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BLM Riparian Area Management Technical Reference: Using UAS Remotes Sensing Imagery to Assess Proper Functioning Condition of Riparian-Wetland Areas

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Abstract
The Bureau of Land Management (BLM) was loaned older military Unmanned Aerial Systems (UAS) and is pioneering their employment for land management applications. Riparian areas make up a small percentage of BLM lands but are some of the most environmentally and economically valuable. Assessments of these riparian areas are required by law. Assessments from UAS imagery could become an important monitoring tool that is cheaper, safer and allows access to previously unreachable areas. This capstone project tests the UAS imagery for conducting riparian proper functioning condition (PFC) and quantitative assessments; and includes a technical reference with an interpretation key and GIS analysis instruction for future assessments. The test area imagery was mosaicked, analyzed and instructions documented for Google Earth, ArcGIS and ENVI software.

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BLM Riparian Area Management Technical Reference: Using UAS remotes sensing imagery to assess Proper Functioning Condition of Riparian-Wetland Areas

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Abstract

The Bureau of Land Management (BLM) was loaned older military Unmanned Aerial Systems (UAS) and is pioneering their employment for land management applications. Riparian areas make up a small percentage of BLM lands but are some of the most environmentally and economically valuable. Assessments of these riparian areas are required by law. Assessments from UAS imagery could become an important monitoring tool that is cheaper, safer and allows access to previously unreachable areas. This capstone project tests the UAS imagery for conducting riparian proper functioning condition (PFC) and quantitative assessments; and includes a technical reference with an interpretation key and GIS analysis instruction for future assessments. The test area imagery was mosaicked, analyzed and instructions documented for Google Earth, ArcGIS and ENVI software.

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Project Definition

The US Federal Land Policy and Management Act of 1976 mandates 5-year ecological assessments (Booth et. al, 2007, 637). Riparian proper functioning condition (PFC) is the standard, qualitative method within the BLM for determining how well the riparian-wetland areas are working and to meet the requirements of the act. PFC examines the hydrology, vegetation and erosion/deposition of soils. Lotic and lentic checklists, created by subject matter experts, are utilized to determine the overall health of the riparian-wetland areas (Prichard, 1998, 1-126).

The existing Riparian Area Management Technical Reference (TR) for using aerial imagery to assess PFC describes the implementation of color infrared (IR) stereo printed photographs for each of the items on the lotic checklist (Pritchard et al, 1999, 1-53). As budgets have been cut in recent years, these images are not being captured as routinely as they used to be, and field offices are losing the equipment and expertise to interpret stereo photographs. A team was formed at the BLM National Operations Center in Denver to discuss the need to adapt to new technologies and find alternative solutions. One option discussed was the use of Unmanned Aerial Systems (UAS). The BLM has been permanently loaned Raven® and T-Hawk UAS drones from military surplus for free. The BLM along with United States Geological Survey (USGS) is pioneering the use of UAS for land management

applications. This new technology for land management is an exciting prospect because it offers the ability to support scientific research and environmental monitoring of wildlife, noxious weeds, fires and land conditions which are crucial to land management in a safer and cheaper method.

I was asked to create a new technical reference for the use of the UAS remote sensing imagery; specifically for assessing Riparian PFC and additional quantitative assessments. At that time, the amount of the PFC assessment that could be determined by UAS imagery was still unknown. However, initial imagery collected during the summer and early fall of 2012 looked promising. Camera and lens adjustments had increased the resolution since the first test flights (Bureau of Land Management 2012).

Remote sensing from UAS can be a valuable tool in conducting proper functioning condition and other quantitative assessments of riparian-wetland areas. Questions researched during this project were: when utilizing the test area data, how accurate is Raven® UAS remote sensing imagery in assessing PFC of riparian or wetland areas and what are the limitations, if any, of using this type of imagery for the PFC checklist and quantitative assessments? The goals of this project were to determine the steps for assessing each of the PFC checklist questions as well as the quantitative measurements and analysis utilizing UAS remote sensing imagery, document them in an interpretation key with examples of what to look for in RBG and

near IR imagery, and instruct how to conduct analysis and measurements within Google Earth, ArcGIS, and ENVI; specifically for this technology and use. An additional goal was to record the spatial and non-spatial resulting data in a geodatabase with relationship feature classes.

The results of this project, documented in the instructions and recommendations within the technical reference, will be used throughout the BLM as the UAS imagery of riparian-wetland areas is collected on BLM lands in different states. The technical reference was created using data from a riparian-wetland area in Arizona.

Project Foundations

Importance of Riparian-Wetland Areas

Riparian-wetland areas are some of the most productive resources found on public and private lands. According to the Clean Water Act, wetland areas are "those areas that are inundated or saturated by surface or groundwater at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions. Wetlands generally include swamps, marshes, bogs and similar areas." These areas are considered to be lentic; where the water is still. Lotic waters are actively moving. Riparian areas are the borders between lands and lotic waters: a river or stream. Riparian vegetation is the vegetation on land that directly influences or is influenced by a body of water. This vegetation is considered a critical piece of river ecosystems. Riparian-wetland areas provide many essential

functions for land and water habitats (Yang, 2007, 353). Riparian vegetative species in these areas supply shade which regulates the water temperatures and provides erosion control. These factors help keep the water habitable for native fish and useable for wildlife (Lattin et. al, 2004, 215). In addition to their environmental value, they have economic value in the water they provide for livestock, timber and mineral extraction. Riparian-wetland areas also provide recreation, cultural and historic values such as an historic trail following a river. The wide ranging benefits of these area makes them highly sought after and as a result, highly vulnerable to overuse (Prichard, 1998, 1). The Bureau of Land Management's (BLM) multiple-use mission is to sustain the health and productivity of the public lands for the use and enjoyment of present and future generations. The BLM aims to accomplish this by managing such activities as outdoor recreation, livestock grazing, mineral development, and energy production, and at the same time conserving natural, historical, cultural, and other resources on public lands (www.blm.gov, 2012). Given this mission the BLM must carefully monitor riparian-wetland areas to ensure their health for each of their benefits and not just one.

Imagery Comparison
The BLM manages more than 245 million surface acres, more than any other federal agency. Even with riparian-wetland areas only making up a

tiny portion of that land it is still an expensive and somewhat daunting task to obtain the assessments along with the other land management priorities. When a ground PFC assessment is completed it can be costly. In 2003, the ground assessment for only eight streams with 60 sampling locations cost $23,000 not including travel. A light plane, aerial assessment sampling 770 locations cost $9000, not including travel or the annual start up fee of $5000 (Booth et. al., 2007, 646). Aerial imagery from aircraft has other drawbacks as well. The resolution is not high-quality enough to conduct some of the PFC checklist. Collecting aerial imagery in these small planes can be dangerous for the BLM personnel onboard the flights due to the sometimes treacherous terrain, unpredictable weather and the potential for crashes. In fact, ocular surveys by subject matter experts in fixed-wing aircraft have been banned within the BLM for the last few years due to safety concerns (Brady, 2012). In addition, some canyons are too narrow for fixed-wing aircraft to fly.

UAS remote sensing is a new technology outside of the military and its use for land management in general, is in its infancy. Currently, the UAS have been tested for watershed management in Arizona and the use of the spread of noxious weeds on BLM lands in Idaho (Taylor, www.local8news.com). Several other projects including fire management, coal seam fire detection and others have been slated for 2013. The use of other types of remote sensing for land management and specifically for

riparian-wetland assessment is not new. Over the years, these different types of imagery have been tested for their ability to be used for riparian-wetland assessment and PFC with varying degrees of success. Aerial photography and other remote sensing methods are recognized as cost-effective means for collecting riparian data and with some limitations for assessing PFC (Pritchard et al, 1999, Background). Landsat (Land Satellite) provides imagery that is visible and near infrared. It is commonly used to estimate the amount of ground cover types within riparian buffer zones. This is important for riparian-wetland health due to the correlation between riparian health and species richness and conversely a negative correlation between urban land cover types within the buffer area and fish species richness. Landsat derived maps tend to be less accurate than air photo interpretations for riparian-wetland health however. Forest and grass cover are consistently underestimated when using the Landsat maps for smaller buffer areas (Goetz, 2006, 133). Landsat is too coarse to identify details about riparian-wetland areas, such as woody species height, although it can be employed to locate the riparian-wetland areas that will need to be assessed. This can be a practical application due to the size of the lands the BLM manages.

Some experts recommend aerial imagery with scales between 1:40,000 and 1:60,000 for observation of features like flood plains, beaver dams, channels and bank vegetation. This range of scale is based on the

preference for total photographic coverage of the riparian-wetland area and number of photographs needed to do so. High resolution would require a great deal more photographs to capture the entire area, increasing the time and difficulty of analysis particularly when dealing with printed photographs (Booth et al, 2007, 637). This is the case with UAS imagery as well however the advanced mosaic and 3-D analysis available within software such as PhotoScan make this analysis more manageable. Accurate feature measurement, other detailed quantitative assessments as well as the details of the PFC qualitative assessments require that higher resolution particularly when dealing with natural color imagery. The recommended imagery scale for riparian vegetation monitoring is 1:2400, shrub identification is 1:1800 and 1:1600 for woody vegetation types (Booth et al, 2012, 513). This higher resolution in the past has been captured by the use of a light airplane, navigation and camera-triggering system, digital camera and a laser rangefinder as was done in the Rock Creek watershed in 2003 as described in Booth et al. The imagery collected was not intended to do riparian mapping of the entire riparian area but to do systematic sampling. The UAS imagery collections for riparian areas, in most cases, will be used for systematic sampling as well.

Health indicators of riparian areas are the width of the stream or river channel, vegetation height, width of riparian vegetation buffer or tree

canopy width. Measurements made using remote sensing techniques reduce the time and cost of the monitoring and allow for the study area expansion.

UAS Options

Raven-RQ-11a UAS are small, lightweight aircraft are launched by hand into the air and fly a few hundred feet above the ground and controlled remotely.

Figure 1: Raven-RQ-11a is launched by hand on BLM lands.

The Ravens were utilized in Afghanistan to spot insurgent forces without endangering military personnel any more than necessary. The Raven is 4.8 pounds and 36 inches long with a wingspan of 4.5 feet (www.avinc.com, 2012). The Raven is seen as a useful tool for the BLM for several reasons. First, it is easily transportable and deployable even in difficult or previously inaccessible areas allowing researchers to collect more information. It can fly in narrow canyons that manned aircraft cannot. Second, due to its much

quieter engine than other UAS or helicopters, it will not disturb the wildlife it may hope to monitor. Third, it also allows for aerial observation day or night which means there is the potential to monitor and count birds resting at night for example. The Raven is launched by hand and utilizes advanced avionics and GPS navigation. The UAS transmits near real-time airborne images, compass headings, and GPS locations to a ground-control unit and remote video terminal. Several different cameras have been tested on the drone with the most successful yet being the GoPro camera. The Raven is powered by a lithium-ion rechargeable battery that allows flights of 60-90 minutes travelling about seven miles at a speed of 30 mph (Drobka, 2012).

The UAS does have some limitations. The Raven has a line-of-sight range up to 10 kilometers according to (www.avinc.com, 2012) although the BLM has not yet tested it at this distance. The Federal Aviation Administration (FAA) requires it to be flown by a licensed pilot if flown over 1000 feet. If this higher altitude is ever needed, it limits the use of the Raven® to two BLM employees at the National Operations Center at this time. It must be flown at least five miles away from any airport and flights must be approved in advance. The Raven does not have wheels so it crash lands every flight. This has caused breaking of camera lenses.

The other option for UAS within the BLM is the Honeywell T-Hawk which allows for tighter control through narrow canyons but is extremely loud which could disturb wildlife.

Figure 2: The T-Hawk in flight

The T-Hawk has autonomous flight with dynamic re-tasking and manual intervention. In practice, the camera is difficult to keep in a downward direction as the T-Hawk's position is adjusted during flight. The UAS is 17.5 pounds and can fly up to 46 mph in 20 knot winds. It has a range of three to six miles. The ground station can store up to 240 minutes of sensor imagery. The same GoPro Camera could be utilized on the T-Hawk in the gimbaled mount (Honeywell Aerospace, 2010). A recent purchase of a camera capable of capturing near IR data has been tested on the T-Hawk. This is an exciting possibility for riparian assessments. These camera types are too heavy for the Raven however.

Camera Options

The GoPro Camera is a low cost solution with a higher resolution (36 times more pixels) than the stock camera. It has HD Video and 11 megapixel stills to use tie point automation tools. It is lightweight and its size allows the Raven to carry it.

Figure 3: Go-Pro Camera

The XNite Canon SX230NDVI Vegetation Stress Camera with GPS is 12.1 Megapixel and lightweight enough for the T-Hawk but not the Raven UAS. Captures Blue, Green and Near Infrared bands (670nm to 750nm). This enables better assessment of plant health. Imagery can be converted to a scaled NDVI picture. The Canon is too heavy for the Raven could only be used on the T-Hawk.

Figure 4: Canon SX230NDVI Vegetation Stress Camera

Approach

The study area for this project will be a riparian area on BLM lands near San Simon, Arizona.
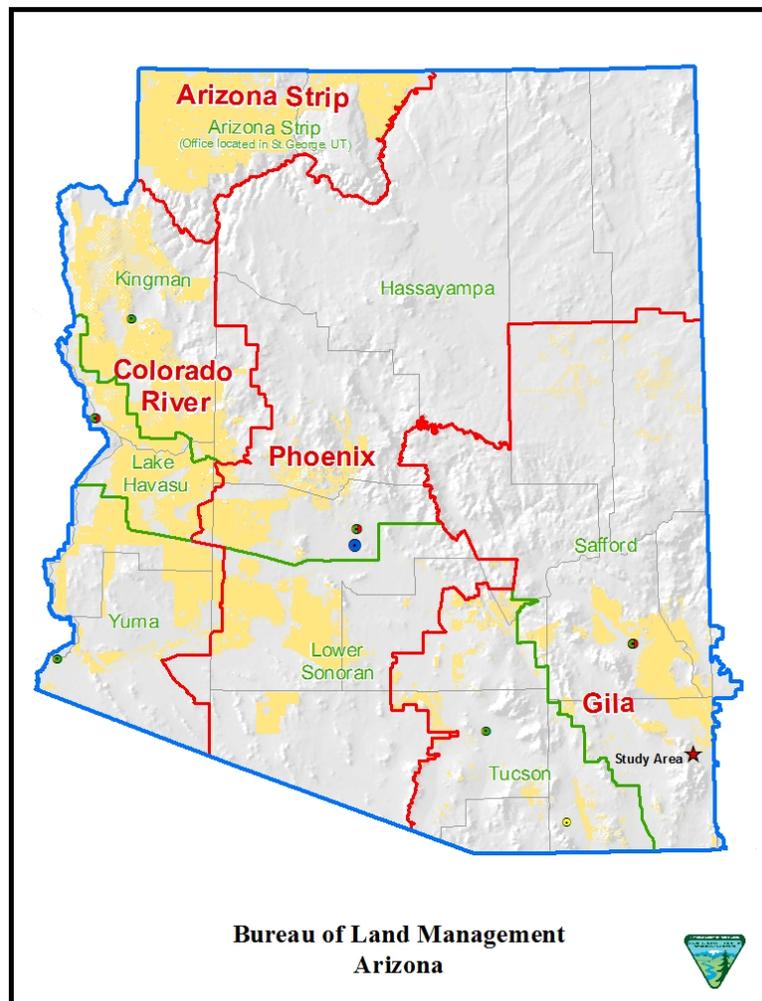
Figure 5: Study Area location with BLM Arizona Districts and Field Boundaries

Remote sensing imagery for the riparian study area was collected by a Raven UAS October 2012. This is a man-made riparian area has been established to create habitat to assist the stabilization of native fish species

to the area. Prior to the creation of the stream, a single pool fed by an aquifer existed on the site.

Figure 6: Test Area - Sandsdraw

Riparian imagery was taken at 50.9 meters (167 feet) in stereo pairs giving a ground resolution of two centimeters per pixel using the original imagery. The 412 images were mosaicked into a continuous aerial image of the area using PhotoScan. Photo panels were not used on the ground for georeferencing the imagery due to the time and cost involved. The test area was viewed in existing Google® imagery for comparison and georeferencing was completed within PhotoScan based on unique features within the study area in both datasets. The unique feature was found in Google Earth and the UTM coordinates noted. The unique feature was found again in multiple photos collected by the UAS and marked with a numbered point. I added a total of twelve control points checking the error rate after each was added to

see if there were any that needed to be repositioned. In some photos the unique feature was visible but due to the angle of view the particular marker had to be removed. The curvature of the photo can be seen in the example image below.

Figure 7: Unprocessed photo of study area

The control points differed in the number of marked photos that could be used to georeference them. The number per control point is listed in the projection column of Table 1. Markers that could be placed near the center of the photo had better results. The most difficult areas were toward the outer edges of the mosaic due to fewer photos being available of those areas and nature of the area itself. The image below is of the entire mosaic. The outer edge of the mosaic is lacking in vegetation and unique features for easier georeferencing.
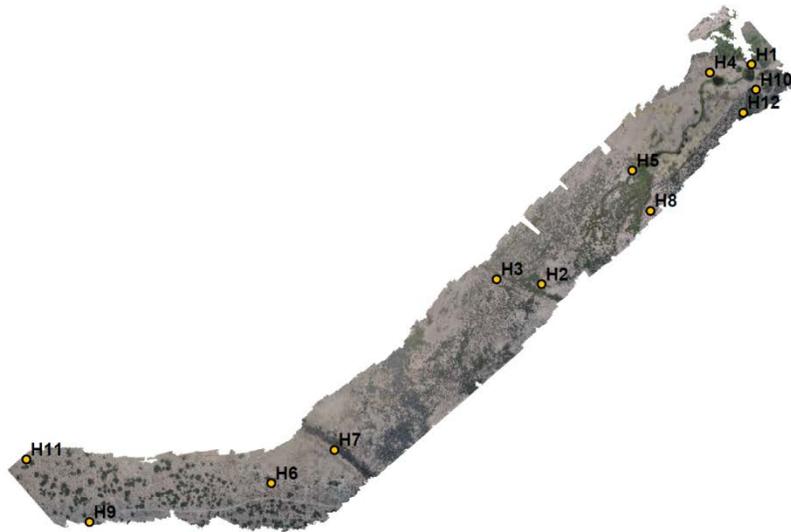
Figure 8: Imagery mosaic with control point locations

More control points were added to the riparian area of the mosaic as this was the study area. The table below indicates the rate of possible error as seen within PhotoScan. Although the pixel error for H1 indicated a large error, this was seen not to really be the case by verifying the location. This location actually has a very clear unique feature.

Table 1: Control Points

Label	X error (m)	Y error (m)	Z error (m)	Error (m)	Projections	Error (pix)
H1	1.133375	0.083252	-1.18902	1.644759	5	87.54818
H2	-0.37986	0.01075	0.302005	0.485403	16	6.573996
H3	0.04476	-0.09365	-0.11084	0.151853	10	3.500823
H4	0.842771	0.073912	-0.44247	0.954729	10	6.693694
H5	-0.334908	0.125158	-0.08285	0.367005	15	8.102218
H6	-0.144444	0.058419	-0.10523	0.188014	21	3.838076
H7	-0.338674	0.062047	0.399038	0.527049	19	8.124753
H8	-0.08967	0.541018	0.649755	0.850249	9	4.346211
H9	2.073667	1.790319	-1.79601	3.275821	4	4.431164

H10	-0.500216	0.257953	0.318303	0.646585	9	8.038628
H11	-0.134173	-1.162164	1.359921	1.793882	12	13.41683
H12	-0.54043	0.112722	0.869463	1.02992	11	7.140179

GeoTiff, LAS and KMZ files were created. The GeoTiff has a ground resolution of five cm per pixel. This is the standard amount of analysis usually conducted by the UAS team or by the Remote Sensing group at the National Operations Center prior to turning the data over to the client (usually a field office or in this case Riparian). For this case, I continued the analysis to develop the technical reference. I created a Digital Elevation Model (DEM) by converting the LAS file with Safe Software's FME Spatial Data Transformation Platform. The DEM could be easily created within PhotoScan as well but the BLM recently added the software to our Citrix farm and we have been encouraged to test its capabilities. This conversion was a basic test on my part.

The next step in the project was the development of the draft interpretation key. Quantitative assessments were chosen by Melissa Dickard, Ecologist, and I based on what we thought might be possible to determine with remote sensing techniques and the most useful to a Riparian ID Team. Quantitative measurements are being used within the BLM and other agencies more frequently and will continue to do so with implementation of the Riparian Area Management Multiple Indicator Monitoring (MIM). Some of these include Woody Species Height, Stubble

Height, Greenline to Greenline width and Pool Depth (Burten et all, 2011, 13-67). Based on the study area the quantitative assessments chosen for the technical reference were slope, stream bank stability, greenline to greenline width, bankfull width, wetted width, frequency of large wood, stubble height and woody species height and slope of reach. The qualitative questions were from both Lentic and Lotic standard checklists–all have Yes or No options some with N/A options[1]. These questions are applied to each definable reach along the stream which means the checklists can be applied multiple times for each stream. The test area for this project included one definable reach. Subject matter experts conduct ground assessments utilizing these same checklists. Recommendations, remote sensing techniques and GIS options were chosen for each of the questions based on their ease of use and accuracy. Several options were given for some questions to give users choices in order to best apply the interpretation key to their study area and/or GIS skill level. In March 2013, Matt Bobo and Jeff Safran (remote sensing experts from the BLM), Melissa Dickard and I met to review my approach for the interpretation key. They offered suggestions and additional options. I incorporated these changes and additions into the key and then started the analysis capturing screenshots and writing directions to be integrated into the technical reference.

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[1] Quantitative and qualitative assessments can be viewed in the interpretation Key within the Technical Reference, Appendix 1.

The imagery was analyzed within ArcGIS, Google Earth and ENVI to attempt to answer the quantitative assessments and PFC checklists. For Google Earth, the KML file was added to Google Earth and some basic assessments were made and documented. I included Google Earth analysis because some subject matter experts may or may not be familiar with ArcGIS or ENVI. Google Earth is relatively simple to use and the profile view of the slope is useful for answering one of the PFC checklist questions. In addition to the slope calculation and viewing, I demonstrated how to measure features, create a vector layer, and view historical layers of imagery. Each of these can assist in the assessment of riparian-wetland health. Google Earth could be primarily used for the quantitative assessments and the visual interpretation of some of the qualitative assessments although the GeoTIFF file has better resolution and viewing within ENVI or ArcGIS would be preferable.

Utilizing ENVI, I illustrated how to load images, measure, add vector layers and conduct the topographic modeling to view hillshade or slope. How to apply the Normalized Difference Vegetation Index (NDVI) was shown even without near IR bands for illustration of texture that can be achieved even with natural color imagery and to show directions for applying it to near IR imagery. Additional tools such as the SAM tool or vegetation libraries were suggested as options within the interpretation key and the options shown in

the GIS options appendix but real examples could not be shown without near IR or hyperspectral imagery.

ArcGIS was used for the majority of the analysis. Helpful tools that Riparian teams might use were described and illustrated with examples. These included the Measure, Swipe Layer, and the search window new for ArcGIS 10. The BLM recently migrated from ArcGIS 9.3.1 to ArcGIS 10.1 so not all users are familiar with the new version.

How to create vector layers and their use for Riparian-wetland assessment were added as well. This included an example for using a point feature class to view density of indicator species, anchored wood within the stream or for noxious weeds by using the Point Density tool. The Slope tool was illustrated and how to add contours to the slope raster from the Spatial Analyst toolbar.

The LAS file exported from PhotoScan was used in ArcGIS to create the LAS dataset. Directions were written for this and how to use the profile and 3-D views. This is an important feature for viewing vegetation heights and the overall slope of the riparian-wetland area.

The NDVI was applied to the natural color imagery in ArcGIS as well as ENVI. While NDVI is most useful when applied to near IR imagery, it does make the vegetation stand out and allows another view for determining the health of vegetation. The other purpose was just to show users of later

projects simple directions for applying NDVI so they could use it on their own near IR imagery.

Instructions for adding SSURGO soils data was included. Each member of the ID team researches the soils in the area prior to the assessment. This is often done with a paper map or by using the online soil mapping service hosted by U.S. Department of Agriculture, http://websoilsurvey.nrcs.usda.gov/app/HomePage.htm. The ability to layer the soils under the imagery is a helpful option.

A riparian ID team, as required for PFC assessments, used the technical reference along with the vector measurements and boundaries I created to perform the quantitative and PFC checklist. This interdisplinary team included: Melissa Dickard, Aquatic Ecologist, National Operations Center; Dr. Mark Gonzalez, NRST Ecologist/Soils, Prineville Deschutes Field Office; Sandra Wyman, NRST - Rangeland Management Specialist, Washington Office conducted the assessments from the imagery to review the accuracy of using the UAS imagery. Lance Brady, Fire Management Specialist and UAS Program Lead, National Operations Center attended the meeting as well as the UAS expert. The results of the remote sensing ID Team were then compared to an on the ground measurements and field notes collected by Heidi Blasius, Fishery Biologist and Jeff Conn, Natural Resource Specialist, Safford Field Office in March 2013. The accuracy of the

UAS assessment was then determined and recommendations for future use added to the Technical Reference.

These results were added a geodatabase with point, line and polygon feature classes with relationship feature classes linking them to the riparian team's assessment results recorded in non-spatial tables. The data standard for PFC data, Riparian Wetland Aquatic Locations (RWAL) had been established but not yet implemented. This assessment was the start of the implementation of the schema. The structure of the geodatabase is illustrated in the Appendix 2 and 3 diagrams. For this project, the arc feature classes were not populated. These were required in BLM spatial schemas in the past to keep track of historical boundaries over time. Polygon features were created from the arcs and boundary movements were documented this way. However, versioned SDE geodatabases are being used now and eliminates the need for the arcs. Polygon features, like the ones created for this dataset, will be created independently. The feature classes were not originally created in this schema because there was ongoing debate at the time about possible changes to the schema. The data was migrated into the schema after completion of the project.

Project Results

The Riparian ID Team was able to answer most the PFC checklists' questions. Their results were compared to ground measurements, field notes

and on the ground photographs of the test area checking the validity of UAS imagery utilization. The team felt their choices based on the UAS imagery were backed up the measurements, field notes and photographs including the identification of species which were noted in the on the ground photographs. The team was able to identify sacton from the UAS imagery which is clearly displayed in this photo taken by the on the ground team.

Figure 9: Ground photo of study area (March 2013)

The exceptions were either due to the limitations of the study area or remote sensing in general. For example, the second lotic question asks if where beaver dams are present are they the active and stable. An example could not be chosen from the study area and the ID team had to select N/A for the question because no beaver dams exist on the reach. The recommendations within the interpretation key could not be tested and/or

added to without a real example. Limitations of remote sensing made lentic question 15, the collection of water samples to check for chemical affecting plant productivity/composition impossible; instead only the overall health of the plants could be analyzed. Water samples would be impossible to collect and assess via remote sensing and indicators such as hoof shear might be difficult to see in its entirety because it may be located under vegetation. Full LiDAR assessment might be useful in this case but outside of the budget of the BLM.

The ID Team's suggested modifications were added to the technical reference. The technical reference will be followed as a best practice when analyzing future UAS data to determine what PFC indicators can be assessed by the technology. This will vary by site, camera and flight conditions.

Discussion

Overall, the project was a success. The end users, the Riparian ID Team, were pleased with the result. The technical reference was accepted. The general consensus is that they will be using it as a starting point to rewrite the existing technical reference for traditional aerial and satellite interpretation in addition to keeping it just for UAS imagery. This technical reference will most likely not be printed like previous ones; instead it will be available across the BLM on the Riparian SharePoint site. This is due to the rapid changes in technology. As software updates are implemented with the

BLM the screenshots and directions may need to be replaced. An upgrade of ENVI from version 4.8 to 5 is anticipated to be accepted on the BLM's baseline for software in the next few months. Significant updates to the display and menus will require updates to the technical reference. Additional tools, including the BLM Monitoring Tool, Intergraph's Stereo Analyst extension and the Forest Service's Valley Bottom Tool are expected to be added to the Citrix environment soon and demonstrations of their use will need to be documented and incorporated into the technical reference as well.

Lessons Learned

My initial interviews should have included multiple experts at the beginning of the project rather than midway through to get a better idea of their expectations. The project was started with the plan based on my interview of the riparian expert who made the request for the technical reference, Melissa Dickard. She is a fisheries expert and because of this has slightly different expectations and needs than other Riparian Team members who are vegetation or soils experts. I was able to make the changes and additions to the technical reference but it would have been easier to do this from the start of the project.

Areas for Further Research

The study area for the this project was chosen because the imagery was already available and it provided a chance to examine the imagery

quality and determine what the possibilities for using UAS for riparian PFC and quantitative assessments and provide feedback to the UAS team regarding the UAS and camera choice for upcoming projects. However, due to being manmade and small size it is not an ideal example. An area for further research that will certainly be applied is the addition of other study areas with different types of riparian-wetland areas. Two more UAS projects for riparian areas are already planned within the BLM for the summer of 2013. These case studies will use the technical reference as a guide and then their results and the recommendations gleaned from them will be added as appendices to the technical reference. This approach has been done with previous technical references and is helpful for future ID teams. They are able to review several examples instead of just one and more accurately apply the information to their own project. Different study areas could provide the chance to use additional spatial analyst tools such as the paired t-test and spatial autocorrelation with Moran's I z-scores as was used by Booth et al for indicator species like the willow.

The other obvious and exciting prospect for further research is utilizing a near IR camera or even better, one with hyperspectral bands. The near IR camera will be tested in a few weeks while the hyperspectral camera and the UAS to carry it are currently outside of the budget. Either option could expand the available analysis to include tools like ENVI's SAM or vegetation libraries. Identification in this manner could either help the ID team

determine plant species or backup their deductions made from visual

interpretation of the mosaic.

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Appendix 1

See separate attachment for Technical Reference

Appendix 2

Feature Dataset
- rwal

Feature Dataset
- rwal_lgcy

GUIDANCE (Reference) TABLES

rwal_len_elmt_gde
- Code
- Description

rwal_len_ecoasys_elmt_gde
- Code
- Description
- Requirement Code

rwal_ecoasys_elmt_gde
- Code
- Description
- Requirement Code

rwal_lot_elmt_gde
- Code
- Description

rwal_rosgen_clas_gde
- Stream Classification Code
- Combination of Attributes
- Rosgen Channel Material Number

rwal_wtlnd_clss_gde
- System
- SubSystem
- Class
- SubClass

rwal_wtlnd_mod_gde
- Wetland Modifier Code
- Wetland Modifier Name
- Wetland Modifier Type Name

rwal_lot_ln
- RWA Identifier
- NHD Reach Code
- RWA Local Identifier
- RWA Identification Date
- NHD Water Body Name
- RWA Local Name
- RWA Location Access Text A
- RWA Location Access Text B
- RWA Location Determination Text A
- RWA Location Determination Text B
- Segmentation Purpose
- Assessment Party Name
- Data Source Code
- Riparian Indicator
- Riparian Potential Reference Code
- Riparian Potential Reference Text A
- Riparian Potential Reference Text B
- Montgomery Buffington Stream Classification
- Verified Montgomery Buffington Stream Classification
- Rosgen Stream Classification
- Verified Rosgen Stream Classification
- Verified Stream Classification Text A
- Verified Stream Classification Text B
- Created Date
- Created by Name
- Modified Date
- Modified by Name
- Coordinate Source Type
- Coordinate Source Code
- Defining Feature Type Code
- Defining Feature Code
- Accuracy Measurement in Feet
- Administrative State
- Administrative Unit Code
- GlobalID
- RWA NHD From Point Rate
- RWA NHD To Point Rate

rwal_len_arc
- Created Date
- Created by Name
- Modified Date
- Modified by Name
- Coordinate Source Type Code
- Coordinate Source Code
- Defining Feature Type Code
- Defining Feature Code
- Accuracy Measurement in Feet
- Administrative State Code
- GlobalID

rwal_loc_int_pt
- Interest Point Identifier
- RWA Identifier
- Interest Point Type
- Interest Point Date
- GlobalID

rwal_len_poly
- RWA Identifier
- NHD Reach Code
- RWA Local Identifier
- RWA Identification Date
- NHD Water Body Name
- RWA Local Name
- RWA Location Access Text A
- RWA Location Access Text B
- RWA Location Determination Text A
- RWA Location Determination Text B
- Assessment Party Name
- Data Source Code
- Riparian Indicator
- Riparian Potential Reference Code
- Riparian Potential Reference Text A
- Riparian Potential Reference Text B
- Wetland Classification Code
- Wetland Classification Modifier(s)
- Administrative Unit Code
- Administrative State Code
- GlobalID

rwal_pfc_asmt_tbl
- RWA Identifier
- Assessment Date
- RWA Identifier Assessment Date
- Functional Rating Name
- Functional Rating Rationale A
- Functional Rating Rationale B
- Functional Risk Rating Trend
- Risk Rating Trend Rationale A
- Risk Rating Trend Rationale B 22
- Assessment Method
- Complex Indicator
- Plant Species Occurrence Code
- Assessment Overall Remarks A
- Assessment Overall Remarks B
- Assessment Restoration A
- Assessment Restoration B
- GlobalID

rwal_asmt_discp_tbl
- RWA Identifier Assessment Date
- Assessment Party Name
- Discipline One
- Discipline Two
- GlobalID

rwal_pfc_ext_fctr_tbl
- RWA Identifier Assessment Date
- External Factor Name
- External Factor Text
- GlobalID

rwal_img_tbl
- Interest Point Identifier
- RWA Identifier
- Image Identifier
- Image Reason One
- Image Reason Two
- Image Reason Three
- Image Date
- Image Time
- Image Party Name
- Image Direction Code
- Image Link
- GlobalID

rwal_len_pfc_tbl
- RWA Identifier Assessment Date
- LE01 Element Number Condition Response
- LE01 Element Number Condition Level
- LE01 Condition Response Text A
- LE02 Element Number Condition Response
- LE02 Element Number Condition Level
- LE02 Condition Response Text B
- LE03 Element Number Condition Response
- LE03 Element Number Condition Level
- LE03 Condition Response Text A
- LE04 Element Number Condition Response
- LE04 Element Number Condition Level
- LE04 Condition Response Text B
- LE05 Element Number Condition Response
- LE05 Element Number Condition Level
- LE05 Condition Response Text A
- LE06 Element Number Condition Response
- LE06 Element Number Condition Level
- LE06 Condition Response Text A
- LE07 Element Number Condition Response
- LE07 Element Number Condition Level
- LE07 Condition Response Text B
- LE08 Element Number Condition Response
- LE08 Element Number Condition Level
- LE08 Condition Response Text A
- LE09 Element Number Condition Response
- LE09 Element Number Condition Level
- LE09 Condition Response Text A
- LE10 Element Number Condition Response
- LE10 Element Number Condition Level
- LE10 Condition Response Text A
- LE11 Element Number Condition Response
- LE11 Element Number Condition Level
- LE11 Condition Response Text A
- LE12 Element Number Condition Response
- LE12 Element Number Condition Level
- LE12 Condition Response Text B
- LE13 Element Number Condition Response
- LE13 Element Number Condition Level
- LE13 Condition Response Text A
- LE14 Element Number Condition Response
- LE14 Element Number Condition Level
- LE14 Condition Response Text A
- LE15 Element Number Condition Response
- LE15 Element Number Condition Level
- LE15 Condition Response Text A
- LE16 Element Number Condition Response
- LE16 Element Number Condition Level
- LE16 Condition Response Text A
- LE17 Element Number Condition Response
- LE17 Element Number Condition Level
- LE17 Condition Response Text B
- LE18 Element Number Condition Response
- LE18 Element Number Condition Level
- LE18 Condition Response Text A
- LE19 Element Number Condition Response
- LE19 Element Number Condition Level
- LE19 Condition Response Text A
- LE20 Element Number Condition Response
- LE20 Element Number Condition Level
- LE20 Condition Response Text A
- LE20 Condition Response Text B
- GlobalID

rwal_lot_pfc_tbl
- RWA Identifier Assessment Date
- LO01 Element Number Condition Response
- LO01 Element Number Condition Level
- LO01 Condition Response Text A
- LO02 Element Number Condition Response
- LO02 Element Number Condition Level
- LO02 Condition Response Text B
- LO03 Element Number Condition Response
- LO03 Element Number Condition Level
- LO03 Condition Response Text A
- LO04 Element Number Condition Response
- LO04 Element Number Condition Level
- LO04 Condition Response Text B
- LO05 Element Number Condition Response
- LO05 Element Number Condition Level
- LO05 Condition Response Text A
- LO06 Element Number Condition Response
- LO06 Element Number Condition Level
- LO06 Condition Response Text B
- LO07 Element Number Condition Response
- LO07 Element Number Condition Level
- LO07 Condition Response Text A
- LO08 Element Number Condition Response
- LO08 Element Number Condition Level
- LO08 Condition Response Text A
- LO09 Element Number Condition Response
- LO09 Element Number Condition Level
- LO09 Condition Response Text A
- LO10 Element Number Condition Response
- LO10 Element Number Condition Level
- LO10 Condition Response Text A
- LO11 Element Number Condition Response
- LO11 Element Number Condition Level
- LO11 Condition Response Text A
- LO12 Element Number Condition Response
- LO12 Element Number Condition Level
- LO12 Condition Response Text A
- LO13 Element Number Condition Response
- LO13 Element Number Condition Level
- LO13 Condition Response Text A
- LO14 Element Number Condition Response
- LO14 Element Number Condition Level
- LO14 Condition Response Text A
- LO15 Element Number Condition Response
- LO15 Element Number Condition Level
- LO15 Condition Response Text A
- LO16 Element Number Condition Response
- LO16 Element Number Condition Level
- LO16 Condition Response Text A
- LO17 Element Number Condition Response
- LO17 Element Number Condition Level
- LO17 Condition Response Text B
- GlobalID

rwal_lgcy_loc_int_pt
- Interest Point Identifier
- RWA Identifier
- Interest Point Type
- Interest Point Date
- GlobalID

rwal_lgcy_img_tbl
- Image Identifier
- RAW Identifier
- Image Reason One
- Image Reason Two
- Image Reason Three
- Image Date
- Image Time
- Image Party Name
- Image Direction Code
- Image Link
- GlobalID

rwal_lgcy_pfc_ext_fctr_tbl
- RWA Identifier Assessment Date
- External Factor Name
- External Factor Text
- GlobalID

rwal_lgcy_len_pfc_pt
- RWA Identifier Assessment Date
- RWA Identifier
- NHD Reach Code
- Assessment Date
- LE01 Element Number Condition Response
- LE01 Element Number Condition Level
- LE01 Condition Response Text A
- LE01 Condition Response Text B
- LE02 Element Number Condition Response
- LE02 Element Number Condition Level
- LE02 Condition Response Text B
- LE03 Element Number Condition Response
- LE03 Element Number Condition Level
- LE03 Condition Response Text B
- LE04 Element Number Condition Response
- LE04 Element Number Condition Level
- LE04 Condition Response Text A
- LE05 Element Number Condition Response
- LE05 Element Number Condition Level
- LE05 Condition Response Text A
- LE06 Element Number Condition Response
- LE06 Element Number Condition Level
- LE06 Condition Response Text A
- LE07 Element Number Condition Response
- LE07 Element Number Condition Level
- LE07 Condition Response Text B
- LE08 Element Number Condition Response
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- LE08 Condition Response Text A
- LE09 Element Number Condition Response
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- LE09 Condition Response Text A
- LE10 Element Number Condition Response
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- LE10 Condition Response Text A
- LE11 Element Number Condition Response
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- LE11 Condition Response Text A
- LE12 Element Number Condition Response
- LE12 Element Number Condition Level
- LE12 Condition Response Text B
- LE13 Element Number Condition Response
- LE13 Element Number Condition Level
- LE13 Condition Response Text A
- LE14 Element Number Condition Response
- LE14 Element Number Condition Level
- LE14 Condition Response Text A
- LE15 Element Number Condition Response
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- LE16 Condition Response Text A
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- LE17 Element Number Condition Level
- LE17 Condition Response Text B
- LE18 Element Number Condition Response
- LE18 Element Number Condition Level
- LE18 Condition Response Text A
- LE19 Element Number Condition Response
- LE19 Element Number Condition Level
- LE19 Condition Response Text A
- LE20 Element Number Condition Response
- LE20 Element Number Condition Level
- LE20 Condition Response Text A
- LE20 Condition Response Text B
- Data Source Code
- Functional Rating Name
- Riparian Indicator
- Functional Risk Rating Trend
- Risk Rating Trend Rationale Text A
- Risk Rating Trend Rationale Text B
- Assessment Method
- Complex Indicator
- Plant Species Occurrence Code
- RWA Identification Date
- RWA Local Name
- Administrative Unit Code
- Assessment Party Name
- Administrative State Code
- RWA Location Access Text A
- RWA Location Access Text B
- RWA Location Determination Text A
- RWA Location Determination Text B
- Riparian Potential Reference Code
- Riparian Potential Reference Text A
- Wetland Classification Code
- Wetland Classification Modifier
- Created Date
- Created by Name
- Modified Date
- Modified by Name
- Accuracy Measurement in Feet
- Point Source Type
- Point Source Description
- Assessment Rating Rationale Text A
- Assessment Rating Rationale Text B
- Assessment Overall Remarks Text A
- Assessment Overall Remarks Text B
- Assessment Restoration Characteristic Text A
- Assessment Restoration Characteristic Text B
- Assessment Team

Appendix 3

RVAA Lentic — 11 ATTRIBUTES

RVAA Lentic Polygons — 21 ATTRIBUTES

RVAA Lotic — 37 ATTRIBUTES

RVAA Location Interest — 5 ATTRIBUTES

Riparian, Wetland, Aquatic Location

RVAA Lentic Poly to Loc Int — Key RVAA ID

RVAA Lotic Lines to Loc Int — Key RVAA ID

RVAA Loc Int Pt to Img — Key INT PT ID

RVAA Lentic Poly to Img — Key RVAA ID

RVAA Lotic Ln to Img — Key RVAA ID

RVAA Lentic Poly to PFC — Key RVAA ID

RVAA Lotic Lines to PFC Asmt — Key RVAA ID

RVAA PFC Assessment — 17 ATTRIBUTES

RVAA PFC Asmt Tbl to Ext — Key RVAA ID ASMT DATE

RVAA PFC Asmt Tbl to Asmt — Key RVAA ID ASMT DATE

RVAA PFC Asmt Tbl to Lentic — Key RVAA ID ASMT DATE

RVAA PFC Asmt Tbl to Lotic — Key RVAA ID ASMT DATE

RVAA Lentic PFC — 82 ATTRIBUTES

RVAA Lotic PFC Table — 70 ATTRIBUTES

RVAA PFC External — 4 ATTRIBUTES

RVAA Assessment — 5 ATTRIBUTES

RVAA Image — 12 ATTRIBUTES

Note: All relationships are single and

RVAA Legacy

RVAA Legacy Lentic PFC — 122 ATTRIBUTES

RVAA Legacy Lentic PFC Pt. — Key

RVAA Legacy Len PFC Pt. — Key RVAA ID

RVAA Legacy Location Interest — 5 ATTRIBUTES

RVAA Legacy PFC External — 3 ATTRIBUTES

RVAA Legacy Lentic PFC Pt. — Key RVAA ID

RVAA Legacy Image — 11 ATTRIBUTES