# 2018 Rio de Flag Floodplain Assessment

## Floodplain Health Assessment

**PO # 18-001691**

Natural Channel Design, Inc.
2900 N. West St, Ste 5
Flagstaff, AZ 86004

**July 2018**

# 2018 Rio De Flag Floodplain Assessment

## Floodplain Health Assessment
**PO # 18-001691**

**Submitted to:**
Jim Janecek
City of Flagstaff Stormwater Section
211 West Aspen Ave
Flagstaff, AZ 86001

**Prepared by:**
Natural Channel Design, Inc.
2900 North West St., Ste 5
Flagstaff, AZ 86004

**July 2018**

# TABLE OF CONTENTS



## LIST OF FIGURES



## LIST OF TABLES

## EXECUTIVE SUMMARY

Key aspects of floodplain health (erosion, aggradation, channel access to floodplain, vegetation composition and distribution, blockage and sediment inflow, trash, etc.) were assessed throughout the Rio de Flag and its tributaries within and near the City of Flagstaff. The study was conducted by analysis of spatially referenced photos taken during November 2017. Each photograph was scored using a scoring matrix which included 12 different aspects of floodplain health. This matrix did not cover floodplain capacity. All scoring was done through visual inspection and estimation following the outline of the matrix developed for the study. Scores were combined into 18 different reaches of stream throughout the city that were delineated by relatively homogeneous health condition as well as inflow of major tributaries.

The spatially referenced scores show a relatively clear effect of urbanization on the Rio de Flag and its tributaries. Weeds, bank erosion, blockages and access to floodplain generally scored best on the western and northern end of tributaries outside of the city limits and decreased as the channel flows through the city to the eastern boundary.

While the data clearly indicate specific areas for cleanup, restoration and protection, they also indicated that many of the issues originated outside of the floodplain. Weeds, sediment production and trash accumulation were key issues and all linked to sources outside of the floodplain. These issues will clearly require cooperation with landowners and city departments outside of the stormwater group. Another key finding is that reaches with low scores in one category were often low scoring in other categories. This indicated the compound effects of multiple stressors (for example bank erosion related to both sediment aggradation, incision and invasion by weeds.)

Suggestions have been made in the form of best management practices, seeding and weed management specifications that can help to address many of the issues.

This data can easily be replicated and the methods can be utilized by citizen scientists with limited training in the future. The data sets are supplied to the city in the form of spatially linked photos in ArcGIS as well as excel worksheets with photo numbers, scores etc. New photos and reanalysis with the scoring matrix can be utilized to understand the effects of restoration projects and implementation of new management strategies. Moreover, mobilization of citizen groups to help with future monitoring further encourages a relatively well informed and interested public into continued participation in aspects of the floodplain that citizens of Flagstaff have expressed concern for including open space, aesthetics, wildlife habitat and recreational activity.

## PROJECT DESCRIPTION

The City of Flagstaff, Stormwater Section wishes to make an assessment of floodplain health for the Rio de Flag, the main drainage through the city, and several of its key tributaries. The major aspects of floodplain health that are of interest are: vegetation components, erosion or aggradation of the floodplain, excessive trash or dumped materials, access to floodplain by the active channel, and culverts or other infrastructure that improperly alters the hydraulic or sediment transport capacity of the channel or inflow. These key aspects of floodplain health combined with hydrologic modeling results which the stormwater section already has in place will provide a snapshot condition of how well specific reaches perform hydrologic, physical and ecological functions.

Although flows are ephemeral, the channel flows often enough and for long enough periods that some riparian vegetation is supported along the length of the channel. Consequently, the channel is recognized for wildlife habitat, aesthetic and recreational values along much of its length. Accordingly, the floodplain of the Rio and its tributaries are targeted for multiple uses compatible with flood conveyance. Open space, wildlife habitat, aesthetics and recreational/non-motorized transportation use are key elements recognized in concert with flood control. Thus, understanding of multiple aspects of floodplain health beyond hydraulic capabilities is key to broad public support for flood control and water quality missions of the city.

Analysis of the site conditions and causes will not only be utilized as a tool to prioritize enhancements and improvement projects but will provide insight into potential shortcomings of current floodplain management regulations. Natural Channel Design (NCD) will provide a report identifying floodplain health conditions and patterns within the data set that was provided by the City. Issues affecting floodplain management will be identified. Suggested changes to city maintenance operations, codes and regulations will be developed and provided in the final deliverable. These suggestions along with proposed future monitoring ideas and information needs for development of floodplain management plan will be provided as well.

### LOCATION

The Rio de Flag is the major water course draining Flagstaff, Arizona. The Rio de Flag is an ephemeral stream for most of its length. However, there are several springs that contribute perennial flow for short reaches. Although the channel lacks perennial flow it has a large watershed which contributes stormwater and snowmelt runoff to the channel. Watershed area upstream of the city limits is 72 square miles. There are numerous relatively large tributaries that join the Rio de Flag within the boundaries of the City of Flagstaff (COF) and the watershed area grows to 114 square miles at the downstream end of the city boundary. The COF greater city limits include approximately 64 square miles.

Most tributary watersheds and the watershed of the main channel of the Rio de Flag originate on Coconino National Forest lands outside of the city limits. The watershed upstream of the city is characterized by relatively steep slopes, ponderosa pine forest and volcanic soils. There is some development on Coconino County lands outside the city limits that could affect downstream floodplain health, however, the majority of the watershed and floodplain leading into the city limits is undeveloped

forest lands. The Rio de Flag watershed is entirely within the Canyon Diablo HUC 15020015 and represents the northern most subdrainage in that unit.

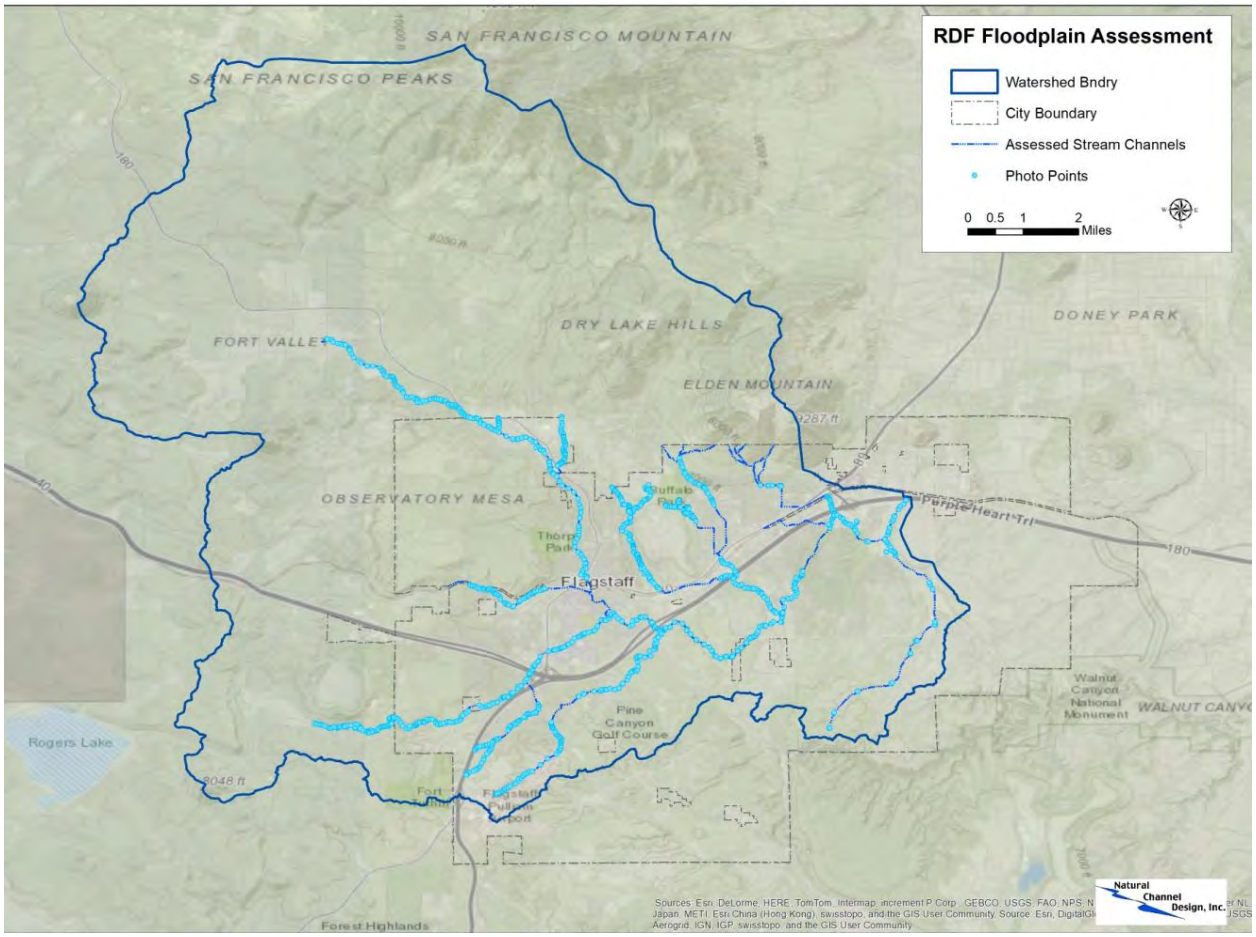



**Figure 1 Location map.**

*The project is located along the Rio de Flag and its tributaries through Flagstaff, AZ. Tributaries originating outside of city boundaries with significant connections to the Rio were also studied.*

## PROJECT OBJECTIVES

The objective of the study is to provide a repeatable and quantifiable snapshot of floodplain health and function throughout the City of Flagstaff. This study is meant to utilize easily available data, which can be updated for new analysis. The use of georeferenced photos provides a means of utilizing easily obtainable data which can be used in a quantifiable manner and easily reproduced. The data produced should help to define problem areas, as well as specific issues that can be addressed through management or enhancement projects. Additionally, the repeatable nature of the study will allow monitoring of regulatory and project success in the future.

## METHODS

City of Flagstaff Stormwater Section provided photographs of the channel and floodplain of the Rio de Flag and its major tributaries. Photos were taken in a systematic manner during the late fall of 2017. Photos were taken roughly every 400 feet along the channel in addition to any structures in the channel (culverts and bridges) and significant inflow channels. There were 17 different stream reaches photographed by the Stormwater Section, with NCD completing an 18$^{th}$ reach in early summer of 2018 for a total of 2100 photographs. Reaches were designated by the stormwater section and further refined during data analysis.

A scoring matrix was developed to evaluate the health of the floodplain shown in the photos. There are seven main categories with twelve total categories. The main categories evaluated were: vegetation, erosion/aggradation, floodplain access, flow conveyance, trash and debris, roads and trails, and inflow sources. Four of the main categories included sub-categories. The vegetation category was comprised of composition and zonation. Erosion/aggradation included bank erosion and bed stability. Flow conveyance considered floodplain blockages and structures such as culverts. Inflow source had three subcategories: pollution prevention, inflow channel condition and sediment source from inflow.

All photos were evaluated for each category. Visual estimates were made based on what could be seen in the photograph. These were visual estimates for conditions such as percent vegetative cover, entrenchment ratio, percent floodplain blockage, etc. presented in the photos. Local knowledge of the floodplain condition surrounding the photo was utilized to augment the photographic information as needed and field verification of conditions at some sites unfamiliar to the survey team. Actual field conditions may vary significantly if the photo was not representative of overall existing conditions.

Each photo was scored from 'one' (indicating poor health) through 'five' (indicating good health) or NA for Not Applicable for each of the 12 categories. A map has been made for each category with each photo color-coded by score. These maps help show hotspots and provide an overall sense of scale of problem areas. A georeferenced database containing all the photos was developed in ArcGIS and is provided as a reference data set/electronic appendix to this report.

Categories and scoring matrix are presented in Table 1 and explained in detail below.

The **vegetation composition** category considered the percent cover of non-native and weedy annual species present and the presence of any highly aggressive invasive species. A vegetative community that appeared to be all native scored a five. A score of four, three or two indicated increasing levels of non-native or weedy annual species percent cover. A 'one' indicates a vegetative community that is dominated by non-native and weedy, annual species. In addition, there is an **invasive weed** map showing the locations of all aggressive, invasive species seen in the photos. Aggressive invasive species are a subgroup of the many invasive species common to the region. These are considered highly problematic in this region and several are often target weed species outside the floodplain area. These include Scotch thistle (*Onopordum acanthium*), diffuse knapweed (*Centaurea diffusa*), common teasel (*Dipsacus fullonum*), and poison hemlock (*Conium maculatum*).

**Vegetation zonation** is an indicator of location of appropriate species growing in relation to the active channel and floodplain. The function being addressed is blockage of the active channel by large diameter stiff vegetation that captures debris and blocks flows as well as having appropriate densely rooted vegetation in active stress areas of the channel to prevent erosion. Ideally, vegetation is distributed in the floodplain similar to that show in Figure 2. Vegetation zonation is scored as a

departure from this norm. A 'five' indicates that the vegetation is appropriately zoned, 'four' indicates that there was some large, woody vegetation in the active channel, 'three' that the floodplain was lacking in trees or in appropriate vegetation, 'two' there was dense, woody vegetation in the active channel and 'one' indicates that the toe zone of the active channel was unprotected by vegetation allowing erosion along the toe of the bank.

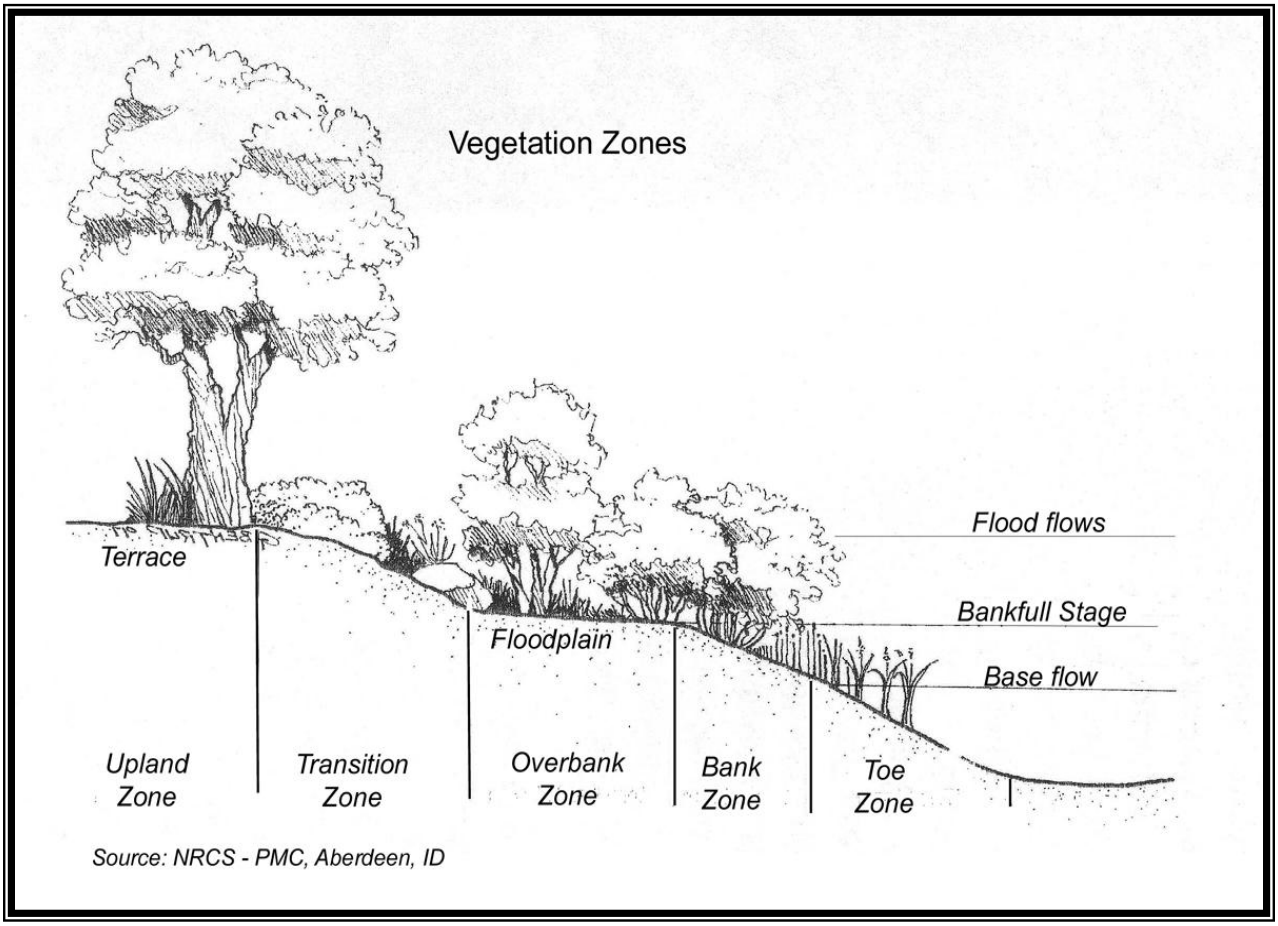



**Figure 2. Reference vegetation zones along streambank.**

*Stylized layout of vegetation zones along cross section of stream bank. Low growing, flexible and rhizomatous materials are closer to the active channel and grade into taller, stiffer and more long lived species at the outside of the floodplain. Zonation is driven by both moisture gradients and the frequency and magnitude of high flow events.*

**Bank erosion** considered whether the banks were stable or eroding and provide an indicator of both channel lateral stability and sediment supply to the channel. Banks that were stable with good vegetation scored a 'five', while stable banks with artificial protections, such as riprap or concrete, scored a 'four' because they lacked habitat and aesthetic qualities. Eroding banks with smaller unprotected areas of generally less than 25% scored a 'three' and eroding banks with larger unprotected areas, often greater than 75% scored a 'two'. Vertical eroding banks with an eroded bank height that was greater than the bankfull height scored a 'one'.

The **bed stability** category determined whether the channel bed was incising, aggrading, or stable as indicated by headcutting or sediment size distribution in the channel. A 'five' indicated a stable channel bed with appropriate vegetation or sediment size to withstand normal erosive forces. 'Four' indicated a stable bed dependent on artificial grade control placed within the channel. An incised bed that has incised, then widened and stabilized with flood plain features and some vegetation scored a 'three'. A bed with signs of instability or inappropriate sized sediment to projected shear stress (i.e. fine sediment dominate bed in a channel that now receives concentrated storm flows from a culvert or ditch) scored a 'two'. A channel with obvious signs of incision, erosion or aggradation scored a 'one'.

**Floodplain access** evaluated the degree to which flood flows had access to the floodplain or were confined within a narrow channel which creates high velocities and shear stress. Flood flows that are allowed to spread across a floodplain travel at reduced velocities and can attenuate as they travel downstream. Additionally, floodplains can help improve water quality of peak flows as vegetation and soil bacteria utilize nutrients and capture other pollutants. An estimate of the entrenchment ratio was used to determine scoring. The entrenchment ratio is a measure of the vertical containment of a channel that is defined as the flood-prone width divided by the bankfull width. Bankfull being the width of the active channel and flood-prone being the width at twice the depth of the active channel. These ratios were estimated from the photos and no actual measurements were taken. An entrenchment ratio of 2.0 means that the flood-prone width is twice the bankfull width. A larger entrenchment ratio means there is a larger flood area/width relative to the size of the bankfull or active channel. Photos that showed larger floodplains or floodplains with minor blockages scored highest (five). Channels with flood-prone width that was less than twice the bankfull width scored a 'two' and if there was no access to the floodplain because the channel was entirely within a pipe or conveyance it scored a 'one'.

The **culverts and bridges** category scored these structures on capacity, floodplain connectivity and condition. Bridges that spanned the entire floodplain scored a 'five'. Geomorphically designed culvert arrays (mimicking natural channel dimensions) or bridges that came close (but not quite) to spanning the floodplain scored a 'four'. A relatively stable, standard design (single barrel or all barrels at same elevation) culvert scored a 'three'. Culverts that were under capacity, created problematic slope breaks in the channel, or high energy flows scored a 'two'. Broken culverts or those with signs of erosion or aggradation received a 'one'.

**Floodplain blockage** evaluated the degree to which the floodplain was blocked by objects like stockpiles or fill. A floodplain that was clear for the full width and in a natural condition scored a 'five'. Floodplains with other uses that did not necessarily hinder flood flows but interacted with them scored a 'four' such as when fill, rock, roads or development encroached on the floodplain but did not block it. A floodplain with less than 50% blockage scored a 3. One with greater than 50% blockage but with accommodations for increased stage a velocity (such as armoring) scored a 'two', while one with similar blockage but without armoring scored a 'one' due to potential for erosion during peak flows.

The **trash and debris** category rated the amount of these materials seen in each photo. Essentially no trash or debris scored a 'five'. Minor debris along the floodline was score as 'four'. Trash and debris buildup around grates and culverts scored a 'three'. Trash and debris dumping along the fringe of the floodplain scored a 'two', while dumping in or near the active channel scored a 'one'.

The **roads and trails** category evaluated the degree travel ways were appropriately placed within the floodplain. A 'five' indicated that there were no roads or trails in the channel or floodplain. A 'four' indicated they were perpendicular to the flow and supported by an appropriate crossing. A 'three'

indicated they ran parallel to the flow but were placed at the outer fringe of the floodplain, while 'two' indicated they were parallel but blocking the floodplain. The photo was scored 'one' when a road or trail was parallel to flow, sunken or at grade or there were roads/trails that were dense, rutted or heavily used by ATVs because of the potential for flood flows to be captured by the pathway and create erosion or divert the channel.

**Pollution prevention** focused on the degree to which inflow areas were influenced by direct runoff from areas which normally provide relatively high non-point source pollution or direct flows from impermeable surfaces. Only the inflow area seen in the photograph was assessed. Low impact development features such as stormwater retention/detention basins may have been installed upstream of the inflow area and were not assessed. The **inflow channel condition** category estimated the degree to which the inflow channel was natural. A fully natural channel scored a 'five', ≥ 75% natural scored 'four', approximately 50% natural 'three', ≤ 25% natural 'two' and a fully paved or piped channel scored 'one'.

The **sediment source** category evaluated the amount of sediment potentially supplied to the channel and its source. If the inflow source was from a forest or a neighborhood with no bare ground it scored a 'five'. Temporary construction site near the floodplain scored a 'four'. Chronic inflow of cinders from roadways scored a 'three'. Chronic dirt roads or erosion in the drainage scored a 'two'. Bare ground or eroding banks near the confluence scored a 'one'.

Scoring was tabulated in an Excel™ spreadsheet that correlated reach designation and photo number with scores for each category and notes about observations made from the photo. Reach designations were used to combine photos and determine mean scores in each category.

Scores for each category at each photo point were plotted in ArcGIS for visual assessment of each reach. In several cases, reaches were subdivided based on scoring observations to provide reach boundaries with more homogeneous scores, thereby providing a better description of the functions in the reach. Mean scores calculated from combining unweighted categories are likely not useful to understand the overall score of a specific reach since scores from each category operate on an independent scoring description which is not related to scoring in other categories. In order to understand the overall health of a reach in relation to other reaches we tabulated the sum of how many categories the reach scored in the bottom 25$^{th}$ percentile compared to other reaches for each category. While this helps to pinpoint specific reaches in the greatest need, as a practical point, scores from individual categories are likely more meaningful to direct management action or regulation changes.

Importantly, these results are also provided in a GIS database which can easily be utilized to locate specific problem areas or reference reaches and drive management decisions or be tied to future monitoring efforts.

**Table 1. Scoring matrix for floodplain health**

*Each photograph was scored utilizing the scoring matrix below. Scores were based on visual assessment of photographs. No measurements were made. However, a subset of photos was field verified by the scoring team.*

## Rio de Flag Photo Scoring Matrix

5 point max (good health), 1 point min (poor health), NA is not applicable

| Main Category | Sub-Category | Score 5 | 4 | 3 | 2 | 1 |
|---|---|---|---|---|---|---|
| Vegetation | Composition | All native | ≤25% non native | 50%/50% | ≥75% non native | Dominated by non-natives and weedy annual species |
| | Zonation | Appropriately zoned | Some large woody in active channel | Floodplain lacking any trees or appropriate vegetation | Dense woody debris in active channel | Toe zone unprotected by vegetation |
| Erosion/ Aggradation | Bank Erosion | Stable banks with vegetation | Stable with riprap | ≤25-50% unprotected bank | ≥50-75 % unprotected bank | Vertical eroding bank >bankfull height |
| | Bed Stability | Stable with appropriate vegetation or sediment size | Stable with artificial grade control | Incised but showing signs of widening or aggrading | Easily erodible bed material with … Bed showing signs of instability | Obvious erosion or aggradation |
| Floodplain Access | | Entrenchment ratio >3 | Floodplain with some blockage | Entrenchment ratio ≈2 | Entrenchment ratio <2 | No floodplain, all in pipe or conveyance |
| Flow Conveyance | Culverts and Bridges | Bridge span over entire floodplain | Geomorphically designed culvert array | Standard design, with over-wide section | Under capacity, slope break, high energy, etc. | Broken, leaking, erosion or aggradation |
| | Floodplain Blockage | Clear for full width - natural | Clear for full width - other use | <50% blockage (stock piles, fill sections, etc.) | >50% blockage with accomodations for increase stage and | >50% blockage - no armoring |
| Trash & Debris | | Essentially none | Minor debris along flood line | Debris buildup on grates or around culverts | Trash and debris dumping along fringe of floodplain | Trash and debris dumping in or near channel |
| Road & Paths | | No roads or trails in floodplain | Roads and trails at grade or supported by appropiate channel | Road or trail parrallel to flow but at outer finge of floodplain | Parrallel to flow and above grade: blocking floodplain | Parrallel to flow: at grade or sunken or dense, rutted, ATV use |
| Inflow Source | Pollution Prevention | Full LID retention/detention | Partial LID | Detention only | Partial detention | Direct runoff to channel |
| | Inflow Channel Condition | Natural channel above | ≥75% natural channel | 50% natural channel | ≤25% natural channel | Paved or piped channel |
| | Sediment Source | Healthy forest or neighborhood with no bare ground | Temporary construction site near floodplain | Chronic inflow of cinders or icemelt from roadways | Chronic dirt roads or erosion in drainage | Bare ground or eroding banks near confluence |

## RESULTS

The original 17 reaches provided by the city are currently divided into 22 different reaches. One reach (18) was added by doing additional survey in 2018. Some larger reaches were subdivided based on junctions with major tributaries or significant changes in surrounding land use.

Tabulated category mean score results are provided in the table below for each reach. There was a tendency for reaches with low scores in one category to also have low scores in additional categories. This is reflected by the 'number of lowest scores' column which sums the number of categories that the reach scored in the lowest 25$^{th}$ percentile.

Summary results indicate that the most widespread issues affecting the floodplain are inflow channel conditions, lack of pollution prevention, effects of roadways including culverts and bridges as well as invasive plants. Trash and debris in the floodplain was not generally a problem although several discreet areas do have considerable litter generated issues. In general, the areas to the west and north either outside of the city limits or in the upstream portions within the city score relatively high in each category while scores generally decrease in the Rio and its tributaries as they progress through the city. The exception to this is Reach 5- Peaceful Valley Wash which is very rural for most of its length but has been heavily impacted by off road vehicle use on a roadway that runs within the ephemeral channel. This pattern is strongest for nonnative species and invasive weeds which do increase dramatically in reaches to the eastern or downstream end of the city. Specific highlights of the results from each category are presented separately below. Maps, indicating scores for each photograph are provided fore each category in the Appendix to this report.

**Table 2. Results for reach analysis of photos.**

*Mean scores for each category by reach. The far right column contains the number of times that each reach scored in the lowest 25$^{th}$ percentile of reach scores for additional categories and provides an estimate of cumulative impacts.*

| Reach | Vegetation Composition | Vegetation Zonation | Bank Erosion | Bed Stability | Floodplain Access | Culverts & Bridges | Floodplain Blockages | Trash & Debris | Roads & Trails | Inflow Pollution Prevention | Inflow Channel Condition | Inflow Sediment Source | # of Lowest Scores |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1a | 3.6 | 4.5 | 4.3 | 4.6 | 3.8 | 2.8 | 4.5 | 4.9 | 3.4 | 1.0 | 4.5 | 4.6 | 2 |
| 1b | 3.4 | 4.9 | 4.5 | 4.8 | 4.6 | 4.2 | 4.5 | 4.8 | 4.0 | 1.3 | 3.1 | 4.7 | 1 |
| 1c | 2.6 | 4.9 | 4.3 | 4.8 | 3.4 | 2.5 | 3.4 | 4.6 | 4.4 | 1.5 | 1.2 | 4.9 | 6 |
| 2 | 4.5 | 4.5 | 4.0 | 4.0 | 3.5 | 2.8 | 3.7 | 4.8 | 4.1 | 1.9 | 2.9 | 4.2 | 4 |
| 3 | 4.6 | 4.3 | 4.5 | 4.7 | 4.2 | 3.4 | 3.8 | 4.5 | 4.5 | 1.8 | 2.6 | 4.9 | 1 |
| 4 | 4.4 | 4.3 | 4.7 | 4.7 | 3.6 | 3.0 | 4.8 | 4.9 | 4.7 | 5.0 | 4.0 | 4.9 | 0 |
| 5 | 3.2 | 4.2 | 4.1 | 4.0 | 4.1 | 2.3 | 4.9 | 4.9 | 3.3 | 1.0 | 2.1 | 4.1 | 8 |
| 6 | 4.5 | 5.0 | 4.4 | 4.5 | 2.6 | 2.4 | 5.0 | 4.9 | 4.5 | 1.8 | 1.0 | 4.0 | 4 |
| 7 | 4.7 | 4.7 | 4.4 | 4.7 | 3.8 | 3.3 | 4.6 | 5.0 | 4.3 | 1.0 | 2.1 | 4.9 | 0 |
| 8 | 4.9 | 4.7 | 4.7 | 4.8 | 4.3 | 3.0 | 4.8 | 5.0 | 4.6 | 1.0 | 3.3 | 4.9 | 0 |
| 9a | 4.7 | 4.3 | 4.7 | 4.8 | 3.9 | 3.5 | 4.7 | 5.0 | 4.7 | 1.4 | 4.8 | 5.0 | 1 |
| 9b | 4.3 | 4.5 | 4.6 | 4.8 | 3.8 | 3.9 | 4.5 | 4.9 | 3.4 | 1.0 | 5.0 | 4.9 | 1 |
| 10 | 4.6 | 4.6 | 4.4 | 4.8 | 4.2 | 3.3 | 4.6 | 4.5 | 4.8 | 1.4 | 4.5 | 4.9 | 1 |
| 11a | 4.1 | 4.6 | 4.2 | 4.0 | 3.2 | 3.1 | 3.4 | 4.7 | 3.6 | 1.0 | 3.3 | 4.7 | 3 |
| 11b | 4.3 | 5.0 | 4.2 | 4.3 | 2.9 | 3.1 | 4.2 | 4.7 | 3.3 | 1.0 | 2.0 | 4.5 | 5 |
| 11c | 4.7 | 5.0 | 4.5 | 4.7 | 4.1 | 3.8 | 4.8 | 5.0 | 3.3 | 1.0 | 3.7 | 5.0 | 1 |
| 12 | 4.9 | 4.9 | 4.2 | 4.9 | 4.4 | 3.0 | 4.5 | 5.0 | 4.8 | 1.0 | NA | 4.9 | 0 |
| 13 | 3.8 | 3.7 | 3.5 | 4.1 | 3.8 | 2.8 | 4.7 | 4.5 | 4.2 | 1.6 | 2.3 | 4.2 | 5 |
| 14 | 4.9 | 4.7 | 4.7 | 4.8 | 4.4 | 3.0 | 4.5 | 4.7 | 4.6 | 1.6 | 1.3 | 4.6 | 1 |
| 15 | 4.9 | 4.8 | 4.7 | 4.7 | 4.1 | 3.0 | 4.2 | 4.8 | 4.3 | 3.1 | 3.7 | 4.5 | 0 |
| 17 | 4.1 | 4.0 | 4.3 | 4.4 | 3.6 | 2.7 | 3.8 | 4.7 | 4.6 | 2.9 | 4.1 | 4.6 | 3 |
| 18 | 2.5 | 2.6 | 3.7 | 4.4 | 3.2 | 2.7 | 3.2 | 4.3 | 4.0 | 1.0 | 2.6 | 3.6 | 8 |

### VEGETATION COMPOSITION AND INVASIVE WEEDS

The vegetation composition category evaluated the presence and degree of non-native and weedy, annual species as well as the presence of highly invasive species. The majority of the Rio de Flag watershed has a primarily native vegetation community that is in good condition, especially in the upstream reaches around the edges of the city limits. This vegetated community composition changes depending on floodplain morphology and can be dominated by either native grasses, willows and other shrubs as well as more upland trees such as ponderosa pine and oak. As the watershed enters more urban areas with higher levels of disturbance, the vegetation begins shifting toward more non-native and weedy, annual species and in some areas becomes dominated by non-natives. These non-natives include Siberian elm, Russian olive as well as weedy annuals and the pattern of occurrence indicates that weed seed is being actively transported by both flood flows as well as prevailing wind patterns (from the southwest). Weedy, annual species (both native and non-native) are a concern because they have shallow root systems and provide the channel with little to no protection from erosive forces and they tend to lower the habitat quality for wildlife. There are high levels of non-native species along the lower reach of the Rio de Flag and along the washes that enter in this area including Spruce Avenue Wash, Fanning and Peaceful Valley. Many of these areas appear to have been disturbed but were not revegetated, leaving them vulnerable to easy invasion by weeds. There is also a section of Sinclair Wash (Reaches 11a,b,c) with some high levels on non-native plants. The non-native section through Wheeler Park just indicates the presence of turf grasses instead of native grasses. This is not generally considered a problem from an erosion point of view, however turf grass does limit the habitat diversity and quality.

Not surprisingly the areas with aggressive invasive species overlap with the areas with least amount of native vegetation. There are also several smaller, scattered populations of invasive weeds found throughout the watershed. There were four key invasive species identified in the photos: diffuse knapweed (*Centaurea diffusa*), poison hemlock (*Conium maculatum*), common teasel (*Dipsacus fullonum*), and Scotch thistle (*Onopordum acanthium*). These species are highly invasive and are of great concern because that can take over both disturbed and natural areas. They can push out native species and form large, dense stands. They are also quite difficult to control once they become established and take years or longer to eradicate.

Common teasel and poison hemlock are almost exclusively found in wetter areas along channels and on floodplains. Working to control these species in the Rio de Flag floodplain is key to controlling these species in the Flagstaff area. In addition to the locations on the map, the unevaluated area of Switzer Wash (Reach 15 Switzer and 13 Spruce Ave Wash) is heavily infested with teasel. Scotch thistle is found in uplands but often dominates floodplains. Controlling this species in the floodplain would make a large impact on the local population.

Diffuse knapweed prefers dryer habitats but is happy to invade and dominate a disturbed floodplain such as upstream of Foxglenn Park (Reach 1b and 1c).

### ZONATION

Poor scores in the vegetation zonation category was due to either dense woody vegetation or an unprotected toe zone in the active channel. Appropriate vegetation such as native grasses and shrubs protect the channel from erosion. This is especially important to the Rio de Flag where most of the reaches are located in relatively fine soils which lack sufficient cohesion to resist erosion without

vegetation or some other protection. This becomes even more important since many of these reaches have either incised due to natural forces or been channelized to increase flood capacity. The channel in the upper Peaceful Valley reach runs down a road which does not have vegetation leaving the toe unprotected.

Dense woody vegetation can block the channel causing increased flood stages and occasionally causing lateral instability. There were a few reaches with consistently lower scores in the zonation category which included Fanning Wash, lower Spruce Avenue Wash, and upper Peaceful Valley. The Fanning reach consists almost entirely of annual species and invasive weeds which provide no protection for the toe of the bank. Spruce Ave Wash has several sections of dense woody vegetation in the active channel which has caused the banks to erode. The eroding banks no longer have vegetation protecting the toe which can lead to increasing rates of erosion.

### BANK EROSION

Overall bank stability within the City is not a major issue in most of the channels. Many of the sites that are eroding are in stable channels that have incised in the past and have widened. There are taller banks that are still unvegetated due to the banks being too steep to support vegetation, but the toes of the banks are stable. This appears to be the case along the Sinclair Wash reaches, and also in the Schultz Reach. The Bow and Arrow Reach 2 has instability at the beginning of the reach near the airport that is causing active bed and bank erosion. This may be a result of increased runoff directed from activities around the airport. Further downstream the channel is relatively stable.

Within Spruce Ave. wash, isolated pockets of bank erosion occur to the north of Butler Ave. These appear to be caused in some instances by trees in the channel creating blockages that can cause widening. Others are caused by culvert alignments. In Spruce Avenue downstream from Butler, incision followed by channel widening is creating highly unstable banks.

Along the lower portion of Fanning Wash, the stream crosses a low water crossing and drops down from approximately 6 feet, followed by another headcut and widening reach downstream. This long reach of tall banks and low stability is creating one of the largest sediment sources in the reaches that have been assessed.

The final problem area is along the upper end of Peaceful valley wash. The channel here is located in a dirt road located in the valley bottom that has captured what would probably have been dispersed flow. Incision and erosion along the road create a long reach of unstable channel and high sediment supply.

### BED STABILITY

The channel beds in the city are overall fairly stable. There is evidence that many channels have incised in the past, but have since stabilized by widening and creating a flood plain. Instability tends to be localized and due to the presence of obstructions such as culverts or floodplain encroachment. Aggradation most often occurs at the entrances of culverts or road crossings where the channel is overwide. Current incisions are due to channel obstructions, culverts, roads or other factors that are not generally apparent in the photos.

Specific problem areas include the upstream end of Bow and Arrow Reach 2. The channel becomes incised at the outlet of a recently installed culvert and remains incised with eroding banks for the next half mile until the valley changes and the stream becomes more stable.

Sinclair Wash Reach 11 shows several areas of aggradation, mostly in relation to culverts. There does appear to be a headcut upstream from the wastewater treatment plant near I-40 that could be a problem. The upstream end of Peaceful Valley Reach 5 is unstable due to the dirt road in the valley bottom that has concentrated flows causing incision. There is also a relatively active headcut in Reach 9a of the Rio de Flag in the Cheshire neighborhood that threatens to move upstream into channel that is in relatively good condition.

### FLOODPLAIN ACCESS

Floodplain access is the ability of flood waters to spread outside of the active channel, reducing the erosive forces of the water on channel banks. This is not a measure of the ability of the channel to carry a given flood flow. Only and indication of the ability of the channel to reduce the erosive stress of flood flows. In some cases, the active floodplain can be very narrow, depending on the stream type and valley it's located in. In natural systems, the stream can adjust to this condition by both channel form and sediment size, but in a manipulated stream where it has been channelized and confined through relatively fine sediments that do not resist erosion, problems can occur such as excessive bank or bed erosion.

Within the city, floodplain access was overall adequate with some floodplain being available for water to spread out. Isolated spots shown on the map within an otherwise good section are typically located at culverts or bridge locations. At these points, there is no access to floodplains. Areas where a lack of floodplain access is a problem include the Bow & Arrow Reach 2 by the airport. Here there is active incision that has created a small gully with little floodplain access. The other site where problems occur is in the lower end of Fanning and the Rio de Flag (Reach 18). Here the channel is confined and active bank erosion is occurring.

### CULVERTS AND BRIDGES

The vast majority of culverts around the City are the standard design that create an overwide area in the channel but generally appear in good condition and are adequately sized with no apparent issues. The photos showed several culverts around the City that were aggrading and filling in, some with significant blockages. Several others had erosion around the outlet, cracked gunnite, failing concrete, or were smashed. A handful of culverts appeared to be significantly undersized, showing sign of frequent overtopping. All of the problematic culverts and bridges are marked on the map and notes of specific failures are within the database file.

### FLOODPLAIN BLOCKAGE

Floodplain blockage includes any obstruction, encroachment, fill or larger trees on the floodplain that can obstruct flows or catch excessive debris. The most widespread types of blockages within the study area include raised road crossings that force the channel into a culvert. Floodplain filling around structures, houses, trails and roads account for further blockages. At the upstream ends of some of the

drainages where the channels are very small, tree growth encroachment onto the channel has caused some blockage.

### TRASH & DEBRIS

Trash and debris accumulations in the channels around Flagstaff are fairly light overall, but with several focal points of trash concentration, typically around larger shopping centers or along I-40 with transient camps. The only reach of stream where woody debris concentrations are present in significant quantities are along Schultz Reach 10, although these don't appear to pose a risk of blockage. The major trash concentrations are located around the Walmart parking lots, and the larger culverts crossing under I-40. Concentration of trash generally becomes reduced as you travel downstream from these areas.

### ROADS AND TRAILS

The most common and significant issues of concern found under the Roads and Trails category were roads and trails, at grade, running in or immediately adjacent to the active channel, rutted roads and trails crossing the channel sometime repeatedly, and roads and trails that were above grade, running adjacent to the channel blocking the floodplain.

In the lower Sinclair Wash reach and the reach of the Rio de Flag immediately downstream, several roads and trails, as well as parking lots, consistently ran parallel to the channel blocking the floodplain and often constricting the channel. In upper Peaceful Valley a rutted road frequently ran down the active channel or was adjacent to or repeatedly crossed the channel bed. In Rio de Flag (Reach 1) and Bow and Arrow Wash (Reach 1), rutted and sunken roads repeatedly ran in the channel. Sometimes the roads were immediately adjacent to the channel or crossed it.

### POLLUTION PREVENTION

The map for pollution prevention simply highlights that the majority of the Rio de Flag watershed has direct runoff of inflow sources to the Rio. This is likely a large under estimate of the amount of low impact development, retention/detention projects installed within the city since we are not looking at areas outside the view of the photo. However, it is evident that areas near the channel that contribute flow to the channel lack pollution prevention measures or even adequate buffer zones.

### INFLOW CHANNEL CONDITION

Inflow channel condition was poorest in the most densely developed areas. This is likely a function of the need for drainage and road crossings in these areas creating a high density of piped and concentrated flows into the main drainage. Less densely developed areas tended to more natural conditions. However, the majority of drainage confluences within the city limits were not fully natural and had been modified to some degree.

### SEDIMENT SOURCE

Sediment sources immediately adjacent to the channel were generally healthy and sourced very little sediment into the channel. This generally matches with the low instance of aggradation throughout the study area. The map highlights a handful of areas where there is chronic sources of cinders and

significant sediment from eroding roads or banks. While eroding banks are obvious sources of sediment, the use of cinders on roadways for road base and traction during snow storms represents a relatively large sediment source that is not recognized outside this region. Some area that capture cinder materials off roadways are scattered throughout the city. These may become more obvious in winter or early spring surveys.

#### MULTIPLE CATEGORIES OF IMPAIRMENT

Initial analysis of the data indicated that reaches with the lowest scores in one category were likely to have low scores in other categories as well. This is somewhat to be expected since high bank erosion is likely connected to floodplain connectivity, floodplain blockage and poor vegetation and vice versa as an example. The reaches most affected this way were identified by creating a category that summed the number of categories where the reach scored in the lowest 25$^{th}$ percentile for that category. The spatial results provide a relatively striking view of the impacts that the urban space has made on floodplain health. Northern and western reaches (upstream) are least affected. The most eastern (downstream) reaches are all heavily impacted and exhibit low scores in nearly half the categories. This result along with others indicate clearly that while floodplain health is driven by watershed forces outside the city boundary, the greatest impacts are created within the city and are likely under the direct control of the city.

## RECOMMENDATIONS

This study points to several floodplain health issues along the Rio de Flag and its tributaries. Some, such as the amount of incision and blockages to the floodplain, are remnants from past manipulations of the channel with the aim to consolidate flood flows on what would have otherwise been a very wide floodplain. These historical actions have set conditions that current managers will have to understand and work with. Other floodplain health issues appear to be created from current activities within the city limits and can likely be rectified through changes in management or through direct actions and maintenance along the floodplain. A partial set of recommendations is provided below and examples of specific specifications and actions that can be incorporated into regulatory code changes are provided in Appendix B.

### *Weeds and Vegetation Management*

The spread of nonnative invasive plants within the floodplain is an important detriment to the resource in several ways. The floodplain acts as a major pathway for distribution of invasive weeds and provides a long-term seed repository that perpetuates the issue for long periods of time. The presence of these invasive plants negatively affects floodplain function, habitat quality, recreational value and aesthetics. It is very important to recognize that floodplains are only a portion of the problem area within the city. The most aggressive weed species are found outside the floodplain as well as within. Effective control will require a coordinated effort.

Common teasel (*Dipsacus fullonum*) is a species that has recently established and currently has a limited but growing distribution that is mainly limited to floodplains. This species can likely be eradicated from the city with a rapid and concentrated effort. The location maps provided in the report provide a good starting point for treatment that can consist of both chemical and mechanical removal. Follow up

treatments will be required but this infestation is in an early stage and timely treatments will save considerable time and effort compared to treatment within the next few years.

The more widespread species will require considerable sustained effort to make progress. Educational and administrative changes should be utilized as well as normal removal methods. Our observations indicate that activities outside the floodplain are heavy contributors to the spread of knapweed and Scotch thistle. Large sites prepared for development but left neglected as well as stockpile areas become ideal establishment areas for these species. The seed produced during the fallow period is easily transported by wind and runoff to other areas and the problem is perpetuated even as development finalizes and landscaping is put into place on the original site. Development codes that mandate temporary plantings and weed management of sites left fallow for more than a growing season should be utilized to help limit this problem.

Similarly, revegetation efforts that are not fully effective allow low density vegetation communities to become infested with invasive weeds. Revegetation in arid environments is more difficult than mesic environments where most techniques have been adapted from. Multiple attempts may be needed if rains are insufficient to support establishment. It is recommended that specifications for revegetation of disturbed sites be based on a performance type specification that allows full payment after establishment or requires further contractor efforts if establishment goals are not met. Such an arrangement would help assure that sites were well vegetated after disturbance and help prevent invasion by nonnatives.

Finally, the city should develop a comprehensive weed management plan that establishes coordination across multiple jurisdictions within the city. It is recommended that this plan identify target species and control methods for each species along with goals for removal and control. A budget for weed management should be established and efforts should be coordinated amongst stormwater, streets, parks and recreation, open spaces and development within the city. Coordination with local groups focused on weeds, the National Forest Service and Coconino County are also warranted. Control efforts will require multiple years and should likely be targeted at source areas in the north and west of the city, then working downstream to the east into rapidly establishing areas.

Maintenance of vegetation within the channel may be required in some areas to reduce stiff woody vegetation that can impede storm runoff and increase flood stage. Vegetation maintenance should be accomplished with geomorphic and ecological principles in mind and with an imperative to maintain high quality habitat along the channel.

Deference should be given to native vegetation growing within the appropriate channel zone. The active channel (below bankfull stage) should be kept free of stiff woody vegetation and flexible native shrubs density should be low in this area. Grasses and wetland plants should be encouraged. Some nonnative grasses (i.e. Quackgrass) may be appropriate vegetation in areas that require protection from erosion and it is well established. Removal of native willows should only occur within the active channel and should only involve cutting and removal of stems rather than excavation of roots that disturb channel sediments. Live cuttings can be planted in appropriate zones of other reaches.

Mature woody trees should be discouraged in the area outside the channel that is approximately twice the width of the active channel. All nonnative elms and Russian olive trees should be discouraged.

***Trash and Debris***

Accumulation of trash and debris is generally limited to specific reaches of the Rio and tributaries. Several areas that have backwatered stormflow act as catchment areas which help keep the problem from spreading out. However, source areas appear to be associated with high traffic commercial areas. It is likely that runoff (and wind carried items) be routed through detention areas that can catch most of the trash generated from the area and allow it to be picked up.

Additional areas sourcing trash were associated with homeless encampments within the city. Tighter enforcement of littering laws in these areas might be possible, but it is likely that the most reasonable path forward is periodic cleanup of the areas during periods of low use.

***Channel morphology***

Impairments to floodplain health related to channel morphology issues are usually linked to either recent or historic incision of channels that have reduced the width of the floodplain and thereby increased stress on the channel which is normally composed of relatively fine grain sediments that have little resistance to erosive forces. The resulting bed and bank instability can take years or decades to reach some stable equilibrium and many reaches of channel may be ill prepared for infrequent, high intensity flooding.

Improving this condition will require consideration of the additional shear stress created from concentration of flows within culverts and other stormwater conveyances. New and replacement designs for culverts should attempt to mimic channel and floodplain dimensions and avoid concentration of flows into pipes that can greatly increase velocity or slope. When concentration of flow and shear stress are necessary components of the design, energy dissipaters or practices that return flow conditions to the basic dimension found prior to the crossing may be required. These may be as simple as building 'media luna' or water spreading structures from native rock at the outlet of the culvert.

Off road vehicle use in the floodplain or channel should be discouraged and existing damage should be repaired to prevent further degradation of the channel and flood plain. Reaches in the Rio de Flag (1c), Bow and Arrow Wash and Peaceful Valley Wash need to consider road relocation or closure along with restoration techniques to repair and revegetate the floodplains.

Head cut areas should be armored as soon as practical. Unstable headcuts can move rapidly upstream during single storm events, causing near permanent damage to channels, wetlands and nearby properties and utilities. Once incised, the ensuing widening, bank erosion and habitat degradation can take decades to repair itself. Repair of these areas may be the simplest and most pressing of items found in this assessment.

At least two reaches of the assessment area may be candidates for full scale channel restoration. Fanning Wash (Reach 18) and Lower Spruce Wash (Reach 13) have multiple impacts to vegetation and

geomorphology that could be successfully addressed using geomorphic and vegetation restoration techniques in combination. Repair of these areas should improve aesthetics, hydrologic function, habitat and vegetation in addition to stream stability. The city should consider developing conceptual designs and costs to prepare for grant writing efforts that secure funds for these projects.

***Sediment sources and non-point source pollution***

Sediment sources along the Rio de Flag and tributaries are relatively limited. However, increased sediment supply is noticeable because most reaches of the natural channels have a relatively poor geometry for efficient sediment transport. Noticeably, increased sediment supply along Spruce Ave Wash has resulted in the need for recent channel capacity maintenance at the corner of Fourth Street and Butler Avenue. In addition to declining conveyance at culverts and bridges, sediment aggradation affects vegetation growth in the channel and accumulation of central bars increases shear stress against banks.

Bank erosion and cinders from snow removal activities appear to the largest sources of sediment. Bank erosion sites often represent unique circumstances that must be understood on a case by case basis in order to affect a successful repair. However, roadway and parking area drainage represent a more diffuse problem. Sediment retention traps provide a relatively effective practice for concentrated runoff flows from these areas. However, ensuring a robust vegetated buffer between the roadway and channel can benefit areas with sheet flow runoff and provide a less maintenance intensive solution. A schematic and explanation of roadway buffers designed for this purpose are provided in Appendix B.

***Monitoring and Citizen Involvement***

The methods employed in this assessment provide an ideal vehicle for citizen involvement and potential future monitoring efforts for the Rio de Flag. The City of Flagstaff, through citizen groups like Friends of the Rio de Flag and other organizations has a relatively active and engaged citizenry that is very interested in issues related to the Rio de Flag, flood control, open space, recreation and science. There have been previous efforts by citizen groups and the volunteer Flagstaff Area Stream Team (FAST) to document ecological and physical conditions along the Rio de Flag and its tributaries. The results from this report can be related to this older data set through spatial correlation. However, the repeatability of the older data set is difficult because it involved somewhat subjective observations by relatively well trained citizens. This proved difficult to repeat on a frequent basis and large portions of the stream length still had not been documented after a decade.

This method requires much less training on the part of the observer (GPS operation and photo replication) and it allows participation in data collection by a much larger pool of volunteers. The photo interpretation matrix was intentionally set up to allow high repeatability amongst a wide variety of expertise. Hence, data collection and analysis can be repeated often and by a wide variety of people. Data assimilation may require specific GIS skills that are not widely held, but this is a relatively small portion of the project.

It is suggested that the stormwater section work with citizen partners to organize citizen data collection efforts several times a decade for the entire water course or as needed within subsections of the project area to monitor general trends or specific project efforts. This would provide a valuable tool to

stormwater section and generate interest, knowledge and support within the Flagstaff populace. The data generated by the efforts would likely lead to citizen group led and sponsored restoration, cleanup and enhancement projects at target areas throughout the length of the channel.

## CONCLUSIONS

Residents of the City of Flagstaff recognize that the drainage easements through the city are capable of providing aesthetic, recreational and ecological benefits as well as physical accommodation of floods. While this study does not address floodplain capacity directly, the findings in this report indicate that floodplains within the City of Flagstaff are generally healthy with several key areas as exceptions. The trend is toward decreasing floodplain health as reaches extend downstream through the city limits. This provides a clear indicator of how urbanization is affecting plant composition, channel stability and other related floodplain functions. However, these findings also provide guidance on how to change management tools and regulations to improve these aspects of floodplain health. Indeed, many of the problems noted in this study are not necessarily problems generated within the floodplain itself but are symptoms of these issues outside the flood plain. Impervious sources of high peak runoff that put additional shear stress on channels, weed sources from lands outside the channel and trash sources from specific areas of drainage outside the channel. While the City of Flagstaff Stormwater Section does have management over the floodplain, solutions to many of these issues will require working among other departments and directly with citizens and citizen groups to provide successful solutions.

The methods utilized in this study can lend themselves to citizen science monitoring of floodplains in the future. Utilization of the methods in the future can allow for citizen involvement in aspects of the floodplain that they care directly about, build an educated and involved citizenry that will be supportive of projects and regulation to improve floodplain health.

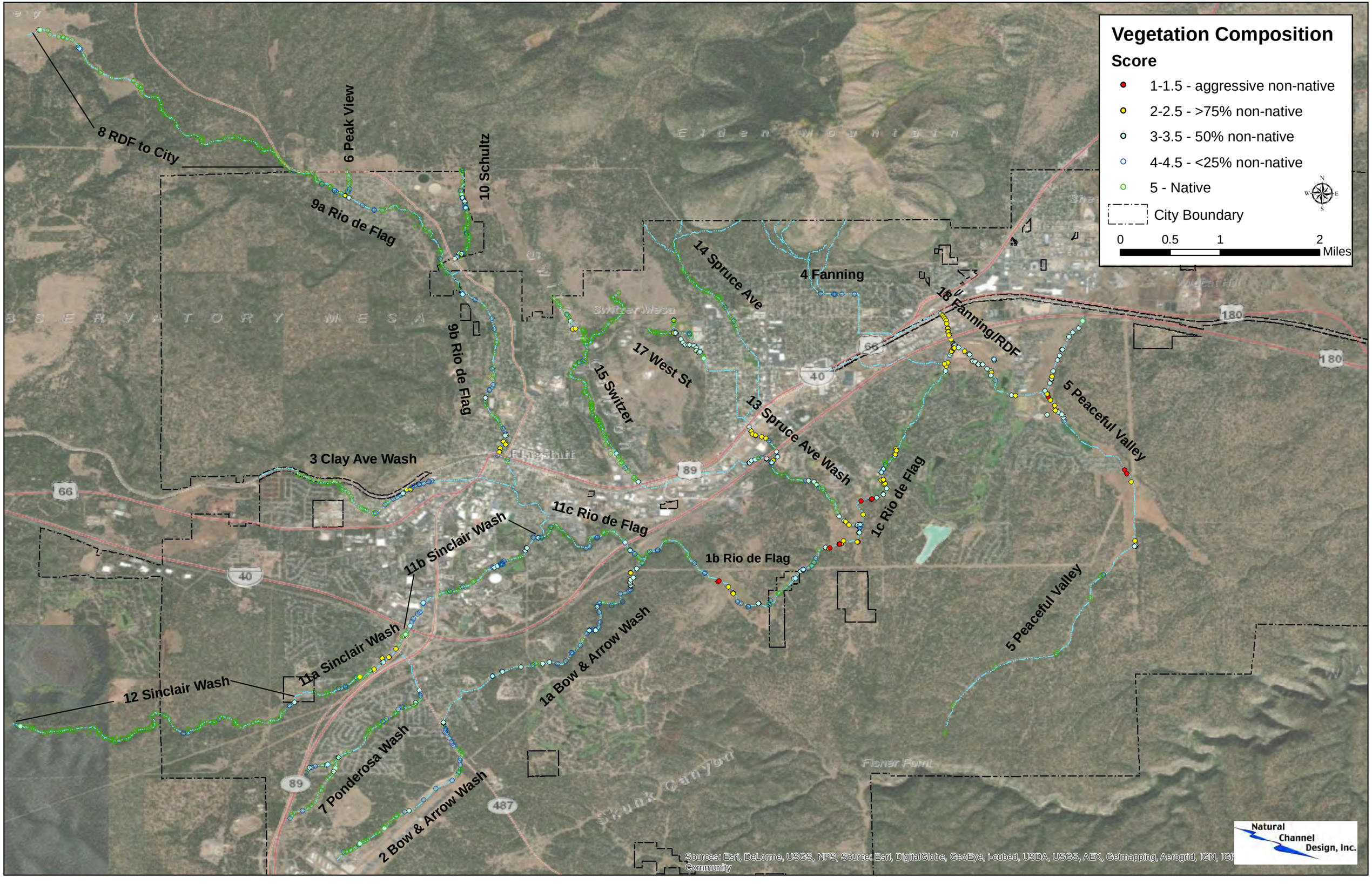
Given the subject of this floodplain health study and the relatively high citizen support that these function have there should be a tendency towards restoration of more natural drainage features through the city. Restoration of floodplain access, reduction of shear stress, natural channel substrate, proper placement of native vegetation and the inclusion of adequate buffers between development and channels will support the aspects of floodplain health studied here. Additionally, paying adequate attention to vegetation/bare ground management and runoff generation outside the floodplain will absolutely help to improve the condition of the floodplain. While such findings are not unique to this study, the clear connections between the floodplain and the watershed can help us to utilize the floodplain as a monitor of the ecological and physical health of the City of Flagstaff.

# TECHNICAL APPENDICES

**Appendix A – Reach Maps**
**Appendix B – Additional Materials**

# APPENDIX A

## REACH MAPS


Vegetation Composition
Score
1-1.5 - aggressive non-native
2-2.5 - >75% non-native
3-3.5 - 50% non-native
4-4.5 - <25% non-native
5 - Native
City Boundary
0 0.5 1 2
Miles
8 RDF to City
6 Peak View
10 Schultz
9a Rio de Flag
9b Rio de Flag
14 Spruce Ave
4 Fanning
18 Fanning/RDF
17 West St
15 Switzer
13 Spruce Ave Wash
1c Rio de Flag
5 Peaceful Valley
3 Clay Ave Wash
11c Rio de Flag
11b Sinclair Wash
1b Rio de Flag
11a Sinclair Wash
12 Sinclair Wash
1a Bow & Arrow Wash
7 Ponderosa Wash
2 Bow & Arrow Wash
Observatory Mesa
Elden Mountain
Flagstaff
Switzer Mesa
Fisher Point
Skunk Canyon
66
40
89
180
487
Natural Channel Design, Inc.
Sources: Esri, DeLorme, USGS, NPS, Source: Esri, DigitalGlobe, GeoEye, i-cubed, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, and the GIS User Community

# Invasive Weeds

## Legend

- Invasive Weeds
- No Invasive Weeds Noted in Photos
- City Boundary

Cedi - Knapweed (any species)
Coma - Hemlock
Difu - Teasel
Onac - Scotch Thistle

0 0.5 1 2 Miles

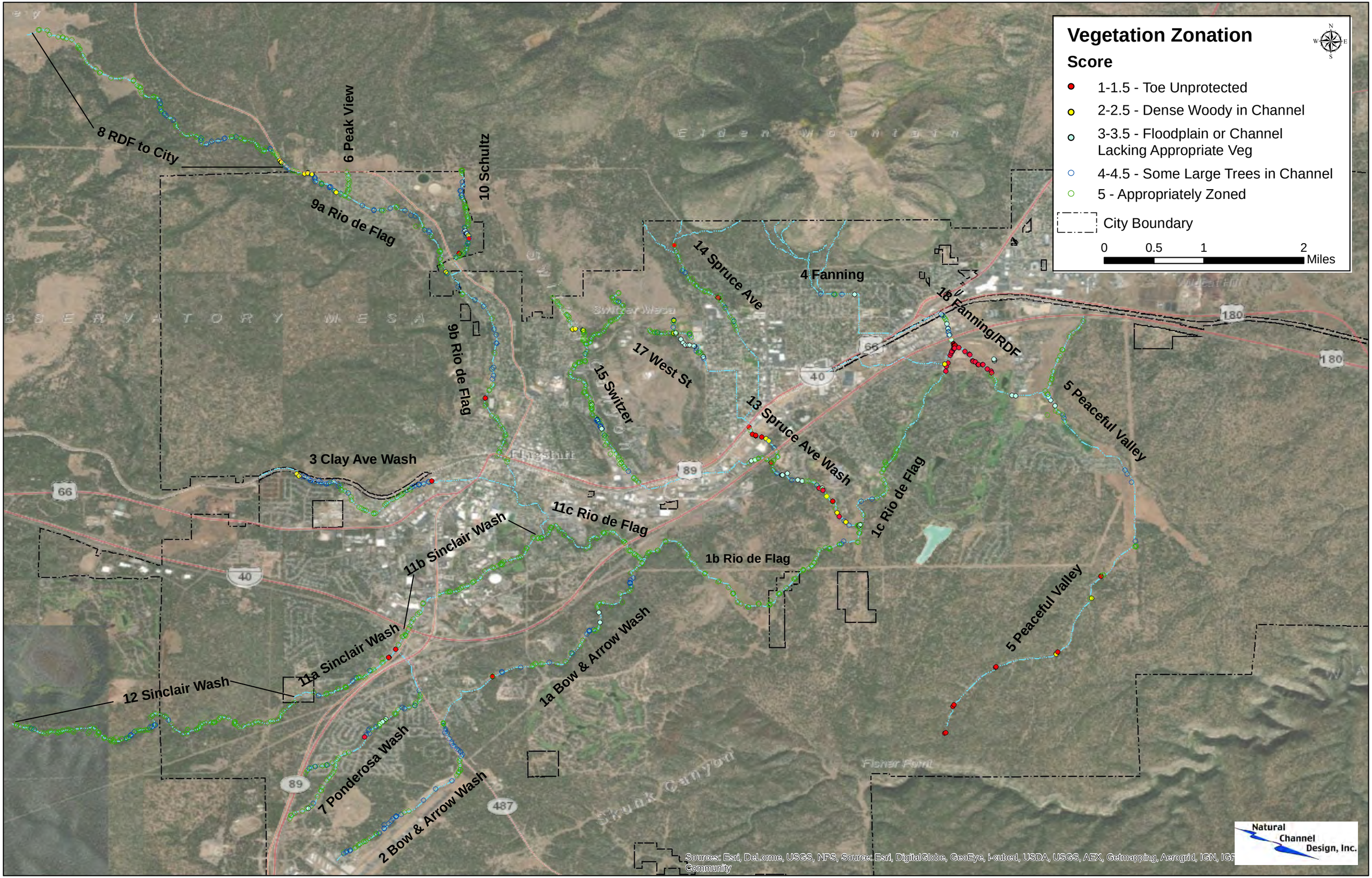
8 RDF to City
6 Peak View
10 Schultz
9a Rio de Flag
9b Rio de Flag
14 Spruce Ave
4 Fanning
18 Fanning/RDF
17 West St
15 Switzer
13 Spruce Ave Wash
5 Peaceful Valley
3 Clay Ave Wash
11c Rio de Flag
11b Sinclair Wash
11a Sinclair Wash
12 Sinclair Wash
1a Bow & Arrow Wash
1b Rio de Flag
1c Rio de Flag
7 Ponderosa Wash
2 Bow & Arrow Wash

Onac
Coma
Cedi
Difu

Observatory Mesa
Elden Mountain
Switzer Mesa
Flagstaff
Fisher Point
Skunk Canyon

Sources: Esri, DeLorme, USGS, NPS, Source: Esri, DigitalGlobe, GeoEye, i-cubed, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, and the GIS User Community

Natural Channel Design, Inc.


Vegetation Zonation
Score
1-1.5 - Toe Unprotected
2-2.5 - Dense Woody in Channel
3-3.5 - Floodplain or Channel Lacking Appropriate Veg
4-4.5 - Some Large Trees in Channel
5 - Appropriately Zoned
City Boundary
0 0.5 1 2
Miles
8 RDF to City
6 Peak View
10 Schultz
9a Rio de Flag
9b Rio de Flag
14 Spruce Ave
4 Fanning
18 Fanning/RDF
17 West St
15 Switzer
13 Spruce Ave Wash
5 Peaceful Valley
1c Rio de Flag
3 Clay Ave Wash
11c Rio de Flag
11b Sinclair Wash
1b Rio de Flag
11a Sinclair Wash
12 Sinclair Wash
1a Bow & Arrow Wash
7 Ponderosa Wash
2 Bow & Arrow Wash
Flagstaff
Fisher Point
Skunk Canyon
Sources: Esri, DeLorme, USGS, NPS, Source: Esri, DigitalGlobe, GeoEye, i-cubed, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, and the GIS User Community
Natural Channel Design, Inc.

# RDF Floodplain Assessment
## Bank Erosion

- 1-1.5 - Vertical Eroding Bank
- 2-2.5 - >75% Unprotected Bank
- 3-3.5 - <25% Unprotected Bank
- 4-4.5 - Stable with Riprap
- 5 - Stable with Vegetation

City Boundary

0 0.5 1 2 Miles

8 RDF to City
6 Peak View
10 Schultz
9a Rio de Flag
9b Rio de Flag
14 Spruce Ave
4 Fanning
18 Fanning/RDF
17 West St
15 Switzer
13 Spruce Ave
Spruce Ave Wash
1c Rio de Flag
5 Peaceful Valley
3 Clay Ave Wash
11c Rio de Flag
11b Sinclair Wash
1b Rio de Flag
11a Sinclair Wash
12 Sinclair Wash
1a Bow & Arrow Wash
7 Ponderosa Wash
2 Bow & Arrow Wash

Observatory Mesa
Flagstaff
Skunk Canyon
Fisher Point

Sources: Esri, DeLorme, USGS, NPS, Source: Esri, DigitalGlobe, GeoEye, i-cubed, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, and the GIS User Community

Natural Channel Design, Inc.

# RDF Floodplain Assessment
## Bed Stability

- 1-1.5 - Aggradation
- 1-1.5 - Incision
- 2-2.5 - Instability - Aggradation
- 2-2.5 - Instability - Incision
- 3-3.5 - Incised but widening
- 4-4.5 - Stable w/ Artificial Grade Ctrl
- 5 - Stable
- City Boundary

0 0.5 1 2 Miles

8 RDF to City
6 Peak View
10 Schultz
9a Rio de Flag
9b Rio de Flag
14 Spruce Ave
4 Fanning
18 Fanning/RDF
17 West St
15 Switzer
13 Spruce Ave Wash
5 Peaceful Valley
1c Rio de Flag
3 Clay Ave Wash
11c Rio de Flag
11b Sinclair Wash
1b Rio de Flag
11a Sinclair Wash
12 Sinclair Wash
1a Bow & Arrow Wash
7 Ponderosa Wash
2 Bow & Arrow Wash

Observatory Mesa
Elden Mountain
Switzer Mesa
Flagstaff
Fisher Point
Skunk Canyon

66 40 89 180 487

Sources: Esri, DeLorme, USGS, NPS, Source: Esri, DigitalGlobe, GeoEye, i-cubed, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, and the GIS User Community

Natural Channel Design, Inc.

# RDF Floodplain Assessment
## Floodplain Access

- 1-1.5 - No Floodplain, In Pipe or Conveyance
- 2-2.5 - ER<2, with fill on edges
- 3-3.5 - ER ~2
- 4-4.5 - Floodplain w/ some blockage
- 5 - ER > 3
- City Boundary

0 0.5 1 2 Miles

N W E S

8 RDF to City
6 Peak View
10 Schultz
9a Rio de Flag
9b Rio de Flag
14 Spruce Ave
4 Fanning
18 Fanning/RDF
17 West St
15 Switzer
13 Spruce Ave Wash
1c Rio de Flag
5 Peaceful Valley
3 Clay Ave Wash
11c Rio de Flag
11b Sinclair Wash
1b Rio de Flag
11a Sinclair Wash
12 Sinclair Wash
1a Bow & Arrow Wash
7 Ponderosa Wash
2 Bow & Arrow Wash

Flagstaff
Fisher Point
Skunk Canyon
Observatory Mesa
Eldon Mountain

66 40 89 180 487

Sources: Esri, DeLorme, USGS, NPS, Source: Esri, DigitalBoge, GeoEye, i-cubed, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, and the GIS User Community

Natural Channel Design, Inc.

# RDF Floodplain Assessment
## Culverts/Bridges

- 1-1.5 - Broken, Erosion, Aggradation
- 2-2.5 - Under Capacity, Slope Break, High Energy
- 3-3.5 - Standard Design, Overwide Section
- 4-4.5 - Geomorphically Designed Culvert
- 5 - Bridge Span over Entire FP
- City Boundary

0 0.5 1 2 Miles

8 RDF to City
6 Peak View
10 Schultz
9a Rio de Flag
9b Rio de Flag
14 Spruce Ave
4 Fanning
18 Fanning/RDF
17 West St
15 Switzer
13 Spruce Ave Wash
5 Peaceful Valley
3 Clay Ave Wash
11c Rio de Flag
11b Sinclair Wash
11a Sinclair Wash
12 Sinclair Wash
1c Rio de Flag
1b Rio de Flag
1a Bow & Arrow Wash
7 Ponderosa Wash
2 Bow & Arrow Wash

Observatory Mesa
Flagstaff
Fisher Point
Skunk Canyon

Sources: Esri, DeLorme, USGS, NPS, Source: Esri, DigitalGlobe, GeoEye, i-cubed, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, and the GIS User Community

Natural Channel Design, Inc.

# RDF Floodplain Assessment

## Floodplain Blockage

- 1-1.5 - >50% Blockage, no armoring
- 2-2.5 - >50% Blockage, accomodations for increased stage
- 3-3.5 - <50% Blockage
- 4-4.5 - Clear full width, other useage
- 5 - Clear full width, natural
- City Boundary

0 0.5 1 2 Miles

N W E S

8 RDF to City

6 Peak View

10 Schultz

9a Rio de Flag

9b Rio de Flag

14 Spruce Ave

4 Fanning

18 Fanning/RDF

17 West St

15 Switzer

13 Spruce Ave

Spruce Ave Wash

1c Rio de Flag

5 Peaceful Valley

3 Clay Ave Wash

11c Rio de Flag

11b Sinclair Wash

1b Rio de Flag

11a Sinclair Wash

12 Sinclair Wash

1a Bow & Arrow Wash

7 Ponderosa Wash

2 Bow & Arrow Wash

Observatory Mesa

Flagstaff

Skunk Canyon

Fisher Point

66 40 89 180 487

Sources: Esri, DeLorme, USGS, NPS, Source: Esri, DigitalBobe, GeoEye, i-cubed, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, and the GIS User Community

Natural Channel Design, Inc.

# RDF Floodplain Assessment

## Trash/Debris

- 1-1.5 - Trash/debris in channel
- 2-2.5 - Trash/Debris along floodplain edge
- 3-3.5 - Trash/Debris impeding flow
- 4-4.5 - Minor debris along flood line
- 5 - Essentially None
- City Boundary

0 0.5 1 2 Miles

N W E S

8 RDF to City
6 Peak View
10 Schultz
9a Rio de Flag
9b Rio de Flag
14 Spruce Ave
4 Fanning
18 Fanning/RDF
17 West St
15 Switzer
13 Spruce Ave Wash
5 Peaceful Valley
3 Clay Ave Wash
11c Rio de Flag
1c Rio de Flag
11b Sinclair Wash
1b Rio de Flag
11a Sinclair Wash
12 Sinclair Wash
1a Bow & Arrow Wash
7 Ponderosa Wash
2 Bow & Arrow Wash

Observatory Mesa
Eldon Mountain
Flagstaff
Fisher Point
Skunk Canyon

66 40 89 180 487

Sources: Esri, DeLorme, USGS, NPS, Source: Esri, DigitalGlobe, GeoEye, i-cubed, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, and the GIS User Community

Natural Channel Design, Inc.

# RDF Floodplain Assessment

## Roads or Trails

- 1-1.5 - Dense, rutted, ATV use, social trail
- 2-2.5 - Parallel to flow, at grade or below
- 3-3.5 - Parallel to flow above grade
- 4-4.5 - Parallel to flow at edge of floodplain
- 5 - None in or near floodplain

City Boundary

0 0.5 1 2 Miles

N W E S

8 RDF to City

6 Peak View

10 Schultz

9a Rio de Flag

9b Rio de Flag

14 Spruce Ave

4 Fanning

18 Fanning/RDF

17 West St

15 Switzer

13 Spruce Ave Wash

5 Peaceful Valley

3 Clay Ave Wash

11c Rio de Flag

1c Rio de Flag

11b Sinclair Wash

1b Rio de Flag

11a Sinclair Wash

12 Sinclair Wash

1a Bow & Arrow Wash

7 Ponderosa Wash

2 Bow & Arrow Wash

Observatory Mesa

Elden Mountain

Flagstaff

Fisher Point

Skunk Canyon

66 40 89 180 487

Sources: Esri, DeLorme, USGS, NPS, Source: Esri, DigitalGlobe, GeoEye, i-cubed, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, and the GIS User Community

Natural Channel Design, Inc.

# RDF Floodplain Assessment
## Inflow Channel

- 1-1.5 - Paved/piped channel
- 2-2.5 - 25% Natural Channel
- 3-3.5 - 50% Natural Channel
- 4-4.5 - 75% Natural Channel
- 5 - Natural Channel Above
- City Boundary

0 0.5 1 2 Miles

8 RDF to City
6 Peak View
10 Schultz
9a Rio de Flag
9b Rio de Flag
14 Spruce Ave
4 Fanning
18 Fanning/RDF
17 West St
15 Switzer
13 Spruce Ave Wash
5 Peaceful Valley
3 Clay Ave Wash
11c Rio de Flag
1c Rio de Flag
11b Sinclair Wash
1b Rio de Flag
11a Sinclair Wash
12 Sinclair Wash
1a Bow & Arrow Wash
7 Ponderosa Wash
2 Bow & Arrow Wash

Observatory Mesa
Eldon Mountain
Flagstaff
Fisher Point
Skunk Canyon

66 40 89 180 487

Natural Channel Design, Inc.

# RDF Floodplain Assessment

## Pollution Prevention

- 1-1.5 - Direct runoff into channel
- 2-2.5 - Partial Detention
- 3-3.5 - Detention Only
- 4-4.5 - Partial LID
- 5 - Full LID Retention/Detention
- City Boundary

0 0.5 1 2 Miles

8 RDF to City
6 Peak View
10 Schultz
9a Rio de Flag
9b Rio de Flag
14 Spruce Ave
4 Fanning
18 Fanning/RDF
17 West St
15 Switzer
13 Spruce Ave Wash
1c Rio de Flag
5 Peaceful Valley
3 Clay Ave Wash
11c Rio de Flag
11b Sinclair Wash
1b Rio de Flag
11a Sinclair Wash
12 Sinclair Wash
1a Bow & Arrow Wash
7 Ponderosa Wash
2 Bow & Arrow Wash

OBSERVATORY MESA
Flagstaff
Skunk Canyon
Fisher Point

66 40 89 180 487

Sources: Esri, DeLorme, USGS, NPS, Source: Esri, DigitalGlobe, GeoEye, i-cubed, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, and the GIS User Community

Natural Channel Design, Inc.

# RDF Floodplain Assessment

## Sediment Source

- 1-1.5 - Bare ground or eroding banks
- 2-2.5 - Chronic dirt road erosion in drainage
- 3-3.5 - Chronic inflow of sediment from embankments or cinder from roads
- 4-4.5 - Temporary construction site nr floodplain or minor sediment input from adjacent land
- 5 - Healthy forest or neighborhood, no bare ground

City Boundary

0 0.5 1 2 Miles

8 RDF to City

6 Peak View

10 Schultz

9a Rio de Flag

9b Rio de Flag

14 Spruce Ave

4 Fanning

18 Fanning/RDF

17 West St

15 Switzer

13 Spruce Ave Wash

5 Peaceful Valley

3 Clay Ave Wash

11c Rio de Flag

1c Rio de Flag

11b Sinclair Wash

1b Rio de Flag

11a Sinclair Wash

12 Sinclair Wash

1a Bow & Arrow Wash

7 Ponderosa Wash

2 Bow & Arrow Wash

Observatory Mesa

Elden Mountain

Flagstaff

Fisher Point

Skunk Canyon

66 40 89 180 487

Natural Channel Design, Inc.

Sources: Esri, DeLorme, USGS, NPS, Source: Esri, DigitalGlobe, GeoEye, i-cubed, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

# RDF Floodplain Assessment

**# of Categories in Lowest 25th Percentile**

- 0
- 1
- 2
- 3
- 4
- 5
- 6
- 8
- Not Evaluated

0 0.5 1 2 Miles

8 RDF to City

6 Peak View

10 Schultz

9a Rio de Flag

9b Rio de Flag

14 Spruce Ave

4 Fanning

18 Fanning/RDF

17 West St

15 Switzer

13 Spruce Ave Wash

5 Peaceful Valley

3 Clay Ave Wash

11c Rio de Flag

11b Sinclair Wash

1c Rio de Flag

1b Rio de Flag

5 Peaceful Valley

12 Sinclair Wash

11a Sinclair Wash

1a Bow & Arrow Wash

7 Ponderosa Wash

2 Bow & Arrow Wash

Natural Channel Design, Inc.

# APPENDIX B

## ADDITIONAL MATERIALS

Included are abridged versions of a Seeding Specification and Weed Management Plan developed for Coconino County

A Seeding Specification at a minimum should specify:

- An appropriate seed mix
- Appropriate timing for seeding
- Seedbed preparation requirements
- Appropriate seeding methods including minimum requirements for hydroseeding
- Requirements for covering the seed with soil and mulch
- Requirement for reseeding if initial effort fails

*2.1.3 Seed Mixes*

The Temporary seed mix shall be used for a short-term cover which germinates and establishes rapidly for effective erosion control, weed control and temporary cover. A Temporary seed mix shall be required and applied to all disturbed areas if disturbed areas are left untouched or open for more than six weeks during the growing season (March through September) or in disturbed areas that will require future weed management or grading and that are left open during the growing season. The Permanent seed mix shall be used as the final diverse native grass mix. The Permanent seed mix will be applied to all disturbed areas before the end of the project.

For wetlands, wet meadows, riparian areas or other areas deemed a special concern for habitat, the seed mix will depend on site conditions and be specially designed to meet those site conditions and habitat goals. For normal construction areas, right of way work and staging areas, the seed mix can be derived from the conditions set forth below.



The seeding rates given below are for mechanical seeding methods, for hand broadcasting the seeding rates are typically doubled.

A. Temporary Seed Mix

| Species | Scientific Name | % Composition | Seeding Rate |
|---|---|---|---|
| Quickguard™ Sterile Triticale* | *Triticum aestivum x Secale cereale* | 100% | 12 PLS lbs/ac |

*or similar

Note: Sterile triticale seed will provide one season of growth only and the area must be overplanted with a permanent cover. All materials shall meet the approval of the Engineer (and USFS biological specialists when on USFS lands) before purchase and application.

-or-

Alternatively, the Temporary seed mix shall consist of at least one cool season and one warm season grass that are native to the immediate area and appropriate for the soils, aspect and hydrologic regime of the site. For most areas around Flagstaff, Blue Grama and Slender or Western Wheatgrass would make a good temporary seed mix.

B. Permanent Seed Mix

i. For volcanic or limestone soils above 6,800 feet in elevation use:

| Species | Scientific Name | % Composition | Pure Stand Seeding Rate PLS lbs/ac | Final Mix Seeding Rate PLS lbs/ac |
|---|---|---|---|---|
| Blue Grama | *Bouteloua gracilis* | 25 | 2 | 0.5 |
| Little Bluestem | *Schizachyrium scoparium* | 25 | 5 | 1.25 |
| Arizona Fescue | *Festuca arizonica* | 25 | 3 | 0.75 |
| Western Wheatgrass | *Pascopyrum smithii* | 25 | 9 | 2.25 |

Potential Alternatives: Mountain Muhly (*Muhlenbergia montana*), Purple Three-awn (*Aristida purpurea*), or Pine Dropseed (*Blepharoneuron tricholepsis*) may be an acceptable substitution for Little Bluestem.
Slender Wheatgrass (*Elymus trachycaulus*), Muttongrass (*Poa fendleriana*), Bottlebrush Squirreltail (*Elymus elymoides*), or Prairie Junegrass (*Koeleria macrantha*) may be an acceptable substitution for Western Wheatgrass.

ii. For limestone soils below 6,800 feet in elevation use:

| Species | Scientific Name | % Composition | Pure Stand Seeding Rate PLS lbs/ac | Final Mix Seeding Rate PLS lbs/ac |
|---|---|---|---|---|
| Blue Grama | *Bouteloua gracilis* | 25 | 2 | 0.5 |
| Purple Three-awn | *Aristida purpurea* | 25 | 6 | 1.5 |
| Indian Ricegrass | *Achnatherum hymenoides* | 25 | 7 | 1.75 |
| Needle and Thread | *Hesperostipa comata* | 25 | 10 | 2.5 |

Potential Alternatives: Sideoats Grama (*Bouteloua curtipendula*), Vine Mesquite (*Panicum obtusum*), Bottlebrush Squirreltail (*Elymus elymoides*), Muttongrass (*Poa fendleriana*)



iii. For sand or cinder soils use:

| Species | Scientific Name | % Composition | Pure Stand Seeding Rate PLS lbs/ac | Final Mix Seeding Rate PLS lbs/ac |
|---|---|---|---|---|
| Blue Grama | *Bouteloua gracilis* | 25 | 2 | 0.5 |
| Galleta Grass | *Pleuraphis jamesii* | 25 | 8 | 2 |
| Indian Ricegrass | *Achnatherum hymenoides* | 25 | 7 | 1.75 |
| Needle and Thread | *Hesperostipa comata* | 25 | 10 | 2.5 |

Potential Alternatives: Sand Dropseed (*Sporobolus cryptandrus*), Sideoats Grama (*Bouteloua curtipendula*), Purple Three-awn (*Aristida purpurea*), Cane Bluestem (*Bothriochloa barbinodis*), Sand Bluestem (*Andropogon hallii*), Vine Mesquite (*Panicum obtusum*: lower elevation)

iv. For clay soils use:

| Species | Scientific Name | % Composition | Pure Stand Seeding Rate PLS lbs/ac | Final Mix Seeding Rate PLS lbs/ac |
|---|---|---|---|---|
| Galleta Grass | *Pleuraphis jamesii* | 35 | 8 | 2.8 |
| Alkalai Sacaton | *Sporobolus airoides* | 30 | 2 | 0.6 |
| Western Wheatgrass | *Pascopyrum smithii* | 35 | 10 | 3.5 |

Potential Alternatives: Blue Grama (*Bouteloua gracilis*), Buffalograss (*Bouteloua dactyloides*), Little Bluestem (*Schizachyrium scoparium)*, Muttongrass (*Poa fendleriana),* Curly Mesquite *(Hilaria belangeri)*

-or-

The permanent cover seed mix shall consist of, at minimum, two cool season and two warm season native, perennial grass species appropriate to the site. Chosen species should be dominant species from adjacent sites with similar soils, hydrology and aspect. Perennial forbs and annual grasses can be added as required per the goals of the revegetation plans. However all materials shall meet the approval of the Engineer (and USFS biological specialists when on USFS lands) before purchase and application.

### *1.1 Hydroseed Additives (if utilized)*

Hydroseeding requires the use of a tacking agent, wood cellulose fiber mulch and an indicator dye. An inoculum may be used if recommended by the supplier.

*2.2.1 Tacking Agent*

Tacking agent shall be a naturally occurring organic compound and shall be non-toxic. The tacking agent shall be a product typically used for binding soil and mulch in seeding or erosion control operations. Approved types shall consist of mucilage or gum by dry weight as active ingredient obtained from guar or plantago. The tacking agent shall be labeled indicating the type and purity.

The tacking agent swell volume will be tested by an approved testing laboratory using the USP method. Test results shall be provided to the Engineer. Material shall have a swell volume of at least 24 milliliters per gram. The standard swell volume shall be considered as 30 milliliters per gram and tacking agent rates will be adjusted to compensate for swell volume variation. Material tested with lesser swell volume shall have the tacking agent rate increased by the same percentage of decrease in swell volume from the standard 30 milliliters per gram and vice versa for material tested with greater swell volume. Tacking agent shall be pure material without starches, bentonite or other compounds that would alter the swell volume test results of mucilage or the effectiveness of the tacking.



*2.2.2 Wood Cellulose Fiber*

Wood cellulose fiber mulch shall be a thermo-mechanically processed wood, processed to contain no growth or germination inhibiting factors. The mulch shall be from virgin wood manufactured and processed so the fibers will remain in uniform suspension in water under agitation to form homogenous slurry. Paper products will not be considered virgin wood. The thermally refined wood fiber mulch shall have the properties shown below…

## PART 2 - EXECUTION

### *2.1 Seedbed Preparation*

Once the project area has been graded to appropriate elevations, ensure that the surface soil is in a roughened condition favorable for seed germination and growth. On sites where equipment can safely operate on slopes, the seedbed shall be adequately loosened (4 to 6 inches deep) and smoothed, with large clods being broken up. Areas that have been compacted by heavy equipment or other operations shall be ripped to a depth of at least 6 inches to ensure adequate permeability. All ripping should be conducted on contour to prevent rilling during runoff conditions. Disking, cultipacking, or both may be necessary to properly prepare a seedbed that is too rough to uniformly scatter seed. Where equipment cannot operate safely, the seedbed shall be prepared by hand methods by scarifying to provide a roughened soil surface so that broadcast seed will remain in place.

### *2.2 Seed Application*

Application rate of seed, as specified, are for Pure Live Seed (PLS). Seed mix species, percent composition, and the PLS application rates per acre are shown in the seed mix tables above, Part 2.1.

All seeding operations shall be performed in such a manner that the seed is applied in the specified quantities uniformly in the designated areas. Seed shall be incorporated into the soil, but not more than 0.5 to 1.0 inches deep if using the dry method or hand application, as described below. Seeding should occur before installation of erosion control fabric, if required. To control erosion and weeds, apply seed to disturbed soil and slopes as soon as is practical after disturbance.

To increase likelihood of seeding success, seeding should be timed to precede seasonal monsoon moisture or winter snow cover. Avoid leaving seed on the soil for long periods of time without adequate moisture for germination and growth or winter cover, as this will promote seed predation by birds and insects. Seed must be worked into ground and protected by mulch. Seeding that occurs late in summer towards end of monsoon season rains may germinate but lack adequate growth during the shortened wet season to successfully over winter.

### *3.3 Seeding Methods*



The following methods may be used to place material:

- *Hydroseeding Method.* Mix the seed with water in the amounts and mixtures specified by the supplier to produce a slurry and apply it under pressure at the rates specified by the supplier. Add wood cellulose fiber mulch after all other materials have been thoroughly mixed in the tank. Mix shall be colored with a green indicator dye. Hydroseeding mixing has the potential to mechanically damage native grass seeds. The mix should be utilized within 1/2 hour of adding seed to avoid over agitation and seed damage.
- *Dry Method.* Use mechanical, landscape, or cultipacker seeders, seed drills, or other approved mechanical seeding equipment to apply the seed in the amounts and mixtures shown in Part 2.1 of this specification. Dry method application must also utilize a weed-free mulch or erosion control fabric application over the seedbed as specified by the Engineer and described in a separate specification.
- *Hand Application* - Hand-operated seeding devices may be used to apply dry seed. Hand application method must utilize weed-free mulch or erosion control fabric application over the seedbed as specified by the Engineer and described in a separate specification.

A Weed Management Plan at a minimum should specify:

- The target area
- The target species and method for keeping species list updated
- Inventory and mapping methodology to help prioritize and track target weeds and treatments
- A management strategy
- The treatment methods and appropriate usage (Mechanical, Chemical, Competing Vegetation, Public Outreach/Education, Collaboration on Multi-Jurisdictional Infestations, Prevention)
- An implementation schedule
- A monitoring plan and record keeping method

# Coconino County

# Weed Management Plan:
# County Maintained Right of Ways

Natural Channel Design, Inc.

July 2016

# TABLE OF CONTENTS



## LIST OF FIGURES



## LIST OF TABLES

# INTRODUCTION

Coconino County, Arizona has the second largest area of any county in the lower 48 states with 18,661 square miles. While generally considered arid, the area covers a diverse array of habitats and plant communities ranging from mid elevation desert scrub to high elevation forests. The county also covers a diverse array of political landscapes as well. These include right of ways that cross Navajo Nation lands, US Forest Service, Bureau of Land Management, Hualapai Tribal lands and boundaries with several National Parks. The county public works department is responsible for weed management on right of ways and other county maintained areas across the county. This covers approximately 1012 miles of right of way of various widths.

The purpose of this document is the development of a weed management plan for county right of ways (ROW) across multiple ecological zones and jurisdictions. The plan is meant to provide guidance as to what types of plants to target, the methods best used to manage them, timing and planning for management activities and administrative tasks required for a successful, long-term management program. In addition, the plan provides specific language, which can be utilized as a specification for weed management tasks in contracts with county contractors (Appendix A).

The goal of the weed management program is to effectively control invasive species and to promote growth of desirable species along roadways. The plan is to significantly reduce the density of invasive species and shift those areas currently dominated by invasive species to native vegetation. Complete eradication of invasive species is not a practical goal over such a wide area. Once native grasses are well established, and there is no further disturbance, minimal maintenance is usually required to maintain the system. Successful establishment of native grasses, however, is key to the long-term success of the weed management program. Flowering native forbs are desirable as well, however grasses are a more economical community to plant and provide year-round competition to weeds. In areas that receive frequent disturbance (ditches with frequent maintenance or borrow pits), growth of native plants will not be achieved and the area will need to be maintained with frequent treatments.

This management plan should be considered a living document. It is not possible to anticipate the entire spectrum of weeds that may invade county ROW's in the future. However, the methods set forth for monitoring and treatment can easily be adapted to meet new situations. Annual monitoring and review of program performance is recommended. Treated infestations should become smaller and less dense over the course of several growing seasons and the number of treated areas should be reduced over a slightly longer time period.

# COUNTY RIGHT OF WAYS

The County was divided into four major geographic areas (Figure 1) representing right of ways in the Navajo Reservation, Flagstaff, Williams and the Fredonia areas. Detailed maps of each area are provided in Figures 2 though 5.

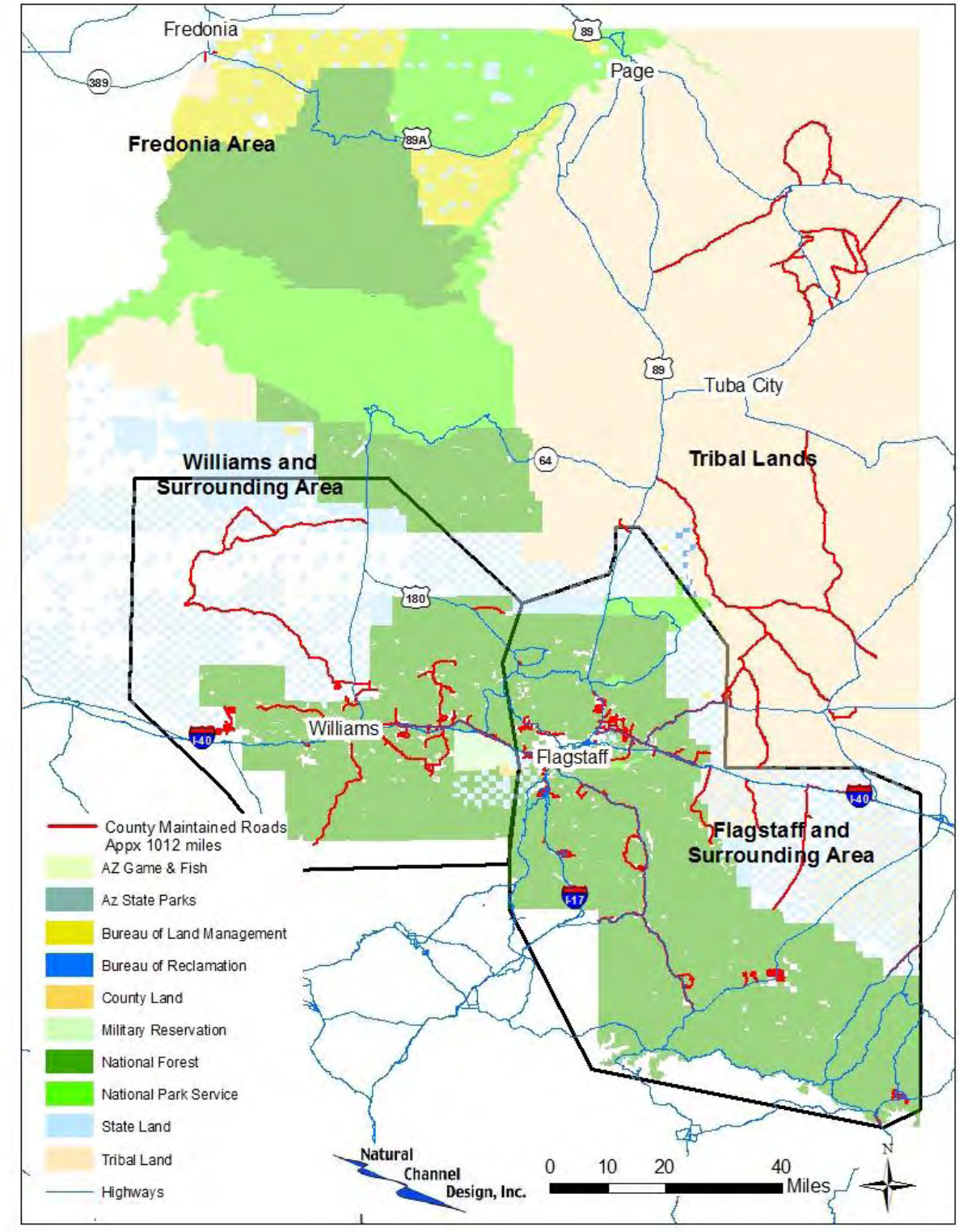



**Figure 1. Overview map of Coconino County ROW's**

# SELECTION OF TARGET SPECIES

Weeds are plants out of place. Even native trees and shrubs can be a nuisance on certain areas of road right of way. However, many invasive species are highly competitive and utilize disturbed areas like ROWs to establish themselves and spread along the ROWs to new areas. Those species that are especially adept at occupying and controlling new territory, while out-competing native species, are the prime targets for control. Additionally, species that can affect the abundance and distribution of ecological keystone native species are targets since the loss of keystone plant species can trigger the loss of dependent species.

The Coconino National Forest shares many miles of road ROW with Coconino County and has the most exhaustive list of target weed species of any agency in the area. The list for target species for Coconino County ROW program is based on the Coconino National Forest list for that reason with a few additions. It should be noted that the list is periodically updated by the Coconino National Forest. The county personnel or knowledgeable consultants will need to review the new lists as they appear.

The Coconino National Forest Invasive weed list for 2016 is provided in Table 1. It provides the scientific name, common name and management goal for the forest. While the list is long, the first 13 species listed represent the most aggressive and disruptive weeds of the group. These species are listed by the forest as 'Class E" (for extreme hazard) species and are considered to provide the greatest threat to the forest's ecosystem (Not all species listed will be located along ROWs) These species receive priority control within the national forest lands and are therefore recommended as the highest priority for treatment on Coconino County maintained land. Other species on the list should be considered for treatment but usually in conjunction with treatment of the Class E species. These other species on the list do represent a threat to native ecosystems but have been shown to be either locally contained, relatively rare, or low level threats.

However, there will often be reasons to include other species in the top priority list for treatment. Currently there are very few areas where musk thistle is found in the county ROW. These areas should continue to be treated to keep this species from spreading. Another consideration for treatment are small areas where less aggressive weeds have formed dense patches that prevent desired vegetation from germinating or growing. A few species we have found to be occasionally problematic include kochia, horehound, Russian thistle and common sunflower.

Many of the species listed have a limited occurrence or have a very specific elevation and habitat type preference. As such they are not found county wide. Persons conducting weed inventory should be knowledgeable in the species identification and biology and should also know how to locate historic records utilizing IMapInvasives and Forest Service databases. Species descriptions are provided in Appendix B.

**Table 1. Coconino National Forest Invasive Weed List (2016)**

*Species on this list are considered weed species in Coconino County. However, most of these species are not included as part of the target species list for Coconino County ROW's since they are low in abundance, and have limited distribution within County maintained lands. These species should be treated if they occur in part of a treatment area which targets "E" species, which are considered aggressive and widespread.*

| SCIENTIFIC NAME | COMMON NAME | OBJECTIVE | R3 CATEGORY |
|---|---|---|---|
| **Acroptilon repens** | **Russian knapweed** | **Eradicate/Control** | **E** |
| **Ailanthus altissima** | **tree of heaven** | **Eradicate/Control** | **E** |
| **Alhagi maurorum (pseudoalhagi)** | **camelthorn** | **Eradicate/Control** | **E** |
| **Arundo donax** | **giant reed grass** | **Eradicate/Control** | **E** |
| **Centaurea diffusa** | **diffuse knapweed** | **Contain/Control** | **E** |
| **Centaurea maculosa** | **spotted knapweed** | **Eradicate/Control** | **E** |
| **Centaurea solstitialis** | **yellow starthistle** | **Eradicate/Control** | **E** |
| **Eleagnus angustifolia** | **Russian olive** | **Contain/Control** | **E** |
| **Euphorbia esula** | **leafy spurge** | **Contain/Control** | **E** |
| **Onopordum acanthium** | **Scotch thistle** | **Contain/Control** | **E** |
| **Salvia aethiopis** | **Mediterranean sage** | **Eradicate/Control** | **E** |
| **Tamarix ramosissima or spp.** | **salt cedar or tamarisk** | **Eradicate/Control** | **E** |
| **Ulmus pumila** | **Siberian elm** | **Contain/Control** | **E** |
| Asphodelous fistulosis | onion weed | Prevent/Eradicate | A |
| Alliaria petiole | garlic mustard | Prevent/Eradicate | A |
| Cardaria chalepensis | lens-podded hoary cress | Prevent/Eradicate | A |
| Cardaria drada | whitetop or hoary cress | Eradicate/Control | A |
| Cardaria pubescens | globe-podded hoary cress | Prevent/Eradicate | A |
| Carduus nutans | musk thistle | Eradicate/Control | A |
| Centaurea calcitrap | purple starthistle | Prevent/Eradicate | A |
| Centaurea melitensis | Malta starthistle | Eradicate | A |
| Cirsium arvense | Canada thistle | Prevent/Eradicate | A |
| Conium maculatume | poison hemlock | Eradicate/Control | A |
| Cynoglossum officinale | houndstongue | Eradicate | A |
| Dipsacus fullonum | teasel | Eradicate | A |
| Euryops subcarnosus | seet resin bush | Prevent/Eradicate | A |
| Hydrilla verticillata | hydrilla | Prevent/Eradicate | A |
| Hyoscyamus niger | black henbane | Prevent/Eradicate | A |
| Hypericum perforatum | common St. Johnswort | Prevent/Eradicate | A |

| SCIENTIFIC NAME | COMMON NAME | OBJECTIVE | R3 CATEGORY |
|---|---|---|---|
| Isatis tinctoria | dyer's woad | Prevent/Eradicate | A |
| Lepidium latifolium | perennial pepperweed | Prevent/Eradicate | A |
| Leucanthemum vulgare | oxeye daisy | Prevent/Eradicate | A |
| Linaria vulgaris | yellow toadflax | Eradicate | A |
| Lythrum salicaria | purple loosestrife | Prevent/Eradicate | A |
| Myriophyllum spicata | Eurasian water milfoil | Eradicate | A |
| Peganum harmala | African rue | Prevent/Eradicate | A |
| Pennisetum ciliare | bufflegrass | Prevent/Eradicate | A |
| Pennisetum setaceum | fountain grass | Prevent/Eradicate | A |
| Potentilla recta | Sulfur cinquefoil | Eradicate | A |
| Taeniatherum caput-medusae | Medusahead | Prevent/Eradicate | A |

*Region 3 Invasive Weed Classification System. The Region 3 invasive weed classification system provides a systematic approach for assigning management emphasis priorities. The invasive weed classes may be further subdivided to meet regional, National Forest, or local needs.*

*Class E species – These invasive weed species have wide distribution across the forest, district, or else within a particular watershed and pose an unacceptable, extreme hazard (accordingly, E) to watershed condition, TES species, wilderness, or other natural and economic resources. These particular wide-ranging species must be controlled continuously to prevent overwhelming damage to natural resources (e.g., a fire cycle introduced by buffelgrass into Sonoran Desert plant communities unadapted to fire). Weeds species in this classification should receive high priority for control and restoration which may supersede Class B species for treatment priority.*

*Class A species – These invasive weed species are newly established or else have the potential to become established on the forest, district, or else within a particular watershed. Such species pose a major or unacceptable threat to watershed condition, TES (threatened, endangered, or sensitive) species, wilderness, or other natural and economic resources. Weeds species in this classification should receive highest priority for prevention, eradication, containment, control, and/or restoration. Management emphasis is to prevent and eradicate whenever possible or else use containment as a last resort.*

## WEED INVENTORY

Prior to any type of annual weed treatment, an inventory of the County maintained roads needs to be undertaken in order to prioritize and quantify the areas needing treatment: identifying target species and developing treatment strategies including timing and type of treatment.

All right of ways will need to be inventoried on an annual basis. However, inventories should occur throughout the growing season on areas that are actively being treated in order to estimate success. To prepare for any spring treatments, the window of opportunity for inventory is usually from April through mid May. Identification of specific species is more difficult at this time since plants are small, less conspicuous and lack flowers. However, early identification creates opportunities for rapid treatment of smaller plants which requires less chemical, is often more successful on younger plants, and younger plants are not in danger of setting seed for the next growing season.

Another key time to inventory for weeds is during the early summer and through monsoon season. This is the easiest time to locate and identify newly emerging problem areas. This dual inventory survey protocol is preferred to a single spring inventory. The second inventory will reveal late season weeds that may not have been large enough to identify in the spring. New weed locations identified during the summer inventory can be targeted for immediate mechanical removal, later fall spraying targeting new rosettes or for a spring treatment. Summer weed treatments can be more difficult to plan and schedule appropriate action before weeds have flowered and set seed. Once seed set has occurred, removal is more difficult and expensive. But these areas can be targeted for aggressive treatment the following spring.

Inventories should be done in a systematic way but do not require lengthy amounts of time. Databases of current and historic weed locations iMapInvasives, Forest Service Surveys) should be consulted to help identify target areas. Once, smaller areas of the ROW have been sampled to identify the species available, the remaining inventory for a reach can be accomplished by a slow drive down the road shoulder. The locations surveyed should be marked with GPS coordinates for mapping in County GIS and iMapInvasives database. All areas that have been inventoried and shown to be free of target species should also be noted. A survey form is provided in Appendix C.

## WEED MANAGEMENT STRATEGY

The weed management plan was developed using a combination of control strategies that should successfully reduce the abundance and distribution of target species. Herbicide applications with some mechanical treatments will be the most widely used treatments. It is anticipated that efforts to control large infestations along County ROW's will take several years of ongoing treatments to be effective. Many of the species being targeted produce copious amounts of seed that can remain viable for years. Control efforts will reduce the seedbank and ultimately the density of weeds while native vegetation can become established. As a result, areas needing treatment and overall cost for treatment should decrease over time. Additionally, since the goal of the management is to convert weedy vegetation along right of ways into native grasses that prevent reinvasion, seeding with appropriate species will be needed in areas that have sparse native vegetation.

It should be noted that different areas of the ROW are expected to contain different plant communities, which can require different methods and timing for control. Prescriptions for each portion of the ROW should be formulated with the latest inventory data as well as treatment history in mind. Additionally, the prescription for each site will likely change over time as the plant community changes in response to previous treatments. It is highly unlikely, that weed infested sites can be restored within a single growing season. The seed bank of non-native plants in many areas of the ROW have built up over the years and can last for many years in the soil until proper conditions for germination and recruitment are met. For these reasons, multiple years of treatment, combined with multiple types of treatments may be required to reach management goals. As prescriptions for specific areas are developed and revised, they should be formulated with the following general points in mind.

- Plan treatments for the early part of the growing season after the majority of target species have germinated but while the plants are still small so that the total amount of herbicide required is minimized. Also for many species, treatment of younger plants is often more successful than mature plants.
- Time treatments so that target species are killed prior to setting seed. In some cases it may take more than a week for plants to die from herbicide treatment. The stress often initiates rapid development of seed which can drop after the plant is dead. If treatment must take place close to seed set, cutting and bagging the seed heads may be needed to prevent the release of seeds.

- It is impossible to control every weed, noxious or otherwise that occurs on the project site. Therefore, those weed species which have the greatest potential environmental impacts are to be targeted.
- Following initial treatments, future treatment activities should be developed based on effectiveness of treatments and the extent of infestation.
- Herbicide treatments utilizing herbicides with known pre-emergent qualities should be applied well ahead of the monsoon season or well after the start of monsoon season to avoid interaction with germinating seed of desirable species.
- Areas with desirable vegetation should not be treated with herbicide if at all avoidable. Reliance on spot treatment of undesirable vegetation is preferred over broadcast treatments.
- Non-specific herbicides should only be utilized in areas without significant desirable vegetation.
- Public outreach efforts will improve program effectiveness as private landowners become aware of efforts and incorporate measures on their own properties.
- Promotion of the growth and dispersal of desirable vegetation within the project areas will help insure that the treatment program is making progress toward a reduced effort level every season.
- Proactive planting and management of disturbed areas will help to minimize weed establishment and propagation.
- Monitoring and data management are key aspects of the management program, leading to knowledge of effectiveness and efficiency.
- Early detection is also an efficient long-term strategy in the management of non-native and invasive species. Quickly detecting invasions that occur allows for immediate eradication measures to be implemented. These areas should be prioritized for treatment.
- Since the management area crosses multiple jurisdictions, there will be a need to incorporate goals and methods utilized by other jurisdictions in an overall weed management program.

## MANAGEMENT METHODS

This section describes several management methods for weed control including mechanical control methods such as pulling and mowing, the use of herbicides, and seeding with desirable vegetation to provide competition. An integrated weed management strategy incorporates active control methods such as herbicides and mechanical removal to provide short-term management and the establishment of competing vegetation as a long-term strategy. The methods outlined here are intended to be a reference for weed management along County ROWs. It is not intended to be a complete guide to weed management.

Effective short-term management of the target species generally requires a two-part approach: preventing seed dispersal and reducing the existing population. Reducing the population entails either physical removal or herbicide treatment. Many of the target species identified in this plan are prolific seed-producers. Preventing seed set and dispersal is critical to preventing the populations from growing larger. Several of the target species have seeds that can remain viable in the seed bank for a minimum of five years and as long as thirty years. Managing these species requires removal of the new plants every year for several years until germination is minimal or absent. In addition, application of a pre-emergent herbicide may be necessary in areas with adequate desirable vegetation but adjacent to weed populations outside of the ROW.

Establishment of native vegetation that can provide competition for invasive species is extremely important and will help to lessen the need for long-term commitment to invasive removal. Seeding areas that have been successfully treated for weed removal will help prevent reinvasion. Seeding should be

timed to avoid pre-emergent affects of herbicides and take advantage of the full monsoon season to ensure establishment. Additional seeding with native flowering forbs can be considered after the initial year of weed treatment. It is recommended that during the initial year of treatment no additional seeding of wildflowers be conducted due to the possibility of those plants being removed by weed eradication efforts.

The use of herbicide on ROWs in the Coconino and Kaibab forests requires a Pesticide Use Permit prior to application. Ensure enough time is allocated for the procurement of this permit during planning. A pesticide use permit for areas within the Coconino National Forest that were treated in 2016 is attached to this report. It is valid until the treatments change. New treatment chemicals or new areas to be treated will require additional permitting through the Coconino or Kaibab National Forest Pesticide Use Coordinator. Mechanical control of target species within right of ways on national forest land does not require a permit.

It is anticipated that efforts to control weeds along County ROWs will take several years of ongoing treatments to be effective. The species being targeted produce copious amounts of seed that can remain viable for years. Control efforts will reduce the seedbank and ultimately the density of weeds while native vegetation can become established. As a result, areas needing treatment and overall cost for treatment should lower over time. The weed control strategies outlined above target the currently known areas of infestation within the work areas of the County easements. Based on monitoring of these areas, subsequent treatment strategies should be developed annually following fall and early spring monitoring.

## MECHANICAL CONTROL

Mechanical control consists of pulling and mowing or cutting. Mechanical control can be used to reduce existing weed biomass which can result in shading of desirable species, and to eliminate the current year's seed source from mature plants that have started flowering but have not yet set seed. Small infestations of plants that are not capable of vegetative reproduction can often be controlled when pulled in early summer or prior to setting seed. However, pulling is not practical for larger areas. Mowing or cutting can be effective control for larger infestations of some annual species, such as kochia or Russian thistle. The mowing will not eliminate the plants, but will reduce the amount of seed produced and will remove much of the shading effect on native species. Mowing or cutting is not recommended for knapweed or Scotch thistle as it encourages additional branching and flowering. In some cases, pulling or mowing in conjunction with chemical treatments can be an effective control method.

### ***Pulling:***

Pulling or uprooting annuals and tap-rooted plants in small areas can be an effective control method with minimal ecological impact and low cost. Pulling will be a common method for treating smaller infestation and individuals. The best time to pull plants is when the ground is moist so that the entire root can be extracted without causing too much ground disturbance. Pulling of annual or perennial plants when they reach the flowering stage is a very effective method of control for many species. Flower heads should never be left on the ground because many plants can set seed even when the plant is severed from the root. The flowering parts should be bagged and incinerated.

### ***Mowing and Cutting:***

Mowing and cutting can reduce seed production and spread and restrict weed growth, especially in annuals cut before they flower and set seed. Mowing also removes taller annuals, reducing shading to native grasses trying to get established. Mowing may be used in areas where herbicide treatment is less desirable in order to remove aboveground biomass, or integrated with herbicide treatments.

Mowing can be an effective control for kochia. Repeated mowing (2 to 3 times a summer) can prevent kochia from flowering and setting seed. Kochia seeds last only a year or two in the seed bank so repeatedly preventing seed set for a few years can severely curtail its population. However, mowing is not an effective control on its own for many species, including knapweed and Scotch thistle, because it stimulates resprouting.

## HERBICIDES

Herbicides can be an appropriate and effective way to treat certain weed species. The application should be timed to capture the proper phenological stage or the most appropriate season for the weeds that are present. Applications timed for the rosette or seedling stages of many annual and biennial weed species can provide effective control. Early spring application may also limit the exposure to herbicide of many native species that germinate or emerge later in the season. Another effective treatment strategy for some biennial or perennial weeds is to treat in the fall immediately after the first hard frost. Early season and late fall time periods may optimize the plant uptake of the herbicide.

Herbicides can be divided between pre-emergent and post-emergent herbicides (or both). Pre-emergent herbicides are applied to the soil before the weed germinates; they disrupt germination or kill the germinating seedling. Post-emergent herbicides are foliar-applied directly to the established plants and/or soil. Some herbicides are effective both pre- and post-emergent.

The effects on non-target species, native grasses and forbs in particular, should be considered when choosing an herbicide. When possible, herbicides with the least toxicity, persistence in the environment, soil mobility, and related side effects should be used. Whether the herbicide is broadleaf specific and does not affect grasses or is nonspecific and will kill both broadleaf and grass species should be considered. All herbicides must be applied according to label instructions and care must be taken for selection of equipment used, and application and timing to avoid unwanted consequences.

It is recommended that the herbicides used in the county be limited to those approved for use on the Coconino National Forest (list obtained from L. Moser, Invasive Species Botanist and Pesticide Use Coordinator, Coconino Nation Forest). This list of approved herbicides, based on the active ingredient common name, is given below along with the Trade name in parenthesis. A brief description of each herbicide is provided in Appendix D. Be sure to obtain and read the label of the herbicide selected for treatment.

- Aminocyclopyrachlor
- Aminopyralid (Milestone)
- Chlorsulfuron (Telar)
- Clopyralid (Transline)
- 2,4-D
- Dicamba (Clarity)
- Glyphosate (Roundup)
- Imazapic (Plateau)
- Imazapyr (Arsenal)
- Metsulfuron methyl (Escort)
- Picloram (Tordon)
- Sulfometuron methyl (Landmark)
- Triclopyr (Garlon)

***Additives:***

Activator adjuvants increase the effectiveness of the herbicide by altering the spray droplet size, distribution of the spray on the plant, viscosity (stickyness) of the spray, evaporation rate, rate of uptake (absorption) by the plant, solubility of the herbicide in the spray solution. Examples of activator adjuvants are:

- *Surfactants* (surface-active agent) promote the penetration of the chemical into the leaves of the plant. Any side effects should be considered when choosing a surfactant.
- *Wetting agents* increase the ability of water to displace air or liquid from the plant's surface so the herbicide will spread more evenly over the plant.
- *Oils* increase the retention time of the sprayed material on the plant and enhance uptake though the leaf surface.

Utility adjuvants are added to improve the application of the formulation to the target plants. An example of a utility adjuvant is:

- *Dye* is commonly used for spot or boom spraying. The presence of a dye makes it easy to see where the herbicide was applied and if it has spilled or leaked.

## COMPETING VEGETATION / REVEGETATION

Ultimately, the reestablishment of native vegetation is the most effective long-term strategy for managing non-native and invasive weeds. Many exotic species are dependent on open, disturbed ground to germinate and grow. As native plants become established and begin to form a more solid ground cover, populations of invasive species should decrease and the area will become resistant to reinvasion.

Areas determined to be lacking in adequate grasses should be seeded with an appropriate native grass seed mix. Herbicide use can occur prior to seeding. However be sure the herbicide has no pre-emergent activity that will result in seeding failure. Once seeding and germination has occurred, herbicide use at the site can continue. However, only broadleaf specific compounds should be utilized and application of those herbicides with a known pre-emergent effect should be timed to have minimal effect on germination of desired species.

The seed mix should be appropriate for the elevation and soils at the site. A native grass seed mix should contain a mix of both warm and cool season grasses. In the Flagstaff area some good choices based on what grows on the neighboring forest and is readily available include: (warm season) blue grama, little bluestem and purple three-awn (*Bouteloua gracilis, Schizachyrium scoparium, and Aristida purpurea*); (cool season) western wheatgrass, Arizona fescue, bottlebrush squirreltail and muttongrass (*Pascopyrum smithii, Festuca arizonica, Elymus elymoides, and Poa fendleriana*). Lower elevation sites with sandier soils will require different species similar to Indian ricegrass (*Oryzopsis hymenoides*) and sideoats grama (*Bouteloua curtipendula*). In areas that will receive relatively frequent disturbance (road ditches) where native grasses are unlikely to become established, foxtail barley (*Hordeum jubatum*) may be a good choice. This is a rapidly growing annual, cool season, native grass that can rapidly colonize disturbed sites. Care should be taken where foxtail barley is applied as it can be considered a pest on pasture lands. Choices for reseeding should be based on native grasses growing adjacent to the right of way. In general the most common cool season and warm season grass will provide a reasonably priced native ground cover.

While native grass species provide ground cover and protection from weed invasion at a low cost, flowering native plants can provide other ecological benefits for pollinators and other insects. Some native wildflowers that also attract pollinators include desert globemallow, firecracker or Rocky

Mountain penstemon, hoary tansyaster, Indian blanket, Mexican hat, tufted evening primrose, Rocky Mountain beeplant, and showy or butterfly milkweed. Again the mix of these species is dependent on the elevation and soil conditions at the site. Additionally, because these species are susceptible to broadleaf specific herbicides, they should not be planted until the need for herbicide applications at the site has become minimal.

## PUBLIC OUTREACH

The ROWs are a relatively small island of habitat in a much larger area of mixed land ownership. Management will be more successful if adjacent lands are managed with a similar goal of addressing weeds. Public outreach targeting the local residents will help private landowners identify and learn how to control the target weed species on and around their property. Educating landowners about the types of weeds and different control measures and encouraging them to monitor and remove weeds on their property will help in the overall weed management efforts.

At a minimum, notice of weed treatment should be provided to adjacent property owners via letter, email or Coconino County website. Notification should include: proposed dates for treatment, area to be treated, target species, proposed methods and a contact number. The contractor should be responsible for posting signs around the treatment area indicating the materials utilized, and any precautions necessary. Such notifications will help build trust and partnership between the county and private landowners.

## ADJACENT INFESTED LANDS

In many instances, weeds are not just growing in the right of way, but are part of a larger area of infestation that continues on the adjacent land. In these cases, management activities conducted on the ROW will have little effect on the overall weed population in a given area and will require continual treatment to keep the ROW clear if the landowner does nothing to control the weeds on their lands. But in these areas, it is important to control the weeds in the ROW to prevent further spreading of the seeds outside the area by vehicles or persons who unknowingly move across the ROW. The use of a pre-emergent herbicide may be warranted in these situations. Also, it would be important to contact the landowner to educate them on the weed problem and encourage them to take action.

## TREATMENT OF DISTURBED AREAS

New construction areas, gravel pits and staging areas are not expected to develop and maintain sufficient native vegetation to prevent invasion of nonnative weed species. These areas are susceptible to invasion of weeds and can become troublesome to other areas since materials and equipment are shipped out to other sites and can carry weed seed with them.

Management of these areas may require use of a pre-emergent herbicide that prevents successful germination of weed seed. Pre-emergent herbicide should be selected for the duration of its affect and the intended use of the borrow material. Long lasting pre-emergent can work for several growing seasons, and should be utilized on areas that contain inert materials or areas that will be left unutilized for several months or more. Shorter duration pre emergent herbicides have a half life of approximately 120 days depending on conditions. Short duration herbicides can be utilized on temporary staging areas or stockpiles of materials that will be utilized in surface treatments where revegetation is planned. It should be noted that once the surface of the treated soil is broken, the pre-emergent qualities of the herbicide are lost since the herbicide is likely to be buried below the shallow zone of soil where seeds germinate.

# TREATMENT SUMMARY BY SPECIES

Russian Knapweed

- Pull seedlings. Mechanical removal not effective on established plants due to vast root reserves.
- Spray herbicide on growing plants.

Camelthorn

- Spray herbicide on rapidly growing plants.
- Mechanical removal is not effective; it can stimulate remaining roots to spread.

Diffuse Knapweed, Spotted Knapweed and Scotch Thistle

- Pull or dig out young plants.
- Spray herbicide on rosettes to early bolting stage. Spraying after flowers have matured may not be effective.
- Pull and bag flowering plants. Incinerate plants to prevent spread of seed.
- Mowing is not recommended.
- Reseeding of disturbed sited with fast growing grass helps prevent knapweed establishment.

Yellow Starthistle

- Pull or dig out young plants.
- Pull and bag flowering plants.
- Mow up to bolting stage.
- Spray pre- and post-emergence herbicides.

Russian Olive

- Mechanical removal of seedlings and saplings before they mature.
- Broadcast foliar spray when leaves are fully developed.
- Cut stump treatment.

Siberian Elm

- Mechanical removal of seedlings and saplings before they mature.
- Broadcast foliar spray when leaves are fully developed.
- Cut stump treatment.
- Girdling stem.

# TIMELINE

Recognizing that the weed management plan will use an adaptive management approach, the timeline as outlined in Table 2 will be reviewed and modified as necessary based on the impact of management actions. Please note that the timing of treatments is approximate since precipitation can greatly affect the timing of germination and flowering.

**Table 2. Annual Weed Management Implementation Schedule**

| Date | Action/Method | Description | Comments/Notes |
|---|---|---|---|
| March - May | Annual Assessment | Depending on elevation – Spot check ROWs and other management areas for early growth rosettes and germination. Refer to iMapInvasives database for additional survey areas. | Map areas for late spring/early summer treatment and prioritize |
| May - June | Herbicide Treatment – Spot Spraying | Treatment of target areas | Prevent growth/seed set of early annuals and perennials |
| late June | Seeding | Seed bare areas with native grass and forbs in preparation for monsoon season | Seed areas that need minimal treatment in future. Timed to coincide with monsoon rains. |
| July/August | Mid Season Assessment | Spot check ROWs and other management areas for late season growth and germination after monsoons have begun | Target late season growth and bolting that is easier to identify. |
| July - September | Mid Season Treatment | Herbicide immature forms, mow or pull late form annual/biennials before seed set, pull perennials before seed set. | Prevent seed set of target species. Bag flowers that could set seed after treatment. |
| September | Monitoring | Assess areas treated for effectiveness, prepare plan for next Spring and Summer treatments. | |
| October/ November | Seeding | Additional seeding as needed/ late season herbicide treatment on certain species prior to dormancy | Plant seed to miss late season rain and minimize predation by insects and birds |

# MONITORING AND RECORD KEEPING

Spring and post-monsoon surveys are recommended to evaluate the distribution and abundance of target species. The monitoring data should be compared to treatment records to ensure that treatments are having the desired effect. Areas should also be monitored for any new weed species that should be added to the target species list as well as the success of the establishment of native grasses.

Coconino County contractors should provide records of site inventories and treatments utilizing a common database accessible by multiple contractors and county personnel. NCD highly recommends that the Coconino County utilize AZ iMapInvasives as the platform for record keeping. This GIS based database captures area (point or polygon), species observed, treatments utilized, personnel and dates in a common data base of other users in the state. It is free and maintained by Arizona Game and Fish Department. Other researcher's and iMapInvasives users will have access to the data. For additional information contact Jami Kuzek at Arizona Game and Fish Department. (jkusek@azgfd.gov or 623-236-7686). The iMapInvasives home page is http://www.imapinvasives.org/.

## JURISDICTIONAL CONSIDERATIONS

ROWs for Coconino County maintained roads cross several jurisdictional boundaries that should be considered during weed management activities. While several ROWs border Bureau of Land Management, National Park Service and Arizona State Trust Lands, these ROWs appear to be separate from the adjacent lands and care should be taken to ensure that the ROW boundaries are clearly known to weed management applicators and respected.

In addition to the ROW's directly adjacent to neighboring lands, there are numerous county maintained roads that cross US Forest Service and Navajo Tribal lands. US Forest Service in particular has very specific procedures for weed treatment on their lands and county treatment plans should conform to these procedures. US Forest Service has specific herbicides and concentrations that are approved for use on forest lands through the NEPA process.

In a similar process to USFS, weed treatments on Navajo Nation Tribal lands are governed by a Navajo Nation Weed management plan. Likewise this plan is vetted through the National Environmental Policy Act (NEPA). Unfortunately as of this writing the plan is not approved and is still in the review stage. It is understood that the proposed methods for weed management within road ROWs follow Arizona Department of Transportation guidelines, which are compatible with this plan. However, this cannot be confirmed until the plan is approved and adopted. Approval should come within the next six months to one year. Once approved, Coconino County should coordinate with Navajo Nation EPA for herbicide use permits as needed.

## CERTIFICATION AND SAFETY CONSIDERATIONS

Herbicide application within the County ROWs will need to be accomplished by a contractor with a Right-of-Way herbicide applicator certification. More remote areas and open lands can be addressed by applicators with forestry or agricultural certification. Mechanical removal does not require a certified applicator.

Herbicide applicators should develop and provide the county with a copy of their safety and spill plan. A sample safety plan is provided in Appendix E and at a minimum, the safety and spill plan should cover the items set forth in the example plan.

Contractor shall provide a traffic control plan, per MUTCD standards, to the County Engineer for approval prior to commencing weed mitigation work within the right-of-way.

## REFERENCES

DiTomaso, J.M., G.B. Kyser et al. 2013. Weed Control in Natural Areas in the Western United States. Weed Research and Information Center, University of California.

White, M.R., ed. 2013. Invasive Plants and Weeds of the National Forests and Grasslands in the Southwestern Region, Second Edition. USDA Forest Service, Southwestern Region, Apache-Sitgreaves National Forest. December 2013. MR-R3-16-6.

Whitson, T.D.(ed.), L.C. Burrill, S.A. Dewey, D.W. Cudney, B.E. Nelson, R.D. Lee, R. Parker. 2006. *Weeds of the West.* Western Society of Weed Science, in cooperation with the Western United States Land Grant Universities Cooperative Extension Services.