system parameters" (GeoTIFF v1.0 section 2.7.2). As recommended by the GeoTIFF standard, this key will be populated only if the projected coordinate system (PCS) is user defined. For example, if a quadrangle-centered plane coordinate system is defined by the GeoKeys, this tag might contain the string

Quad-centered PCS, not related to any standard ground grid.

This key is for descriptive purposes only; application software should not attempt to parse it to extract coordinate system information. Most USGS RFS data will use a standard PCS such as UTM, so the GeogCitationGeoKey will not be populated.

(5) ProjectedCSTypeGeoKey (3072.d, c00.h) (required). This key contains a coded value for the projection, datum, and possibly plane coordinate zone. Legal values for this key are listed in section 6.3.3.1 of the GeoTIFF standard.

(6) PCSCitationGeoKey (3073.d, c01.h) (required). This is a free text field for describing the projection and datum. Most USGS RFSs are projected on the UTM and use this field to describe the projection, zone, and datum. In these cases, the GeoKey contents should be in the following form:

UTM Zone <number> <N/S> with <datum>

where

<number> is the UTM zone number, and

<datum> is the common datum abbreviation, such as NAD27 or NAD83.

For user-defined coordinate systems, this key may contain any descriptive text deemed appropriate. Contents of the PCSCitationGeoKey are for descriptive purposes only. Application software may display this key as simple metadata but should depend on the ProjectedCSTypeGeoKey (and possibly other keys) for precise coordinate system information.

Applications should not attempt to parse the PCSCitationGeoKey to obtain projection or datum information.

Other GeoKeys may be populated at the data producer's option. Other keys will be needed if user-defined geographic and projected coordinate systems are used.

APPENDIX 2-A

Summary of RFS TIFF Tag and GeoKey Requirements

Appendix 2-A: Summary of RFS TIFF Tag and GeoKey Requirements

The following table summarizes the TIFF, GeoTIFF, and GeoKey requirements described in section 2.10.

The values in the table are consistent with the TIFF and GeoTIFF standards, but there are less options than are allowed by TIFF. Additional guidelines and requirements for the values of tags and keys are detailed in the body of this standard.

Additional tags and keys may be used at the data producer's option, providing they do not conflict with the required tags.

See the body of the standard for details on required versus optional tags and keys.

TIFF tags required by baseline TIFF				
TagName	Decimal	Hex	Type	Value
ImageWidth	256	100	SHORT or LONG	
ImageLength	257	101	SHORT or LONG	
BitsPerSample	258	102	SHORT	8
Compression	259	103	SHORT	1 or 32773
PhotometricInterpretation	262	106	SHORT	3
StripOffsets	273	111	SHORT or LONG	
RowsPerStrip	278	116	SHORT or LONG	1
StripByteCounts	279	117	LONG or SHORT	
Xresolution	282	11A	RATIONAL	
Yresolution	283	11B	RATIONAL	
ResolutionUnit	296	128	SHORT	2
ColorMap	320	140	SHORT	768

TIFF tags required by RFS, though not required by baseline TIFF				
TagName	Decimal	Hex	Type	Value
Orientation	274	112	SHORT	1
ImageDescription	270	10E	ASCII	
DateTime	306	132	ASCII	
DocumentName	269	10D	ASCII	
PageName	285	11D	ASCII	

TIFF tags defined by GeoTIFF				
TagName	Decimal	Hex	Type	Value
ModelPixelScaleTag	33550	830E	DOUBLE	
ModelTiepointTag	33922	8482	DOUBLE	
GeoAsciiParamsTag	34737	87B1	ASCII	
GeoKeyDirectoryTag	34735	87AF	SHORT	
GeoDoubleParamsTag	34736	87B0	DOUBLE	
ModelTransformationTag	34264	85D8	DOUBLE	

GeoKeys defined by GeoTIFF and used by RFS				
TagName	Decimal	Hex	Type	Value
GTModelTypeGeoKey	1024	400	6.3.1.1 code	1
GTRasterTypeGeoKey	1025	401	6.3.1.2 code	1
GTCitationGeoKey	1026	402	ASCII	
GeogCitationGeoKey	2049	801	ASCII	
ProjectedCSTypeGeoKey	3072	C00	6.3.3.1 code	
PCSCitationGeoKey	3073	C01	ASCII	